DATA-DRIVEN LIFE

Smart home automation system based on location

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Abstract. Human interaction with various technologies in daily life produces data which can be captured and monitored. Increasingly smart systems are being applied in domestic home environments and are shown to offer advantages, as well as health and assisted systems. However, smart systems design is often led from a technical perspective and a large-scale perspective rather than social problems. However, my research is about everyday efficiency and comfort. Thus, the research investigates a physical computing system of combining geolocation with sensor technology for household appliances to improve the existing smart home system (SHS). The action research approach is collecting prospective and current users' perspectives about smart home technologies by conducted a preliminary survey. These analyzed results narrowed the research direction, framing the design structures of this project. Accordingly, the outcome of the research is an open-source system, it can intelligently control the home appliances depending on the location of users. This SHS introduces a design direction of employing geolocation data in the system to make a home more automated it will improve the efficiency of home living. Furthermore, it enhances the SHS's interactivity, creating a more flexible and intelligent home solution.

Keywords. Smart home technology; Data-driven design; Physical Computing; Geolocation; Home Automation

1. Introduction

With the development of technology, it is believed that human is living around by data, also, they are producing data when using any techniques. Moreover, with more techniques involved in daily life, more data produces and real-time. (Speed and Luger, 2019). Collecting and analyzing these data is a core principle of smart system thinking which imagines solving a host of problems related to ways of living in cities. For example, almost everyone uses a smartphone with mobile network data and GPS, which means we produce new data with every inch we move. These data can be collected and re-use again and again in other aspects, for example, the map APP can access the GPS data and generate the route for the user.

This example explains the initial idea of this research: collecting and driving data to improve everyday living. More especially, this research focuses on the intelligent system used in residences. Modern technology can make life more convenient and makes it possible for people to gain control over everything. However, a good smart system will focus on every detail in daily life and consider the user's actual needs but not only led from technique perspectives (Ding et al., 2011). Thus, the research investigates a physical computing system of combining geolocation with sensor technology for household appliances to improve the existing SHS.

The research consists of four iterations, the premilitary survey, sensing technology test, GPS collect and time utilization rate optimization. Each step connects and their outcomes solve four different aspects of this research. Accordingly, the outcome of this research is an open-source physical computing system based on Arduino and other modules. It assumes the user's distance from home, can modify the SHS control the home appliances based on the distance changes. With this SHS, those home appliances such as bathtub, microwave or air-conditioner can automatically start preparing for the user during the commuting time. Thus, the automation system can increase the time utilization ratio by controlling home devices in advance. In doing so, t It designs a workflow for the SHS based on geolocation data. And this physical computing system can enhance the service of current SHS and improve its interactively and flexibility.

2. Research Aims

This research aims to improve the efficiency of everyday living with SHS. More specifically, the research focus on designing a workflow for SHS and a physical computing system including software and hardware. The hardware is a microcontroller system consists of an Arduino unit assembled with a Neo-6m module, an ESP8266 WIFI module, and an OLED module. By exploring the coordination of various components through two iterations, the research further aims to optimize and developed a more adaptable SHS system.

3. Research Question

Based on the research elements outlined in the introduction, and within several precedents in the SHS field, this research aims to address one questions:

How to produce an auto-control smart home system based on the user's geolocation.

4. Methodology

Before starting the project, action research can narrow the design scope. Jean defined "action research" separately. The word "action" refers to what we want to do, and "research" means how we achieved the goal. In the " action" part, designers have to think about relevant factors such as the social, political or historical contexts. And the "research" is the implementation plan of the design goal after the consideration. The second rule of action research is our action research cannot be abstracted away from background research (Mcniff, 2013). Also, researchers can think of yourself as a part of the research and ask your own experience (Hearn and Foth, 2005). Furthermore, "Learn by Doing" is one of the key principles in action research. The design planning and implementing process can consist of various iterations to observe and reflect the design method.

Their explanation of action research gave suggestions on design direction, narrow the research question: how this system can help to solve some individual problems or even make some difference in this field. The revision is quite important in the action research stage, the flow from proposing the research objectives until the final plan is iterative or cyclical. For this project, a premilitary survey will be conducted in the beginning, and observations and reflections will repeat through the research process regularly to adjust and improve the design. Also, because this research is relating to home experience, users test will be held, at last, participants' experiences and suggestions can provide further design instructions.

5. Literature review

SHS isn't a brand-new idea today, however, it becomes more complicated with more dynamical parameters and elements employed in one system (Harris, 2012). At the early stage, the predecessor of SHS is a responsive system (RS). The origins of RS go pretty far back in history. One of the first feedback-control responsive design can be traced back to the 1700s by Cornelis Drebbel. He invented a mercury thermostat which could keep a place at constant temperature by measuring by the expansion of a liquid held in a vessel connected to L-tube containing mercury. (Yakovis and Chechurin, 2015). Cornelis designed a feedback loop to control the RS in this project, with his idea, more new inventions based on his RS appeared. SHS developed quickly since the advanced of technology. SHS can be defined as a residence to integrate and control different home automation systems with a central control system. Communications and interactions will conduct through the transfer of various data between various single systems.

On the whole, one SHS can be demonstrated in three aspects, component, function and outcome. These three aspects constitute the workflow of a smart home. (Jia et al., 2018) The most essential part of the workflow is the components. Components can be defined as the actuator families, for example, the traditional components such as HVAC or lighting functions associated with the sensing control system. With multiple combinations of components, they offer a variety of different functions. The function always applied with an intelligent responsive design which might optimize the building design in several aspects, such as energy, comfort or more environmentally friendly and sustainable.

If the SHS is creating a single system in residence, the IoT is connecting multiple single systems within the cloud. The word IoT stands for the Internet of things, it means humans and machines link with external components via the internet. (Park and Rhee, 2018) Allow automatic and safe connectivity and data exchange between physical and virtual objects is the basic idea of the Internet of things (Khan et al., 2012). An IoT product typically requires support from several hardware and software components associated with a multi-layered stack of different IoT technologies (Wortmann and Flüchter, 2015). Furthermore, one IoT stack usually consists of three main layers: product, connectivity, and cloud (Porter and Heppelmann, 2014). The product can be a device or system, with IoT technologies, multiple single components connect via the internet, transferring and integrating the data into the cloud to manage and optimize.

Nowadays, many residential adopt the concept of ubiquitous sensing where the sensors networks integrate via the internet. Tiger Place, a retirement community, which is an example of using the cloud to monitor SHS and adopting countermeasures to analysis results. This living laboratory applied with several sensors within the infrastructure and home interior products in each room (Skubic and Rantz, 2016). In Tiger Place, the end-users, caregivers or doctors and research teams can access and analyze every single intelligent device in the system. To a certain extent, Tiger Place shows the participation of users and developers in improving, updating and analyzing the project together with the concept of IoT (Ding et al., 2011).

Comparing smart home and IoT, they have similarities which is connecting products with the internet, however, the IoT is acting as a platform allowed the end-users or devices such as multiple SHS to connect with the IoT cloud to manage and monitor each system.

The method of building a smart system is varied, and each of them has different features. Physical computing is one of the popular methods to build an interactive physical system using seaware and hardware. Besides, Arduino is an open-source electronics platform that is adaptable, and programmable. Users can easily assemble an application with variable sensing or control components (Popiel, 2015). Arduino can be programmed using C++ language, also compatible with most of the platforms and external components. Also, comparing Arduino and other development platforms, it has the advantages of low-cost, convenient operation and easy assembly.

Nowadays, smart technology is mainly focused on bigger pictures instead of the aspect of details in daily life (Ding et al, 2011). However, more than 83% of the prospective users believed that the SHS should help the users to lead a more convenient life, including saving energy, providing comfort and saving time (Wilson, Hargreaves and Hauxwell-Baldwin, 2017). Accordingly, this research focus on improving the time utilization by control the home appliances to prepare and complete tasks in advanced.

Through a series of researches, SHS is a mature concept nowadays, and there are numerous valuable precedents. However, it keeps developing fast with technological advancement. The research will continue to explore how to design a geolocation based SHS.

6. Case Study

The case study includes three aspects, collecting geolocation data, designing the auto-control physical computing system and researching user experiences.

6.1. PREMILARITY SUERVEY (ITERATION 1)

According to the research goal, this project focuses on user’s everyday living and home experience by using SHS. Thus, current and prospective SHS users' perspectives are important. Collecting their experience information will help the research to narrow and focus on more specific problems. First of all, I conducted a questionnaire surveys within 20 interviewees from different background. There were 45% of them have full-time jobs, and, 50% of them were students. Also, 15% of the students got part-time jobs.

In the questionnaire, the survey opened with users' basic background information, for example, their age and occupations. Because the participants usually have different perspectives and experiences with different vision location.

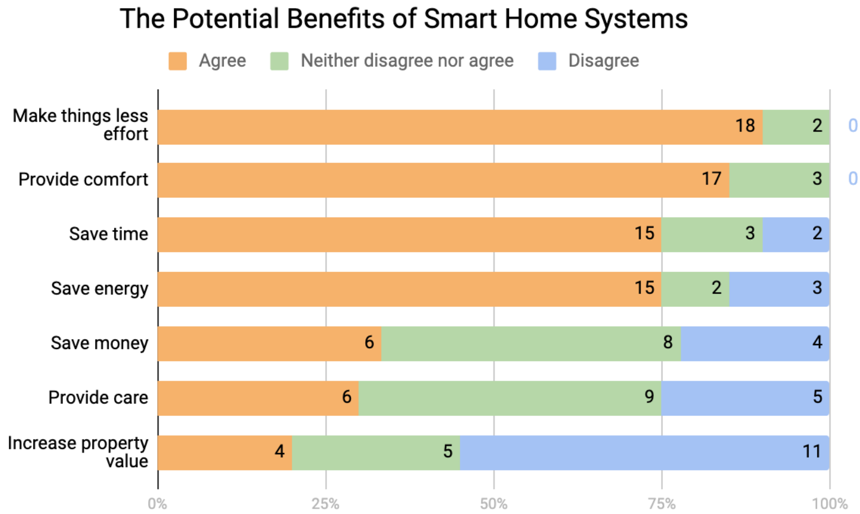


Figure 1. The potential benefits of smart home systems.

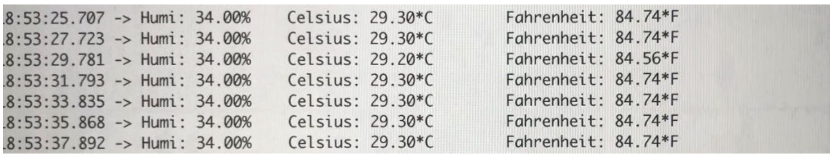
According to figure 1, more than 85% of the interviewees believed SHS could help the users to lead an easier everyday life. Specifically, the SHS will makes things less effort and provides comfort. Also, some of the participants pointed out that their smart home devices could connect with an APP on mobile phone to control home devices. According to Tom, Charlie and Richard's research published in 2017, more than 83% of the SHS' prospective users agreed smart home technology will make life more comfortable and convenient (Wilson, Hargreaves & Hauxwell-Baldwin 2017). Through the above research, this research emphasized the time utilization rate in daily life.

The second aspect of the first iteration was researching the average commute time of 20 participants. The answers were from 0.5 hours to 1.5 hours in consequence of the distances from home were varied. The result was the same as the survey released in 2019 by Household, Income and Labor Dynamics in Australia (HILDA). In the research, city workers in Sydney typically spent more than an hour commuting per day. Also, the commuting times varied with different cities' traffic conditions. Ye and Ma (2019) proposed long-duration commuting will reduce the time the person has for other activities. According to the statistic, the design objectives were clear because of the analyze of social requirements. The research narrowed to design a SHS and workflow to increase the time utilization ratio for commuting time.

6.2. PYSICAL COMUTING METHOD EXPLORATION (ITERATION 2)

According to design objectives, one of the outcomes of the research is to design a physical commuting system for SHS. The open-souse microcontroller named Arduino was used in making hardware design. The first experimental research was using a relevant module to test sensing functions by using sensors. There are various sensors that could be assembled with Arduino. The DHT 11 and DHT 22 are common humidify and temperature sensors. Comparing two of them, DHT 22 has better performance in function. Also, its temperature and humidity reading ranges are larger with higher accuracy. However, DHT 11 has a price advantage. In this stage, the DHT 11 sensor chose in hardware design because it can meet the requirement of this iteration.

The physical part of the system consisted of a DHT 11 module, an OLED screen, and an Arduino microcontroller. The code was written on a flatform named Arduino IDE in C++. The OLED screen showed the real-time result of DHT 11 sensors, another data displayer was the serial port displayer on the platform, it could visualize the result in line chart.



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.8:53:25.707 -> Humi: 34.00%    Celsius: 29.30*C        Fahrenheit: 84.74*F
.8:53:27.723 -> Humi: 34.00%    Celsius: 29.30*C        Fahrenheit: 84.74*F
.8:53:29.781 -> Humi: 34.00%    Celsius: 29.20*C        Fahrenheit: 84.56*F
.8:53:31.793 -> Humi: 34.00%    Celsius: 29.30*C        Fahrenheit: 84.74*F
.8:53:33.835 -> Humi: 34.00%    Celsius: 29.30*C        Fahrenheit: 84.74*F
.8:53:35.868 -> Humi: 34.00%    Celsius: 29.30*C        Fahrenheit: 84.74*F
.8:53:37.892 -> Humi: 34.00%    Celsius: 29.30*C        Fahrenheit: 84.74*F
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Figure 2. DHT sensing results displayed in serial port

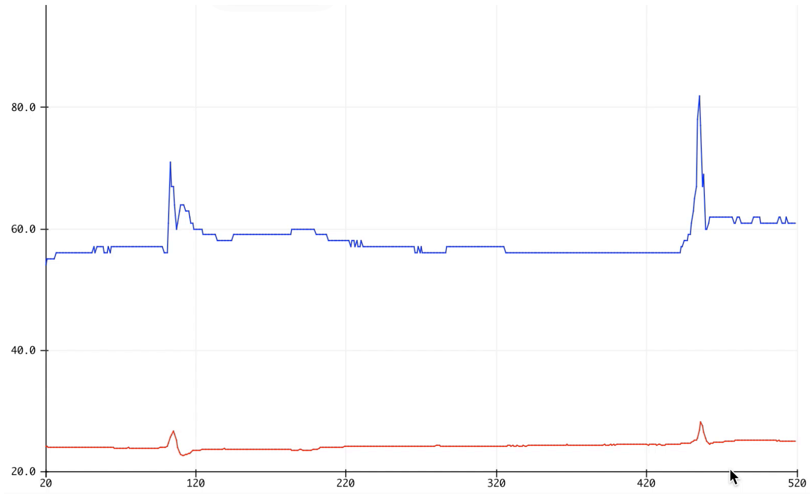

Figure 3. DHT 11 sensing results in line chart

As shown in figures 2 and 3 the real-time humidity and temperature data visualized in serial port displayer in the line chart. The blue line represented humidity data, while the red line represented temperature data. The great fluctuation of the humidity result showed that DHT 11 sensor was not accurate enough to use in a real project.

Thus it can be seen that some of the low-cost digital sensors or other components such as DHT 11 are easy to assemble with the microcontroller, but they are not stable and accurate enough. However, it does support the basic function of the research design and provide helpful research results.

6.3. REAL-TIME LOCATION COLLECT (ITERATION 3)

As the research goal introduced in research aims and questions, this project aims to design an SHS which can control home appliances bases on the user's location. Also, according to iteration 2, it proved that the Arduino and other open-source modules could support the following research. Therefore, the third iteration explored how to use these components to build a physical computing system that could detect the user's real-time location and visualize on displayer.

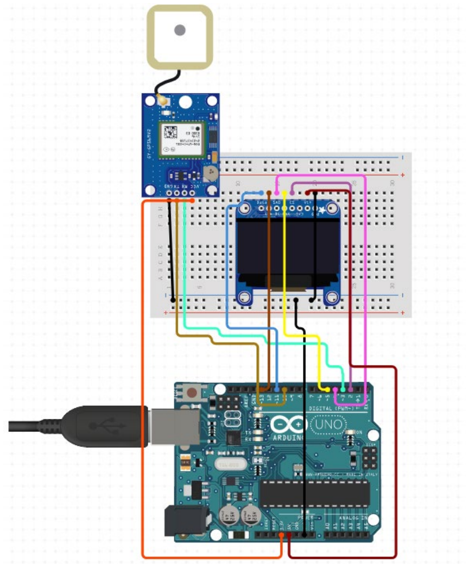

Figure 4. Physical computing design of iteration 3

In figure four, it displays the physical design by using an Arduino kit, an OLED screen, and Neo-6m global position system module. The Neo-6m GPS module is a cost-effective and high-performance digital component, it can collaborate with the Arduino board and access the GPS data.

The outcome of iteration three was the real-time location in the National Marine Electronics Association format generated by Neo-6m GPS module. It consisted of six different GPS data included GPRMC, GPVIC, GPGGA, GPGSA, GPGSV and GPGLL data. In the serial port displayer, code GPGLL means latitude and longitude of the current location. Accordingly, iteration three demonstrated that the Neo-6m GPS module collaborated with the Arduino kit could obtain current location data.

6.4. AUTOMATIC PYSICAL COMPUTING SYSTEM (ITERATION 4)

Through the previous experiments, they have shown that Arduino assembled with a range of modules could achieve different outcomes. The final iteration was aiming to design the workflow of automatic SHS based on the user's location. In this stage, it explored how to increase the time utilization ratio by control home devices at residence during commuting.

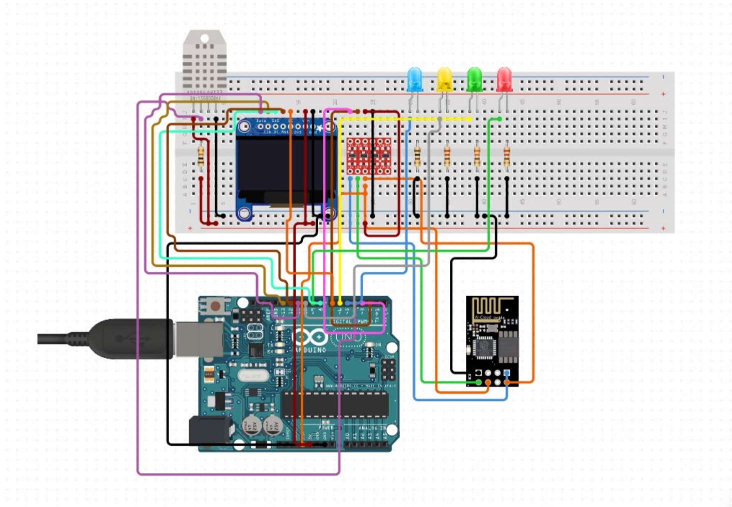

Figure 5. Physical computing design of iteration 4

To do that, the physical computing part at this stage included an Arduino microcontroller, an OLED screen, ESP8266 WIFI module, and multiple LED lights. The ESP8266 WIFI module is a self-contained SOC that can connect the microcontroller with the internet. In iteration four, the ESP8266 WIFI module helped Arduino connecting with a laptop or mobile phone platform to control and start the SHS system. To modify the user's movement, the distance data was assumed in software design, with the set speed of the user, the distance reduced 1 meter per second. And, the test user spent 31 minutes to arrive at residence.

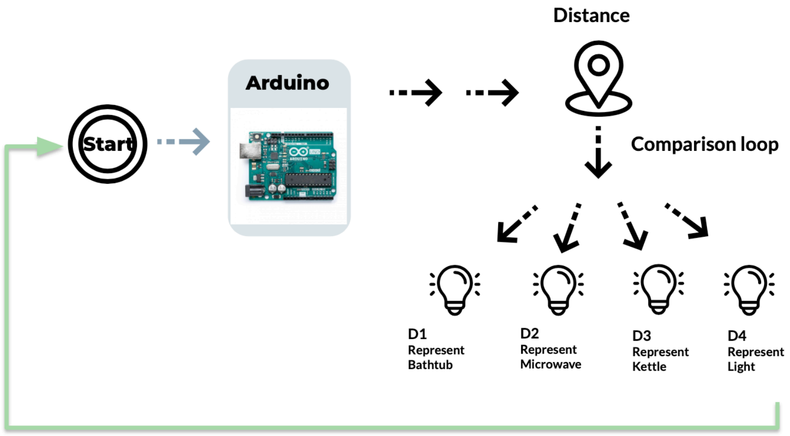

Figure 6. Workflow of the SHS

According to the research, this SHS aimed to explore the time utilization rate. Thus, another core in software design was multiple comparison loops. More specifically, when the distance is lower than the setpoint, the SHS will start the corresponding home appliances. For example, the user plans to enjoy a bath when he(she) arrives home, the SHS will calculate the preparation time and start to prepare the water for the user in advance. As shown in figure six, it shows the workflow of this SHS, and home appliances can finish or prepare in advance during the commuting time, which increase the commuting time's utilization ratio.

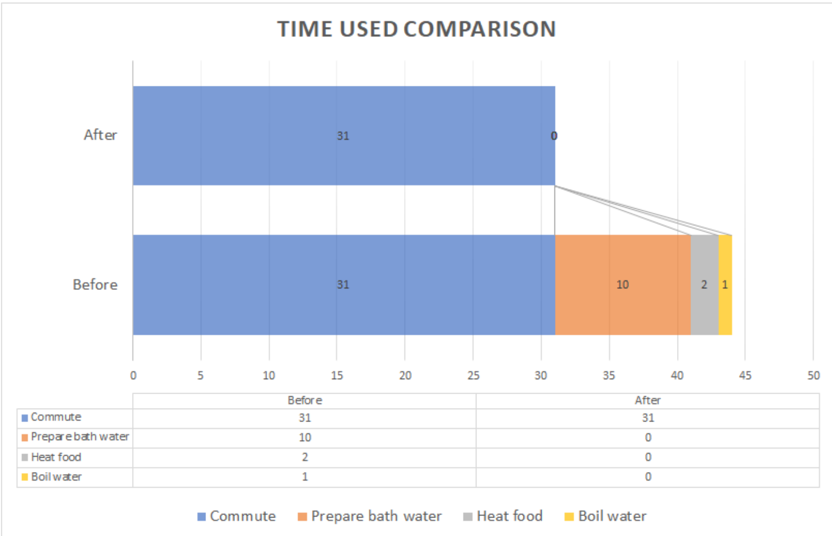

Figure 7. Time used comparison

According to figure seven, it gives the example to explain how does the SHS save time for user. To make full use of commuting time, the SHS can connect with multiple home appliances and start working based on user's requirement.

7. Discussion

To some degree, the outcomes of four iterations achieve the initial goal of the research through the experiments and four iterations of exploring physical computing and building an automatic SHS. In the first iteration, the premilitary survey researched the service condition of SHS and perspectives from 20 current and prospective users. The results narrowed the project's aim and gave a clearer design direction. Then, iteration two and three focused on testing and designing a basic physical computing system using Arduino and other digital kits. These experiments confirmed that the Arduino kit is a low-cost, convenient operation and easy assembly method to customize a physical system. At last, the iteration four aims to design a workflow and SHS which could increase the commuting time utilization rate.

"Lean by Doing" is a helpful methodology in action research, it suggested designer can review, reflect and observe in various iterations in design process (O'Brien, R., 1998) This method is also useful in research phases, more specifically, each steps of this study linked together by reflecting and observing. Although the outcomes of this project have reached the target, there are three aspects need to be further researched in future research.

Firstly, the SHS workflow design in iteration 4 was based on assumed distant data. However, the SHS should connect with users' mobile devices to collect real-time distant data. Through the experiment in iteration 3, it used the Neo-6m GPS module and the Arduino kit obtained the real-time GPS location successfully. Therefore, the first design direction is continue developing the current SHS in iteration 4 to use real-time location data by adding the Neo-6m GPS module.

The second design direction in future research is developing a mobile platform to control the SHS system such as an APP or a website. In this APP or website, it can visualize the real-time condition of the SHS and smart home devices. Multiple smart home appliances can connect via the platform, this idea is the same as the Internet of Things technology.

At last, even there were premilitary surveys done in iteration one, and they did provide helpful design ideas for the following research, the rest iterations can add users tests too. Because the SHS is a project close to the user's living experience in daily life, it is important to understand user's actual needs and collect their feedback in each step. The user's experiences will help the project to review and optimize in the next step.

8. Conclusion

This research study explores the utilization of geolocation in the smart home system and home automation. It focuses on the possibilities of controlling the smart systems in resident with users' real-time geolocation which make the everyday living more time-efficient and convenient. With four iterations, the outcomes prove that this physical computing smart system can improve efficiency in daily life by making full use of commuting time. To test the result, this research investigated the saving time by comparing traditional and geolocation-based systems included the automatic operations of bathtub, kettle, and microwave. The result showed that assembling geolocation-based smart systems at residents could save 34% of the time. Thus, the outcome gives a positive answer to the original aim which is whether the smart home systems can be optimized by accessing the user's geolocation. However, this research can be continuous developed in the future.

Overall, this research designs an automatic SHS based on geolocation data which will make the everyday living more flexible and intelligent. More specifically, it provides a workflow of obtaining real-time GPS location in SHS. Moreover, it enhances the current SHS and improves its interactivity and flexibility, this will make everyday living becomes more convenient and comfortable.

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Appendix A: Questionnaire Key Notes in Iteration 1

Questions	Results	Significant answers
Have you ever used smart systems before?	85% - Yes 15% - No	1. The Sydney coordinated adaptive traffic system is an example of a smart system. This system can analyze real-time data and manage traffic. 2. I think the smoke alarm in my apartment is the smart system. Because is an automation system, and the DFES will be alerted to attend the premise in response to an alarm. 3. The uni's student card?
Have you ever used smart home technology in your residents?	40% - Own single smart home device	1. I used a voice-control lamp at home. 2. I have a Google Home speaker. It's a voice-control system. 3. I have a Tmall Genie at home. It is a smart speaker.
	30% - Own multiple smart home devices.	1. I bought other smart devices such as a smart light. I can use an app to control the light or voice-control other accessories.
	60% - I don't have SHS or smart device at home.	1. I don't think it's necessary. 2. The price of installing a SHS is not cheap. 3. I have a full-time job, so I spend most of the time outside my home. 4. Maybe privacy concern? For example, the wireless security camera. I read some news about it before.
What benefits do you think about SHS?	85% - Make life more convenient.	1. I think the smart home technology can have me save time and make things less effort.