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AnyControl - IoT based Home Appliances Monitoring and Controlling

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***Abstract*—Technologies for Internet of Things (IoT) such as sensor, network and data processing are advancing rapidly. Thanks to the evolution, many potential applications have been developed in the fields of analysis and automation. In this paper, a platform was designed to connect sensor data with users daily life. As an application of it, AnyControl - a home appliances monitoring and controlling system was implemented. Although home appliances are becoming more intelligent day by day. Not only are manufacturers promoting new smart appliances; there are also many smartphone oriented remote controller products. However current products always have platform compatibility problems, additionally, user interaction in such systems are becoming more and more complex. This work proposes an approach to enhance old appliances and the controlling experience through an IoT based Home Appliance Controlling System. With sensors the appliances can be controlled environment condition trigger. The sensor data are processed by single-board computer and delivered to mobile applications through wireless connection. The results of implementation and experimentation has shown the proposed system and platform can provide more IoT application possibilities daily life.**

***Keywords*—Sensor Network, Remote Control, Smart Appliances, Data Streaming**

I. Introduction

Recently, thanks to the large diffusion of sensors and wireless network, Internet of Things (IoT) technologies have advanced rapidly. The vision of IoT is to enhance the connectivity from "any-time, any-place" for "any-one" into "any-time, any-place" for "any-thing"[1]. Mainly there are two categories for IoT applications: Analysis and Automation[2]. Mobile devices have gradually become a central terminal for every user to communicate with the cyber world and even the physical world[3]. As a result, users demand for retrieving information and controlling things through mobile devices are growing rapidly[4]. When talking about mobile controlled devices, the most popular topic should be home appliances.

However, issues such as Compatibility and Usability often hinder a user's desire to use these new technologies. Many home appliances companies are making multifunction products and dedicated mobile applications, aiming at establishing new platforms for home and living environment[5]. However due to companies working behind closed doors, it is hard to use a single platform to control products from multiple manufacturers. Not to mention older appliances models which are not built with the new functionality. On the other hand there are many universal remote control products that provide an interface to manage and control home appliances. With those devices users can combine all the remote controls in their home into one smartphone application. Although it's convenient to control different appliances with one controller, the setting and controlling process becomes very complex. There are still many opportunities to take advantage of current technologies to build more user-friendly platforms for appliances controlling.

This work attempts to propose a new approach for Home Appliances Controlling Environment, and will improve user experience by enhancing two main aspects:

Compatibility
: Support products from different models, brands. Especially for existing old appliances.

Usability
: Help users control appliances based on environment and activity, providing more possibility for automation.

Smart appliances should not only be connectable and controllable by smartphones, but also be part of a user centered controlling environment. This environment should allow easy configuration and control of appliances based on their need. In this work, a scientific study was conducted; technology trends and related works were evaluated to seek new possibilities in appliance control. The expected results of the study are to verify the concept of activity based universal controlling environment and through the implementation and evaluation, provide an feasible model for related systems and products.

II. Related Work

Many researches about Appliances Controlling System have been conducted, there are also some related products have been developed. In the following part of this chapter, several works are introduced. After understanding each work's point of view, advantage and disadvantage, the issues and expected solutions are discussed.

A. Researches

Researches about Appliances Controlling System started from early on. It can be discussed from various angles.

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1) Previous Research: This is a previous study[6] of this work. The system tries to build a Universal Appliances Controlling System which can control different appliances together based on tasks. It provide a web interface for user to manage their appliances, and make it possible to control appliances through infrared signal with Arduino platform[7].

2) Wireless Sensor Network Based Smart Home: Wireless sensors have been widely used in home appliances controlling[8]. Most of the sensors are used for detect the environment change and user's activity. With those information the system can learn and define human behaviours[9]. In those works[10][11][12] there are some similar implementation. Many unobtrusive sensor are installed throughout user's house. Using ZigBee or other wireless connection, the system can collect all the sensors data to monitor the house environment.

3) Controlling User Experience: As discussed above, normal appliances controlling processes have focused on devices functions. This process could be more user centered by improve the User Interface and Experience. Smartphone application or web page have already become easily accessible for normal users. Many implementation are trying to integrate the remote control into web interface[13]. It can improve the controlling experience by combining functions and appliance into grouped tasks based on the users activity. Similar concepts have been described in the research *From devices to tasks: automatic task prediction for personalized appliance control*[14] .

B. Existing Products

1) Universal Controller Application: Beacon[1] developed a universal remote control with no wires or power cables. The Beacon device is regarded as a bridge, smartphones can communicate with it through Bluetooth, through the smartphone application, users can send IR signals from Beacon to control there appliances. In addition, *Broadlink e-Remote*[2] is providing similar functions. But Broadlink e-Remote needs Wi-Fi environment. Another product *L5 Remote*[3] is different from above, in that it is an accessory universal IR controller that can be plugged into iPhone or iPad.

2) Sensor Based: As the sensor technology develops, we have also seen the advent of various ranges of sensor-based smart controller and applications in our lives. *WeMo Switch + Motion*[4] can turn appliances, which plugged in the switch, on or off when the sensor detects movement. The WeMo devices use a Wi-Fi connection to communicate with each other and the user's smartphone. Application of IOS can be used to setup and control the devices.

3) Self-learning: Another two products are kind of different from those above. *Nest*[5] and *Tado*[6] are both a portable thermostat and appliance controller device with pretty and tidy design. They can detect the users existence and switch the appliances automatically. They are also equipped with a learning mechanism that can provide proper service based on the users customization. They also have a nice look smartphone application as the basic interface. Users can monitor their appliances from anywhere with an Internet connection.

[1] http://griffintechnology.com/beacon
[2] http://www.broadlink-jp.com/
[3] http://l5remote.com/
[4] http://www.belkin.com/whatiswemo/
[5] https://nest.com/
[6] https://www.tado.com/

C. Limitations in Appliances Controlling Services

Many works and products were intruded above. The methodologies, features of those work are not identical with each other, nevertheless they all have some certain limitation on compatibility and usability. These limitations come from the diversity of controlling technologies, such as different Infrared protocols, and as a result many old appliances cannot be integrated into those systems. The controlling process and interface of the works above are basically structured based on the appliances' functions and the normal remote control. Therefore these systems will be limited by the appliances actually used.

Because of the divers usage requirements and environments, it is difficult to make a common platform for Appliances Controlling. But the roles of appliances in a user's activities are similar, that is to support and provide required functions and information. Thus the technology of appliances controlling should be constructed based on users'activity. The approach proposed in this work focuses on help users concentrate on their activities in daily life rather than what appliances to use to support these activities. With an add-on module, most of the families should enjoy new controlling experience with their old appliances.

III. System Description

A. Objectives

The proposed system AnyControl tries to provide User-centered experience for home appliances controlling. The concept is that users should not be concerned about the appliances, but their activities themselves. With this system, users do not need to look for the specific function of appliance on the remote control. For instance, a target user A who is used to watch TV after coming back home in the evening. In normal circumstances, A need to turn on the light, air conditioner, and the TV in his living room. There are several interactions between A and appliances during the controlling process, however his goal is just have a relax. To simplify the controlling process could improve the user experience. The more transparent the operation are, the more enjoyable an experience it creates for the user. Therefore, objectives were set based on Compatibility and Usability needs.

1) Enhance Old Appliances: Every new generation of appliances will bring many new functions that the old appliances are lack of. The proposed system should able to deployed in normal home environment. So that normal user could apply it to the existing appliances easily. Instead of changing the appliances, an add-on module will be more convenient and fast. IoT technologies using sensors, network connection, and single-board computer can be applied as add-on modules to the old ones, they can be enhanced and even have more functions than the new models.

Although many new remote control technologies have been used such as Bluetooth, ZigBee. Infrared is still most widely used in normal homes. To provide economic solution, the first implementation will be conducted with Infrared.

2) Task based and Sensor Triggered Automation: Controlling process should be organized based on tasks, and these tasks will be defined by users according to their activities. A history record of the operations based on different activities, could support a self learning and prediction service. Through organization based on tasks, the existence of appliances will become secondary to their collective function. Only the functions that related to the current activity will be added into the operation list of the very task. To trigger each task, not only can the applications interface used, but also sensors and other web APIs. To detect and serve users' activities, environment sensor could be helpful. After uses defined tasks for different activities, they can setup the trigger for each task. As a result, the controlling process will be executed automatically while users' activities are proceeding.

Environment condition information would be very useful in other cases. Users can monitor their house condition with the data in a remote place. Or the computer can analyse the data to make advises and provide the information in proper moment for users. Or the data could be used not only inside a family, it can be used in a range of community, to provide more helpful result in different fields.

B. Systems Architecture and Components

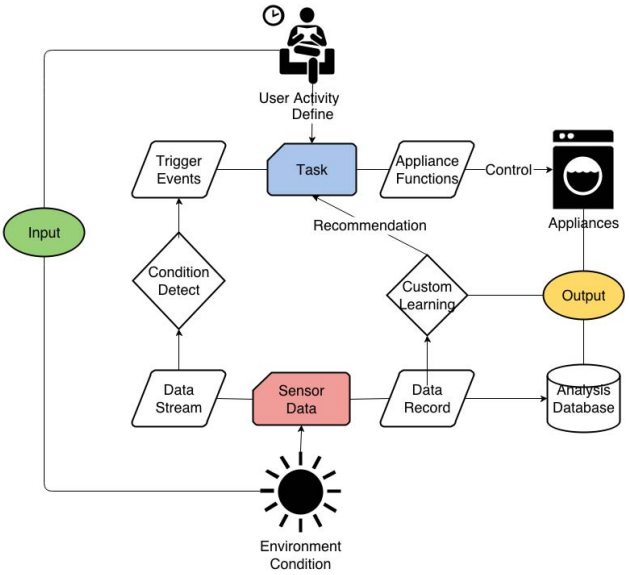

Fig. 1: AnyControl System Architecture

Figure 1 shows the basic architecture of the system. Information input consists of user activity and environment data. Inside the system, tasks will be defined by users customization, then a connection was made with appliances functions. As output, the system will control the appliances based on tasks, and also provide useful information or recommendation to users.

The system consists of three main components.

Environment Sensor
: As an input source to serve user activity, multisensory of different environment conditions are required. The sensor data will be retrieved and transferred inside the system.

Universal Controller
: With single-board computer platform, it can provide infrared learning function and internet connection ability. This will enable the processing of sensor data, and also the task output which can interact with appliances.

User Interface
: Web view based smartphone application will be applied to this system, so that it can be used in different mobile platforms even PC browsers. With clear designed interface and functions, users can manage their task and appliances easily through the application.

IV. Implementation

A. Environment Sensor

As a collaborator of this research, OMRON Corporation provided Integrated Environment Sensors as showed in Figure 2. The sensor can communicate with PC through serial port. When serial request was sent to the sensor, it will send back the sensor data package, which include the data as below:

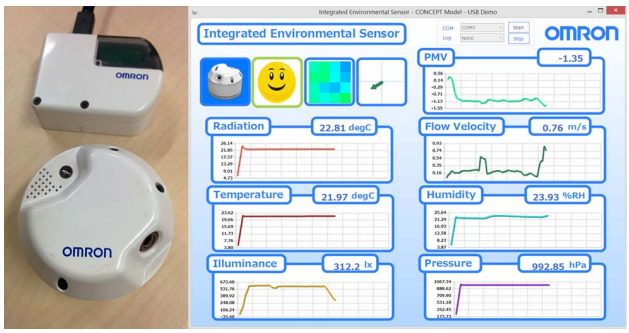

Fig. 2: OMRON Integrated Environment Sensor and Sensing demo

- Radiation Temperature
- Temperature
- Illuminance
- Flow Velocity
- Humidity
- Air Pressure

A python program was made for processing the sensor data. At first it collect sensor data through serial communication in realtime. After parsing the data, a time series JSON array was created. An JSON sample is as below:


```
{"DateTime":"14/04/24 18:19:32:059",
"pmv":"−0.12","temp":"25.23","humi":
"28.37","light":"838.00","vx":"0.00",
"vy":"−0.38","vt":"3.23""velo":"0.38",
"radi":"25.36","pres":"1004.90",
"ir00":"24.29","ir01":"24.39",
"ir02":"24.39","ir03":"24.19",
```

```
"ir04":"25.19","ir05":"24.39",
"ir06":"24.29","ir07":"24.19",
"ir08":"29.39","ir09":"27.09",
"ir10":"24.09","ir11":"24.19",
"ir12":"29.89","ir13":"27.69",
"ir14":"24.09","ir15":"23.89"}
```


Then sing WebSockets protocol[7], the python program provides an real-time streaming function using the JSON data. Clients such as smartphone applications and web browsers can receive this data with internet connection. This feature is used to connect environment condition changes with users's mobile devises through internet. The program becomes a web server which provide api for clients to grab sensor data in remote places and real time.

B. Universal Controller

Raspberry Pi is a Linux based single-board computer, it has the capability on serial communication, internet connection, web server, and also infrared modules[15]. Therefore is was chosen as the fundamental framework of the Universal Controller. The python program for sensor data can be easily deployed on it. The next step is the controlling operations.

Fig. 3: Infrared Learning Setup on Raspberry Pi, using TV, Light and Air conditioner Remote Control

Linux Infrared Remote Control(LIRC)[8] is a library for Linux system to use infrared modules sending and receiving IR signals. For prototype test, remote controls for lights, TV, air conditioner were recorded through Infrared Learning function(Figure 3). The config files of the remote controls will be used to manage and control appliances.

C. User Interface

An Android Application based on Web view was designed. It has 3 main screen(Figure 4), each of them provides function as below:

[7]https://www.websocket.org
[8]http://www.lirc.org/

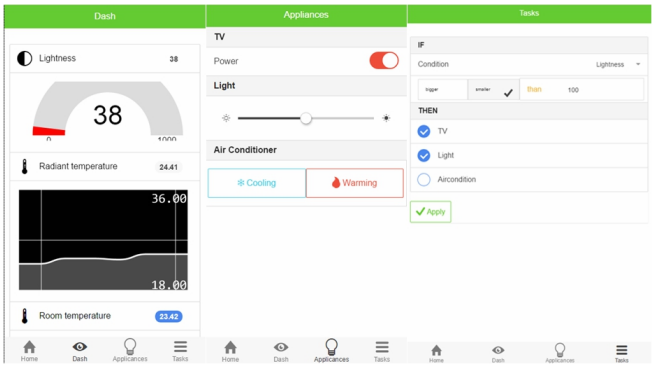

Fig. 4: Android Application Screens of 3 Main Functions

Monitoring
: On the left of Figure 4, it is a UI for the visualization of Environment Sensor Data with numbers and charts. Users can monitor and watch the change of their home condition remotely.

Controlling
: The Universal Controller can send infrared signal for each appliances based on LIRC config file. In the middle of Figure 4, there are buttons for different appliances. The buttons or switches on the screen were connected to those controlling operations, such as adjusting the brightness of light. The application becomes a integrated remote control for home appliances.

Trigger Tasks
: Finally on the right of Figure 4, users can set up tasks based on Environment condition changes. Users can input the condition and result on the screen for each task. For example, if user set the condition as "brightness is under 200", and the result as "turn on light". Then when it is getting dark, the Universal Controller can send infrared signal to turn on lights automatically. With controlling appliances in groups, users can define tasks for their activities. They can choose the related appliances for the target activity and turn them on at the same time.

Fig. 5: Demonstration of AnyControl

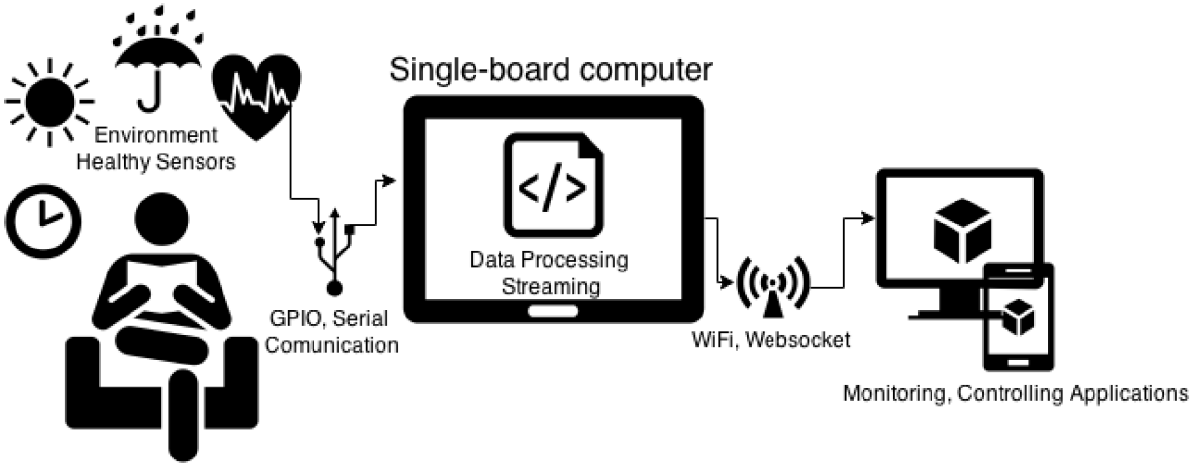

Fig. 7: Portable Sensor Data Streaming Platform

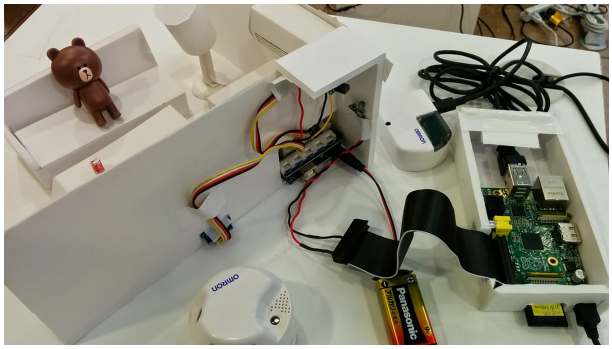

Fig. 6: Electronic Components of the Demonstration

D. Demonstration

In order to make a portable prototype which can be demonstrated conveniently in different places, a paper living room with virtual home appliances was built(Figure 5). Arduino with infrared modules were used in the virtual living room(Figure 6). 2 LED lights and a Buzzer were attached to the Arduino represent different appliances like TV. Infrared signal recorded from normal remote controls were saved and used to control the virtual appliances.

By using the android application, users can interact with the virtual appliances. They can also set up tasks and environment triggers using the sensor monitoring.

V. Discussions and Future Work

A. Discussions

By demonstrating the prototype to numbers of users, issues emerged from the evaluation and feedback. One of the big problem is the infrared learning process is still difficult to normal users. The system should provide more flexible feature to let users set up their appliances without much effort. Providing a appliances remote control list could be helpful. Another problem is that when using infrared to control appliances, it is hard to know if the operation was conducted correctly or not. The infrared of Universal Controller is kind of one-way communication, however environment condition could be used for detect the appliances status although this is not efficient and accurate. For example, using illuminance sensor for Lights operation, Temperature sensor for Air Conditioner, etc.

B. Future Work

Currently the prototype is only a single system application. In the next step, it would be applied into bigger scales from different rooms to buildings, even communities. By building up a database of the environment sensor and user custom of appliances operation, this system could become a note of the Big Data of IoT(Figure 7). Also it only supports Infrared controlled appliances, other technologies like Bluetooth and ZigBee should be considered. To provide a service for real-time environment information sharing and analysis. Issues such as user privacy and security, also need more effort to work on.

VI. Conclusion

In this work it has been shown that it is possible to control appliances automatically according to defined tasks. By connecting with sensor technology and other web services, home appliances controlling could become more user-friendly and enjoyable. There are also many limitations in the proposed design. However those limitations serve as a reminder to carefully consider the structure of our system, and give additional insights for future research. The relationship between users' activities and the environment needs to be studied further. With the proposed platform, more and more sensors can be connected and streamed data to the internet. Therefore not only home appliances, more devices and services will be involved in the future.

VII. Acknowledgments

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