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Research paper

A low-cost IoT smart home system

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Abstract

Internet of Things (IoT) is an emerging technology that has been recently incorporated into our daily living which makes our life more comfortable. This paper describes the designing and modeling of our sensible home automation system using the Internet of Things. We created a highly-effective and low-cost smart home especially for people with visual disabilities or hearing disabilities or pet owners by using the Internet of Things (IoT) technology. Our smart home not only uses various sensors to provide real-time reactions to users in four main aspects which include clothing, food, shelter and travelling, but it also uses a web server to store the collected data, provide data statistics, and support some data analysis. Specifically, this smart home focused on temperature and humidity monitoring, security, health monitoring, home life safety, and pet/elderly/disabled monitoring functions. Our home automation system using IoT has been proven to work satisfactorily by connecting simple and low-cost appliances to it to control them remotely through the Internet. This low-cost system is designed to provide simple access for the elderly, people with disabilities, and pet owners for a better standard of living.

Keywords: *Internet of Things (IOT); Smart Home; Home Automation System; Sensor; Low-Cost Semicolon.*

1. Introduction

Internet of Things (IoT) is defined as “an open and comprehensive network of intelligent objects that have the capacity to auto-organize, share information, data and resources, reacting and acting in face situations and changes in the environment.” [1]. IoT has becoming a hot topic in research, industry, and social community as its concept has the potential to impact how we live and how we work. The main concept is connecting any devices with an on and off switch to the Internet. This can include smartphones, fridges, lamps, washing machines, coffee markers, alarm systems, and sensors to the internet, where these devices could form a link of communication between people and themselves. The idea of IoT is a giant network that connects between “things”, including between people-to-people, people-to-things, and things-to-things [2].
Growth of a smart home system cooperating with the IoT has been rapidly increasing around the globe to provide comfort, intelligence, safety and improving quality of life [3]. Currently, the usage of smart fridges, smart TVs, smart washing machines, smart shoes, and other home appliances are widely in used [4]. However, the practice of using these products through a unifying software interaction, or through a product that unifies these devices, is still a fairly new concept. A smart home consists of the following main functions [5]:

1) Alert
2) Monitor
3) Control
4) Intelligence

For Alert, the smart home system can sense its environment and send alerts to the user. This alert function could be sent to the user on a regular basis at a predefined time, using email, tweets, message, or other social media. Monitoring is an important function in a smart home as it keeps track of the activities in the home. For example, monitoring could happen through various sensors and send alerts for such uses as switching on the air-conditioning when the temperature is above the set point. Another function of a smart home is to allow the user to control the house, such as in switching on/off lights, locking/unlocking doors, opening/closing windows, etc. Controlling gives a way for users to control various devices in a simple and easy way, such as via a mobile app. The Intelligence function is associated with automatically making decisions on the occurrence of various events. As such, it uses an artificial intelligence mechanism, which is built into the system. For example, it allows the coffee maker to make coffee automatically upon the arrival of guest, or the fridge could automatically order food items when there is a shortage of it in the fridge.
Smart homes using Internet of Things (IoT) allows the user to automate, monitor, and control home devices from anywhere and at any time through any Internet connection by any one [6]. Using IoT, a smart home could provide greater safety and comfort, more energy savings, and an enhanced security environment [7-9]. The designing, developing, and applying of the IoT smart home is valuable as it could offer a comfortable and potentially cost/energy saving for homeowners. Moreover, it could provide a powerful means to support people with special needs, such as the elderly and people with disabilities for the monitoring and controlling of home appliances [10]. In this paper, a low-cost wireless controlled smart home system for monitoring and controlling the home environment is presented. We aimed to create a friendly and easy to operate system for people with disabilities and pet owners to use in the future. Hence, our IoT smart home consists of the following features:

- Effective temperature & humidity monitoring by using sensors
- High security by using RFIDs
- Health monitoring by using pulse sensors
- Home life safety by using smoke sensors

- Pet / disabled / elderly monitoring by using a robot car

2. Our proposed IOT smart home

Figure 1 shows the concept and overview of our IoT smart home for people with disabilities and pet owners.

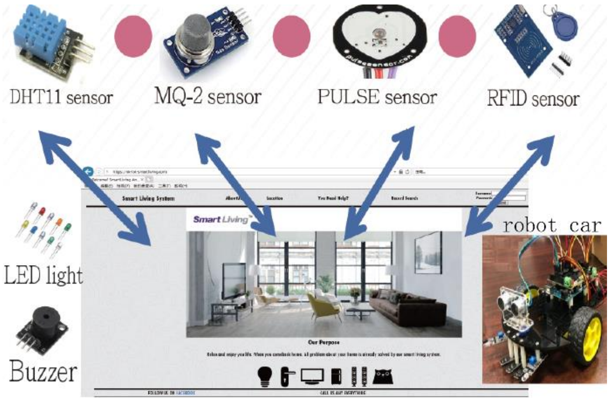


Fig. 1: A) Iot Smart Home Concept.

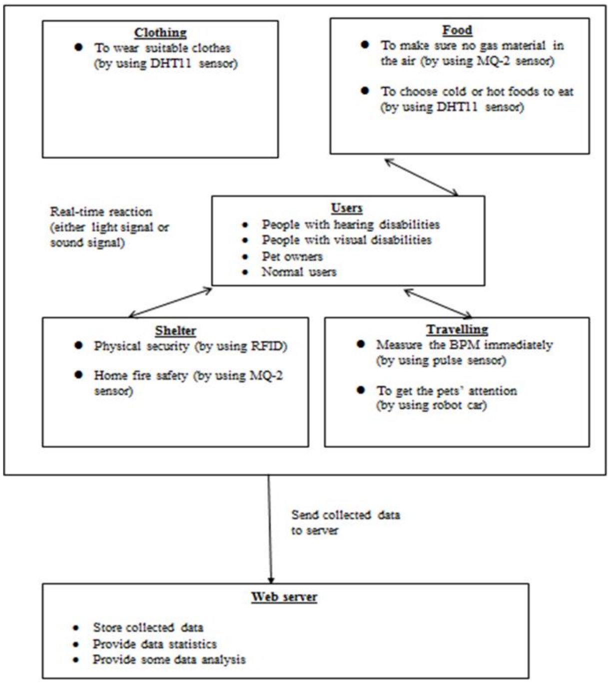


Fig. 1: B) Overview of Our IOT Smart Home.

System Architecture

With expansion breadboards, a smart home can support many new IT products such as a DHT11 Temperature Sensor, an Arduino Temperature Control Fan, an RFID Security door (via NFC), a Pulse Sensor, and a Robot Car. This combination can insure options such as accurate temperature readings to automatically turn on the Temperature Control Fan to high, medium, and low temperatures [11]. Our IoT devices have the following functions:

- connect with sensors, breadboards; communicate and connect with a computer via codes;
- allow management by a third-party control, beyond fist party tool (e.g., PHP website and mobile apps).

Hardware selection

1) DHT11 digital temperature and humidity sensor

DHT11 digital temperature and humidity sensor (Figure 2) is a basic, low cost digital temperature and humidity sensor. The sensor includes a resistive sense of wet components and NTC temperature measurement devices and connected with a high-performance 8-bit microcontroller. It uses a capacitive humidity and a thermistor to measure the surrounding air, with 20-80% humidity readings with 5% accuracy and 0-50°C temperature readings ±2°C accuracy rates.

Fig. 2: DHT11 Temperature and Humidity Sensor.

DHT11 sensors have several features, including:

- Low cost
- Long-term stability
- Relative humidity
- Temperature measurement, excellent quality, fast response, strong anti-interference ability, long distance signal transmission, digital signal output, and precise calibration

2) RFID door Security (via NFC)

At present, many devices may not be suitable for people who are disabled to use. We hope to apply smart technologies into their lives. Access control systems can be built on the RFID circuit board, so it makes more convenient for the person who is disabled to access a door. The RFID system (Figure 3) can also be used as a security guard system. Currently, many people who have a full-time job may choose to hire domestic helper to clean their houses. Setting up an RFID can bring safer homes to working people because it could keep track of a cleaner's working hours through the RFID card reader record. If a stranger enters the house, the security system can detect it, too. In this way, home security can be improved.

Fig. 3: RFID Sensor.

RFID refers to Radio Frequency Identification. RFID uses the "Internet of Things" to read and identify objects. This technology is now widely used in real world applications and not new, though some people may not be aware of this technology. The convenience of RFID can also be shown at the home or in transportation. We can use the card reader at the home as an access control system to facilitate users to enter or exit the home. The most important aspect is that RFID can quickly process the scanning work and shape diversification. Moreover, the size of the structure is not limited, and RFID is easy to control.

The concept of RFID is very similar to barcode scanning. However, this RFID is a dedicated RFID reader, and only a specific RFID tag can pass inspection. Thus, the security of RFID is higher than ordinary bar code scanning. The most special feature is that it does not require a very short distance for identifying the RFID tops. Therefore, the visibility of RFID recognition is high, and its ability to penetrate the contact is also very high.

3) SEN-11574 pulse sensor

Heartbeat data can be included in many Electronic design and microcontroller projects, but the heartbeat data is difficult to collect. The pulse sensor helps us to collect heartbeat data. Figure 4 shows the SEN-11574, which is a pulse sensor (0.625" Diameter and 0.125" Thick) for collecting induction instant pulses (i.e., heart beat). This sensor can help to measure the human heartbeat (Figure 4). The signal from the ambient light sensor is amplified through op Amp, and the signal is ready to read by the microcontroller. It also includes an open-source monitoring app that graphs a person's pulse in real-time.

The pulse sensor data can be used to analyze different heartbeat patterns every day (Figure 5a and 5b). It allows users to clearly indicate and assess the cardiovascular system during physical activity. Users could then share this information with their physicians during a physical examination. This may be most useful for those who have chronic diseases, allowing users to be better aware of their heartbeat patterns and activity.

The pulse sensor has several features, including:

- It can accurately measure the wearer's position and return information to facilitate the interpretation of the system.
- It can easily measure wearer's BPM and IBI and can keep track of the heart rate chart.
- It can provide timelier wearer status.
- Our Arduino processing software plots heart rate and pulse data instantly, reliably exporting the data to the user's software or web app.
- It raises people's awareness of whether they are exercising within their target area.

Fig. 4: Pulse Sensor.

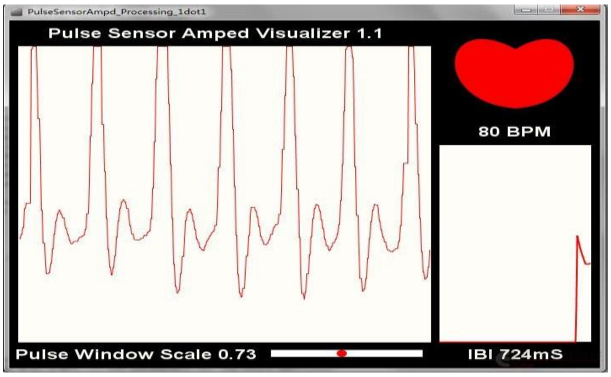
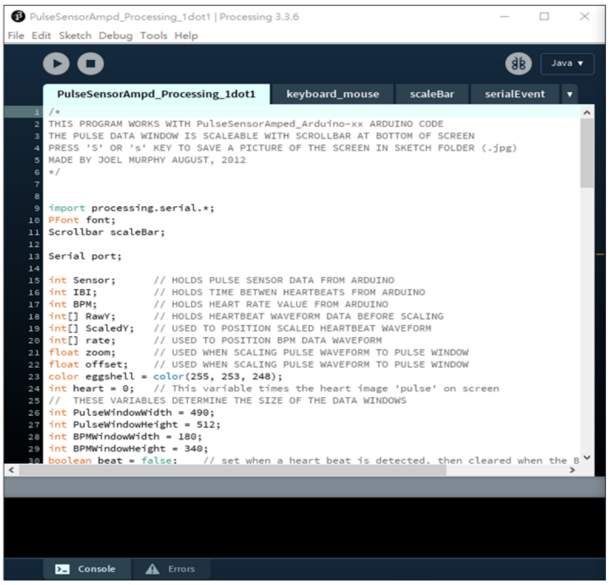


Fig. 5: A) Work Case of the Pulse Sensor.



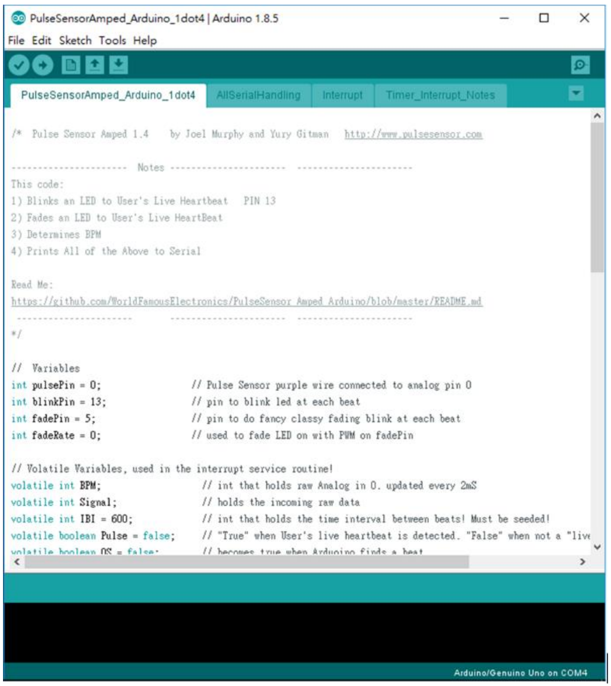


Fig. 5: B): Work Case of the Pulse Sensor.

4) Gas Sensor (MQ2 - Smoke Sensor) module

To ensure the safety of elderly people and people with visual impairment who are living alone, the installation of smoke detectors in the home is crucial. An MQ-2 smoke sensor (Figure 6) can detect combustible gas which is found in the general home environment. The sensor outputs a voltage that is proportional to the concentration of smoke/gas. The greater the gas concentration, the greater the output voltage. The lower the gas concentration, the lower the output voltage.

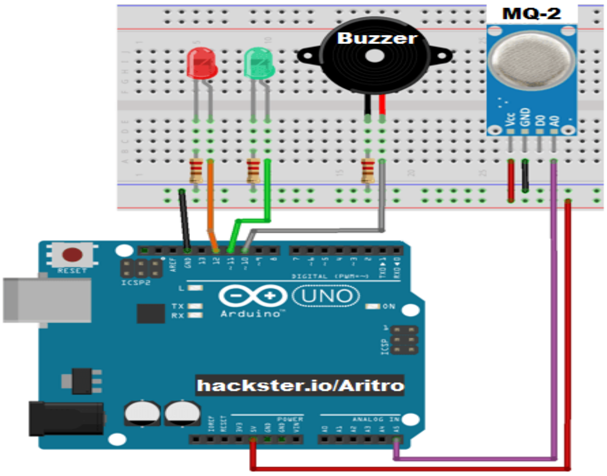


Fig. 6: MQ2 - Smoke Sensor.

A small smoke detection system, the MQ-2 smoke sensor combines sensor, buzzer, and processor, and its cost is lower than that of a traditional smoke detector system by 10-20%. An MQ-2 smoke sensor is smaller in size and easier to install compared with traditional smoke detector.

5) Arduino robot car

We designed the smart home for pet owners as well as people with visual or hearing disabilities, so we selected a moving robot car rather than an item in a fixed location. This is because a fixed position camera, such as CCTV, can be ineffective in daily safety and security management. For instance, the camera could be badly placed, broken, or under insufficient lighting conditions, and most elderly or people with disabilities may be unable to solve these issues [12], hampering the function of the camera for security monitoring purposes. The role of a robot car is to provide a carrier for the Arduino UNO and sensors. Figure 7 shows the Arduino robot car in our IoT smart home. It can be used as a toy car, allowing pets to play and keep occupied. Robot cars allow for user control as well as automatic driving. We installed sensors in a moving car to collect more data within the home setting to provide more comprehensive information. The robot car is comprised of three main parts: Sensor, Microcomputer, and Motor. Each part is indispensable. Sensors give data to microcomputers to process; while microcomputers give the signal to monitor and give reactions to users.

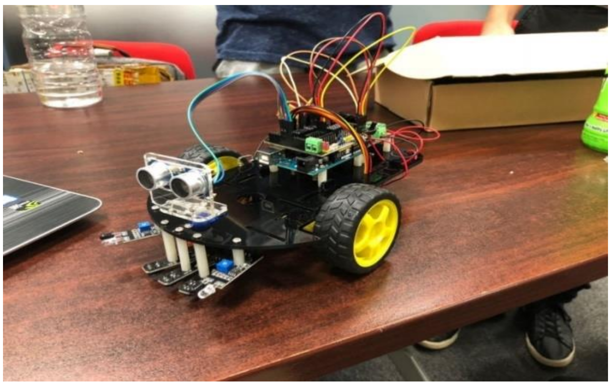


Fig. 7: Arduino Robot Car.

Software selection

1) Arduino Software

Arduino Software (IDE) is the Arduino Integrated Development Environment, comprised of a text editor for writing code, a message area, a text console, a toolbar with buttons for common functions and a series of menus. It connects to the Arduino and Genuino hardware to upload programs and communicate with them (Figure 8).

Fig. 8: Arduino Software.

2) Visual Micro (Visual Studio)

Visual Micro is an extension for Microsoft Visual Studio 2008-2015 and for Atmel Studio 6.1-6.2 that allows any Arduino project to be developed, compiled, and then uploaded to any Arduino board, while benefitting from the powerful features of Visual Studio and Atmel Studio. Visual Micro is fully compatible with the Arduino development environment and uses the same libraries, source code, and development tools. The difference lies in Visual Micro's user interface which provides an advanced and professional development environment and allows for more advanced development than the existing Arduino IDE.

Compared with Arduino IDE, there are several advantages of the Visual Micro:

- Cross Platform Shared Code and Library Editing - We can take advantages of Visual Studio Shared Cross-Platform Projects which allow cross-platform code to be created in smaller projects that are automatically combined with the program code during development. Shared projects and shared libraries can be in any location which makes source control and version control very easy.
- Arduino Compatible Board and Library Manager - The plugin also supports all Arduino library formats and all third-party Arduino compatible hardware, advantageous for the more advanced users.
- Higher compatibility - Arduino code created with Visual Micro can be more compatible with hardware from a wide range of manufacturers. Arduino sketch/project code does not need to be changed to work in Visual Studio, remaining fully compatible with the Arduino IDE (whichever version you are using). All Arduino examples for installed hardware and libraries can be used without modification.

Smart Living Analysis System

Figure 9 shows our smart home analysis system which can help to collect and upload large amounts of data to the database in the server. Then, it will automatically show users the real status of the sensors' data.

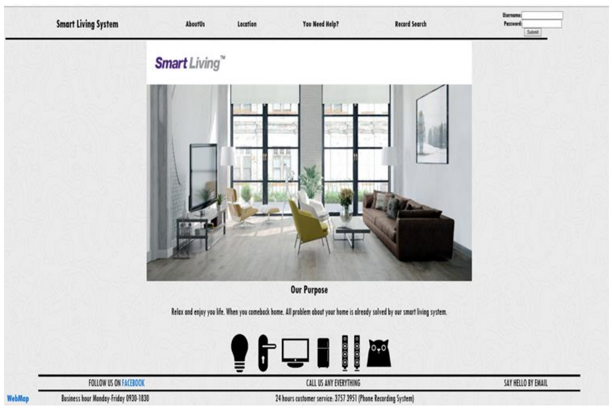


Fig. 9: Smart Living Analysis System.

This system allows the users to choose what kind of sensor data they want to analyze. Based on the data collected by temperature and humidity sensors, the system shows the environment is "Cold", "Normal" or "Hot". RFID sensors can detect different card types, such as showing the relevant card number. A smoke sensor can detect the environment as "Touch alarm" or "Normal". A pulse sensor can detect the heartbeat data as "Too slow", "Normal" or "Danger."

3. Conclusion

The IoT concept can be used in our homes in the future. This paper presents the design and provides an implemented model of the systems that could be used in these future homes. Our home automation system using IoT has been proven to work satisfactorily by installing simple and low-cost appliances for it to control remotely through the Internet. This low-cost system can be accessed remotely, making it easy and simple to access for the elderly, people with disabilities, and pet owners for a better quality of life. Using this framework, the system can be expanded to include home security options, such as capturing the facial image of a person moving around the house and storing data to the cloud. This type of system could be used in hospitals and assisted living facilities or for people with disabilities in various environments for enhanced monitoring to increase their personal independence and security [13].

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