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IMPLEMENTATION OF SMART BUILDING
(a Complete End to End Solution for Smart Building System)

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***Abstract*—Communication and information technology created a great impact on the way we live, it had changed our life style a great deal, it opens new track to human to invite methods to combine services and systems with the new technology.**

In this context Smart Building which is a mixture between application of communication, programming, and control systems became a popular perspective to applied on different types of buildings whether through conducting, services, systems or the three combined.

This work aims to study this type of buildings and the possibility of controlling their resources easily through using the smart devices and also the possibility of controlling the buildings remotely through the internet.

Also " Mind wave Mobile Headset " has been used to read the brain signals (EEG signals) to use them in controlling the building through program loaded on Arduino device..

Keywords— Arduino, Smart building, Mind wave.

I. INTRODUCTION

A smart building is a structure that uses automated processes to automatically control the building's operations including heating, ventilation, air conditioning, lighting, security and other systems. It uses sensors, actuators and microchips, in order to collect data and manage the systems according to a business' functions and services.

This work aimed to design and build a smart building which can be controlled entirely through a smart device. In addition it will be controlled by an Electroencephalography (EEG) signal.

This work contains a web application to control the building through any smart device from anywhere via the internet. It also contains a new innovation " mind wave mobile headset " which is put on the head of a human and takes the mind signal, interoperated and converted it to an electrical signal used to control the building utilities through an Android application.

This work is organized as follows: Section II covering the main concepts of the Smart Building and its components. Section III representing the implementation of the Hardware connection and the Software of the work. Then the automation hierarchy of smart building is discussed in section IV , V and VI. Section VII contains experimentation Model for The Smart Building. While section VIII representing Practical Case to Control The Smart Building. Finally section IX drawing the major conclusions from this work and providing some topics that need further investigation and development.

II. SMART BUILDING

Smart buildings are sometimes referred to as 'automated buildings', 'intelligent buildings' or buildings that incorporate smart technology. It is a term uses to describe buildings that include technologies such as [1]:

- Automated systems.
- Intelligent building management systems.
- Energy efficiency measures.
- Wireless technologies.
- Digital infrastructure.
- Adaptive energy systems.
- Networked appliances.
- Data gathering devices.
- Information and communications networks.
- Assistive technologies.
- Remote monitoring.

A smart building uses sensors, actuators and microchips, in order to collect data and manage it according to business's functions and services. This infrastructure helps owners, operators and facility managers to improve asset reliability and performance, which provides comfort, security, energy efficiency (low operating costs) and convenience at all times, also optimizes how space is used and minimizes the environmental impact on buildings.

Today, buildings are complex concatenations of structures, systems and technology. Over time, each of the components inside a building has been developed and improved, allowing building owners to select lighting, security, heating, ventilation and air conditioning systems independently.

Making a smart building begins by linking core systems together such as lighting, power meters, water meters, pumps, heating, fire alarms and chiller plants with sensors and control systems and then connecting the building automation system to enterprise systems. At a more advanced stage, even elevators, access systems and shading can become part of the system [2][3].

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Integration is enabling facility executables to reap smart-building benefits, both in new construction and also by gradually transforming existing buildings into smart buildings.

Installation of smart products give the building and its occupants various benefits the same benefits that technology and personal computing have brought to us over the last years, convenience and savings of time, money and energy.

A. Benefits of Smart Building

Creating or transforming a building into a smart building is beneficial for both the owner and the organization working within. In general Smart building strategy can reduce energy costs, increase the productivity of the facility staff, improve building operations, support sustainability efforts ... etc. The most important benefits of smart building are summarized in the following points:

- The ability to control the building.
  It provides good control of internal conditions of the building, in addition to the possibility of controlling and monitoring the entire building remotely.
- Reducing operating costs.
  Smart buildings are usually highly efficient buildings where operating costs are significantly lower than similar buildings, intelligent monitoring and control of energy- intensive systems such as HVAC and lighting help reduce costs.
- Fast and effective service.
  Smart building technologies give building management professionals the tools they need to better serve users. Accessing building systems via the Internet makes it easier for users to assess real-time conditions, detect problems, and monitor building performance off-site, and problems are identified early and solved immediately.
- Web-based security system.
  A Web-based security system which can be used in smart building allows security personnel to be able to view live video from surveillance cameras on a laptop or portable device .
- Enhanced life safety and security.
  The operators in the smart building are more aware of what's happening in the building, this enables them to efficient lighting controls and efficient HVAC, which leads to contribute to preservation of their life cycle to the total smart building.
- Compatible with Existing buildings.
  Automation systems can be applied on even old buildings. There is no need to establish a new building instead.
- Providing significant benefits to building owners and end-users, also increasing the level of comfort and time saving.
- Smart buildings are more effective to operate, and offer so much potential for future efficiencies.

B. Smart Building Component

There are main parts and components that make the building become smart and distinguished from normal building.

- *Hardware*

Smart buildings need the ability to recognize what's happening with an environment (inside and outside a building), needs something like human senses. For this purpose smart buildings are equipped with sensors and meters. So, a building can determine light intensity, inside and outside temperature, detect a gas leak and so on.

Besides observing the environment, a building also should be able to change its state. For this purpose "smart" buildings are equipped with devices and actuators that can control various engineering systems like lighting, heating, air conditioning .. etc [4].

- *Software*

Sensors and meters provide only raw information. A smart building needs to extract useful information, learn from this information, make decisions and even predict status of environment and people activities. It is done by special software which is an artificial intelligence of a building [4].

Software is a vital part of any smart building, and the target systems comprises all parts of the buildings and all pieces of building equipment that have a direct or indirect impact on the energy of the building. This includes all appliances that consume, generate or store energy [4].

- *Network*

To allow the building to act as a whole a communication network is required. It connects all devices to each other and with the artificial intelligence component. It is the nervous system of a building [4].

III. Implementation of Smart Building " Practical Part "

In this work, two different methods have been used to control the smart building. The first was to control the smart building by using a Mindwave mobile headset, while the second was to control the smart building by web application.

The automation hierarchy of smart building consists of three levels as shown in Fig1. These levels are field, automation and management levels, where the field and automation levels are shared for both methods in management level.

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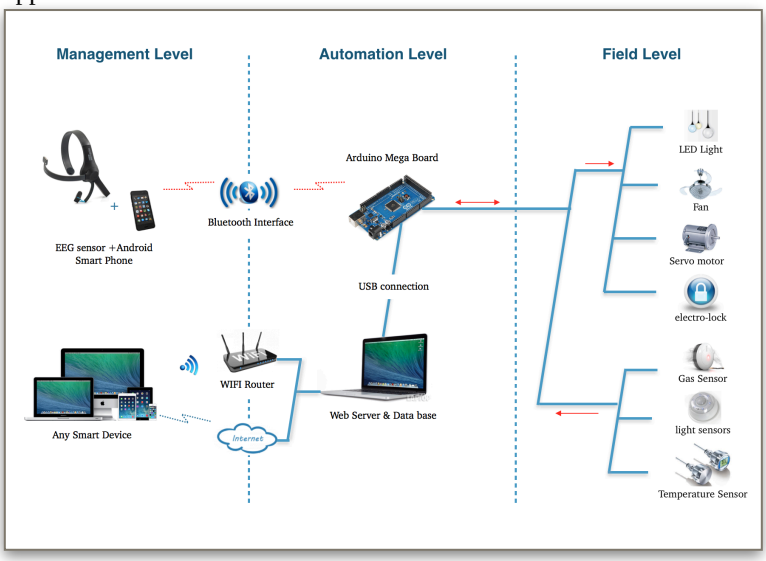


1. Automation Hierarchy of Smart Building

The main reason for using two methods to control the smart building is to provide more than one option for controlling the building in flexible and easy way and to commensurate with most segments of society as well as to reduce the cost.

Web application provides the possibility of controlling the building and monitoring its condition via the Internet or a local network by using any smart device that has a web browser, It also provides the possibility of controlling the building remotely from anywhere.

While, the Mindwave mobile headset is a new innovation and has been used in this work to be used by a certain class of society such as people who have physical impairment, it provides easy way for them to control the building, And it also can be used by anyone.

This work also contains the Arduino controller and some components such as fans, lEDs, sensors .. etc, to build a model that simulates a real building. Components will be controlled by the Arduino controller that receive orders either by Android application which is considered as an interface for the Mindwave mobile headset or Web application.

IV. FIELD LEVEL

The lowest level of the automation hierarchy is the field level, which includes the field devices such as actuators and sensors. The task of the devices in the field level is to send or receive data to or from automation level and this data may be both binary and analog.

At the field level, interaction with the physical world takes place. Environmental data are collected (measurement ,counting, metering) and transformed into a representation suitable for transmission and processing.Likewise, parameters of the environment are physically controlled (switching, setting, positioning) in response to commands received from the system.

In the practical implementation of the work a set of equipments and component have been linked with the Arduino microcontroller and controlled by it, when it receives an order from the web application or Mindwave Mobile Headset via the android application or through some of sensors.

V. AUTOMATION LEVEL

Automation level is for control, Operation and monitoring the equipments and component in field level based on orders that are received from Management Level.

The Arduino Mega 2560 has been used in this work as a controller which connects field level with management level.

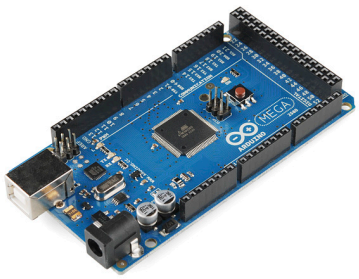
Arduino communicates with " the software of hardware controller " which in turn communicates with Smart Building Database and send orders to the Arduino controller based on the saved data in this database.

A.Smart Building Controller

A controller (also known as a control panel or control unit) is a device, historically used mechanical, hydraulic, pneumatic or electronic techniques often in combination, but later in the form of a microprocessor or computer, which monitors and physically alters the operating conditions of a given dynamical system [5].

A Control Unit (CU) directs all input and output flow, and it is considered as the processor brain because it issues orders to just about everything and ensures correct instruction execution.

The Arduino Mega2560 Fig2 is a microcontroller board has 54 digital input/output pins (15 of them can be used as PWM outputs), 16 analog inputs, a 16 MHz crystal oscillator, a USB connection, a power jack, and a reset button.



2. The Arduino Mega 2560

Code of the Arduino board has been wrote by using the Arduino IDE. This code defines the operating way to the Arduino board. In other words, how the board will control the electrical component based on the received orders from the USB port or via bluetooth connection, also based on the received data from sensors.

- *Arduino Flow Chart*

The Arduino gives orders for equipment and electronic components that have been connected with it based on the commands and data that the Arduino received from the Web application and android application as shown in first flow chart in Fig3, or received from sensors as shown in second flow chart in Fig4.

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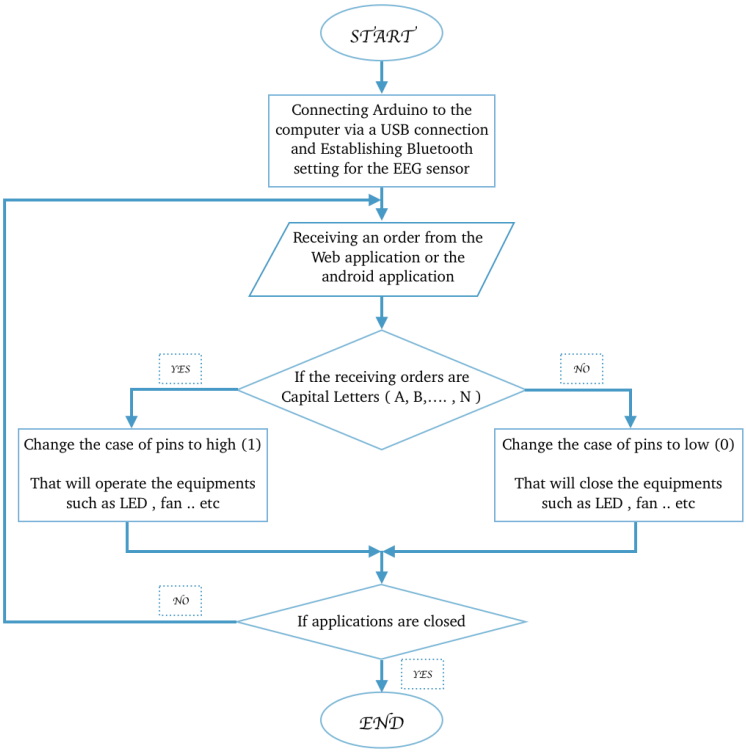
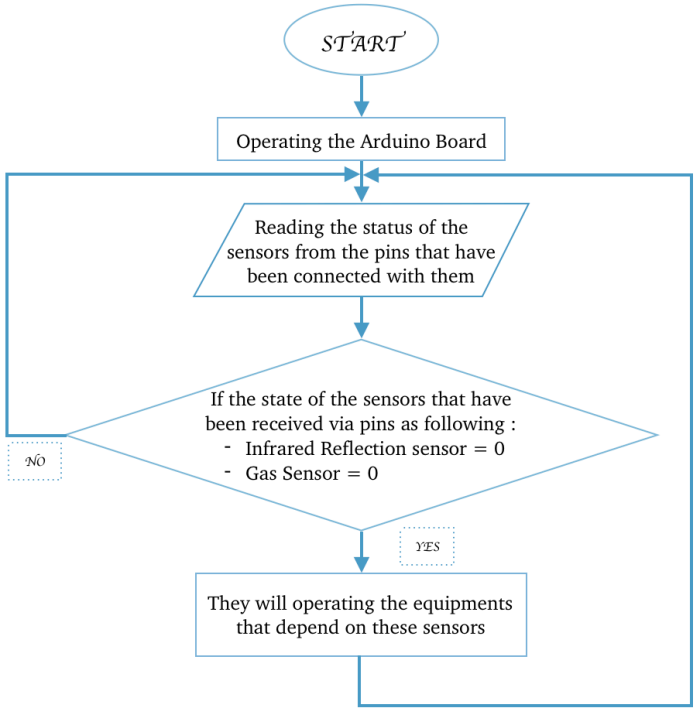


3. Arduino with Applications Flow Chart



4. Arduino with Sensors Flow Chart

B. Smart Building Database

A database management system (DBMS) is a software system for creating and managing databases. The DBMS provides users and programmers with a systematic way to create, retrieve, update and manage data [6].

The DBMS essentially serves as an interface between the database and end users or application programs, ensuring that data is consistently organized and easily accessible, it is actually a tool used to perform any kind of operations on data in database, also it provides protection and security to database [6].

Smart Building Database has been created by using SQL server, then it has been connected with web application and " the software of hardware controller ". This database consists a set of tables contain data for the smart building.

The main table in this database called switches, it consists a set of fields. Each field stores specific data for equipment as following:

- Switch_Name field contains the name of component.
- Switch_Status field contains the current status of component if it is on or off (true or false).
- Switch_Changed field become ' true ' during the process of changing the status of the component.
- SwitchData field contains the data of sensors.

The data for equipment and devices which is controlled by applications are stored in switches table as shown in Fig5.

ID	Switch_Name	Switch_Status	Switch_Chang...	SwitchData
25	Fan 1	False	False	NULL
26	Fan 2	False	False	NULL
27	Fan 3	False	False	NULL
28	Fan 4	False	False	NULL
29	LED 1	False	False	NULL
30	LED 2	False	False	NULL
31	LED 3	False	False	NULL
32	LED 4	False	False	NULL
33	Servo Motor 1	False	False	NULL
34	Servo Motor 2	False	False	NULL
35	Servo Motor 3	False	False	NULL
36	Lamp	False	False	NULL
37	Solenoid	False	False	NULL
41	Sinsours	True	False	temp=40Gas=0...

5. Switches Table

The web application stores any changes occurs in the Switches Page in switches table and the software of hardware controller communicates with database every second to see if there any changes in the status of switches to send them to smart building controller via the serial port.

The web application also generates a set of tables in database to store user data (the user name and password) to make a user ables to log in for Switches Page.

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VI. MANAGEMENT LEVEL

The management level is the top level of the automation hierarchy, it provides web and terminal services for operation and monitoring.

At this level, information from the entire system is accessible. A unified interface is presented to the operator for manual intervention. Access to automation level values is provided, including the modification of parameters.

Management Level in this work includes two methods to control the smart building, Mindwave mobile headset with android application and the web application. They will be discussed in more details in next subsections.

A. First Method " Mindwave Mobile Headset and Android Application"

Mindwave Mobile headset as shown in Fig6 is a wireless device used to record the EEG signals, then it sends a corresponding data of the brain waves to the device connected with it via bluetooth connection [7].

6. The MindWave Mobile headset

The headset uses eSense meters for Attention and Meditation. The meter value for each type of eSense is reported on a relative eSense scale of 1 to 100.

Given that the Attention can be controlled through a focus, two actions have been chosen in practical implementation of the work " single and double blinking " which they give different range of values on eSense scale.

The headset records low frequencies of single blinking and gives small values on eSense scale while higher frequency is recording when the Human blinks his eyes twice and the values will be higher on eSense scale.

Android application as shown in Fig7 is designed to communicate with the headset and it acts as an intermediary between the Mindwave Mobile Headset and the smart building controller " The Arduino ". It takes advantage of these values in order to send commands to the Arduino.

Android mobile which contains this application, receives signals from the Mindwave Mobile Headset via bluetooth connection and It also sends orders to the Arduino via bluetooth connection.

7. The Interface of Android Application

B. Second Method " Smart Building Web Application "

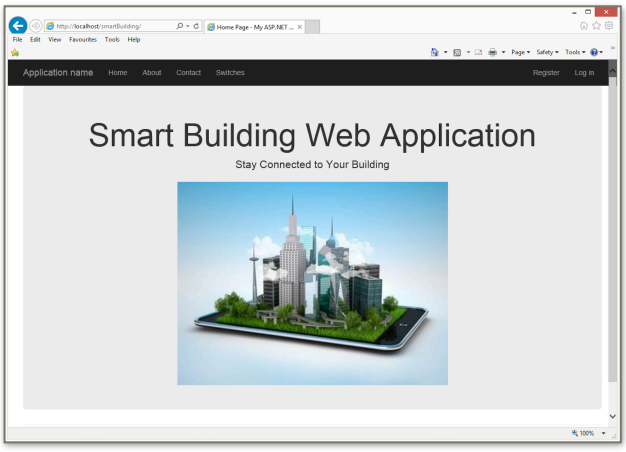
A web application " web app " is a software program that is stored on a remote web server and delivered over the Internet through a browser interface. Unlike traditional desktop applications, which are launched by operating system. It will make it independent of operating system, place, and used hardware.

Web application is used to control the smart building by using any device from anywhere via the Internet.

Web application has several advantages over desktop applications. They run inside web browsers which mean it will operate in any device has a web browser rather than the operating system, so it can considerably lower the costs because of reduced requirements on the end user system.

In this work, Smart building web application has been created by using ASP.NET MVC framework and C# language via Microsoft visual studio.

After the creation of web application as shown in Fig8, it has been published in a local web server, and can be opened and used by any smart device exist on the same network of the local Web server by writing the URL (http://localhost/smartBuilding/) of the application in the device's browser.



8. Web Application

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The Smart Building Web Application consists of four pages (Home Page, About, Contact, Switches)

C. Comparison Between the Two Methods

Table1 compares the two methods in management level of smart building to clarify the difference between them and their specifications.

I. COMPARISON BETWEEN THE TWO METHODS

Comparatives	**First Method** Mindwave Mobile headset and Android Application	**Second Method** Smart Building Web Application
Requirements	Mindwave headset and Android device	Any device has web browser
Access method to the controller	Bluetooth connection	Wifi connection
Provision of services	Used by any one , even if the user has physical impairment	Provides friendly interface for web browser users
Possibilites	Controls appliance of the smart building	Controls appliance of the smart building and knows the status of some sensors
The cost (for user)	Higher cost	Lower cost

VII. EXPERIMENTATION MODEL FOR THE SMART BUILDING

Designing and implementation an experimentation model for smart building as shown in Fig9 has been done to apply the idea of the work.

9. Experimentation Model for The Smart Building

VIII. PRACTICAL CASE TO CONTROL THE SMART BUILDING

As a practical case to control the component in smart building, this section will explain the way to open " LED 2 " by using the two methods.

A. Using The First Methods

The following steps clarifies how to open the LED 2 by using the Mindwave Mobile headset and Android Application:

- Operating the headset and putting it on the head where the sensor arm resting on the forehead above the eye.
- Establishing Bluetooth setting to connect the mobile with the headset and the Arduino board.
- Changing the focus to LED 2 button by blinking the eye as one blink to reach the targeted button.
- Selecting the LED 2 button by blinking the eye as double blink.
- Closing it by following the same previous steps.

After doing these steps the LED will operates as shown in Fig10. These steps also can be apply for all other equipments.

Sometimes, some delay occur to implement this process due to the nature of human eye, because blinking is a semi-autonomic rapid closing of the eyelid which means in some cases the headset will not record the range of blinking frequencies.

B. Using The Second Methods

The following steps clarifies how to open the LED 2 by using the web application:

- Opening the web application by writing the URL(http://localhost/smartBuilding/) of the application in the device's browser.
- Opening Switches page by login to the page via entering the email and Password.
- Pressing the edit button that located next to LED 2 switch.
- Changing the current status of it , then pressing on save button to save the change.

After doing these steps the LED will operates as shown in Fig10. These steps also can be apply for all other switches.

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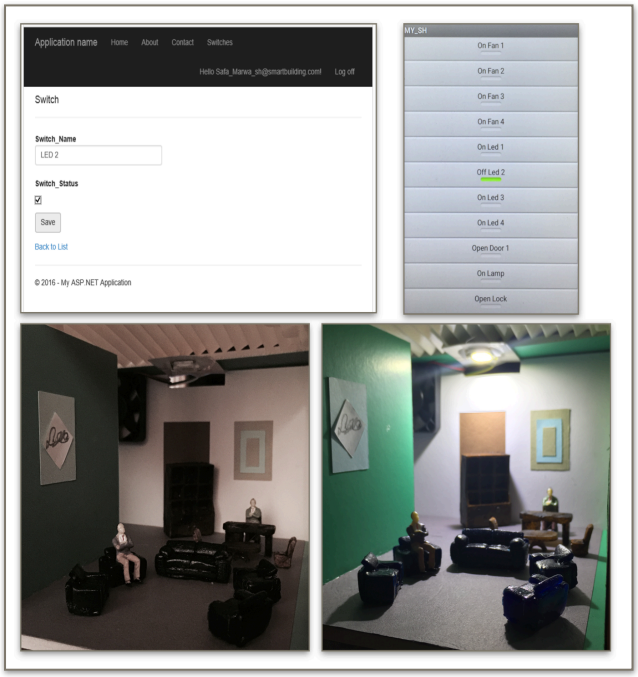

10. Practical Case to Control the Smart Building

IX. Conclusion & Future Work

A. Conclusion

The idea of the smart building has been implemented in this work, where the work has been done in three levels of the Automation Hierarchy (field, automation and management levels) as following:

- *In the management level*

Two different methods have been implemented to control the smart building. The first was a Mindwave mobile headset, and the second was a web application.

- The Mindwave mobile headset is a new innovation that has been used to control the building via Android Application which in turn acts as an intermediary between the Mindwave Mobile Headset and the smart building controller " The Arduino ".
  Two range of the EEG signals are used and the Android application takes advantage of these frequencies in order to send commands to the Arduino.

- Smart building web application has been created to control the building and monitoring its condition by using any device from anywhere via the Internet or a local network.
  As an experiment for the smart building web application, it has been published in a local web server, and can be opened and used by any smart device exist on the same network of the local Web server.

- *In the automation level*

The Arduino Mega 2560 has been used in this work as a controller, it controls a set of equipments based on the received orders from the web application and Android application, or the received data from sensors.

-*In the field level*

A set of equipments and components have been linked with the Arduino board and controlled by it. Some sensor also has been used to send data to the Arduino.

Designing and implementation an experimentation model for smart building has been done to apply the idea of the work.

B. Future work

We are looking to implement our work in real case in the future, this requires to develop the work in several parts, such as:

- Publishing the web application on web server to be used by any device via the internet.
- Creating more applications for the Mindwave mobile headset compatible with other operating system rather than the Android.
- Using other types of controllers have more ability than Arduino board, that can be used to control the appliances of real building.

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