

# The Real-world Performance of Smart Home Technology

An Impact-Analysis of Smart House Devices with Comparison of Current Voice-interface

Devices

## I. INTRODUCTION

### A. Definition of Smart Home

For our advancing technologies developing in remarkable progress, nearly every technical innovations and productions can be classified into the network of Internet of Things. The network of Internet of Things is the combination of physical communication, devices and other innovations that contain wireless connections, sensors, and electronics on the function of data collections.

From the concept of Internet of Things(IoT) to the new fashionable idea of Artificial Intelligence(AI), the development of the advancing technologies are stepping forward with such incredible progress. However, beyond the level of innovations, how these innovation are going to promote the equalities of homes and average civilians can bring the real impacts attracted the the attention of the world. Focus on the actual products, back to the year of 2012, Apple invented Siri based on the new voice-interface technologies in 2014, Amazon published the new Echo family products, while Google introduced the Home in 2016. A smart device can be intensified as “an ordinary appliance with a sophisticated computer installed to give it more functionality that can monitor so many aspects of daily routines[1].

The appearance of smart home technologies, can become unbelievably common; the various security systems are appearances of smart home technologies. More recently, from the examples we can see in the nearby markets: beyond the level of our current security system, the sensors, cameras, light

monitors, thermostats, self-controlled air-conditioning systems and especially, the voice-interface interaction devices like Google Home and Amazon Echo, are all classified as smart home technologies.

To explain the concept of smart home, Artificial Intelligence must be considered. From the year of 1956 to 2015, the concept of Artificial Intelligence have been developed outside the attention of general public. However, since the year of 2015, as the current technologies become enough to support the innovation, but not only the concept of artificial intelligence, projects and products of artificial intelligence attract the attention. At the same time, numerous experimental products emerged, include Intelligence Cloud technologies from Oracle and Amazon, self-driving technology from Tesla[2]; among this, smart home have been developed as part of the artificial intelligence field. According to the Smart Home Association: the definition of smart home is the integration of technologies and services through home networking for a better quality of living. Why smart home? To what extent does the idea of artificial intelligence developed to the concept of smart home technologies? Statistically speaking, as the average age of global population increase, we are having a larger group of elder populations. According to Population Reference Bureau, from now to the year of 2060, the population of America beyond age 65 will intensively increase from 46 million to 98 million[3]. Additionally, the general culture of America determined that the elder population normally lived alone.

Overall, the current and future culture of our nation created the potential market of the

smart home technologies. Additionally, as the increasing of elder population appeared in most developed nations and some of the developing countries, the markets for the smart home technologies, merely just on the elder population, is unmeasurable. Applications of the smart home technologies can also encompassed in different areas, including interactive conference rooms, and office environment[4].

### B. Function of Smart Home

However, as the research of smart home technologies processing, the next level focus have been shifted from the experimental products, to the real-world use of the smart home solutions. The function of current smart home can be classified as follow: welfare(health and personal care devices), entertainment (electrical furnitures with its advancing functions), environment(remote management of energy using), security(home security, sensors, alert system) and communication(remote personal resources management and communication with other people)[5].

Welfare function of the smart home, which works for the benefit of the elder population; the existing smart home devices responsible for this function include the health monitoring devices(heart rate detector, blood pressure detector, etc.); worth noticing, most existing researches regarding the real-world smart home functions are focusing on the welfare function with elder population. Also, as mentioned in the previous sections, the updating security system commonly appeared in every household today are considered as the best representation of the security functions of the smart home system. Specifying to the certain existing smart home system, like in the *Ontology-Based Management of the Telehealth of the Smart Home, Dedicated to Elderly in Loss of Cognitive Anatomy*, the paper introduced an smart home model ontology(from philosophical perspective, ontology is the relations between different categories of beings) based model of the TSH(Telehealth Smart Home, Telehealth let hospitals provide health cares services using electronic communication solutions like

smartphones and two-way videos)in modularize approach. Ontology is on the perspective of smart home devices, is potential enough based on the development and configuration of effective applications. The goal of the system is to take advantages of the full potential of ontologies to describe the domain, in order to provide an effective base for the development, the configuration and the execution of software applications on solving problem of elder diseases like Alzheimer's disease in this world with a rapid increasing aging population[6].

To better understand the concept of smart home, different perspectives have to be considered. From functional perspective, smart home is "a monitored, sensed environment that informs occupations allowing active control or automatics." While from instrumental perspective, the smart home system can be identified as "an optimally managed building energy system allowing information and price-responsive adjustments to behavior. For the social-technical characteristics, smart home is a digit-technological networked vision confronted by the mundane realities of domestic life.[7]"

### C. Smart Grid & Smart Home

In the civilian use field of the artificial intelligence, smart home and smart grid technologies have high similarities but different. The smart home technologies are focus mainly on the function while the smart grid is more focused on connections of datas among households. On one hand, smart grid is more focused on the inter-connections of households, smart grid is definite as "an intelligent electricity network that integrates the actions of all users connect to it and makes use of advanced information, control and, communications technologies to save energy, reduce cost and increase reliability and transparency.[8]" smart grid can also be served as electric power grid infrastructure for efficiency improvement, reliability ensuing and cyber security, with smooth integration of renewable and alternative energy sources, with association of automated

control and modern communications technologies. [9]

For the smart home technologies, it's more focused on the functions and the real-world benefits regard to the average households. Due to definition, smart home is considered as "a monitored, sensed environment that informs occupations allowing active control or automatics.". Differentiate from smart grid, smart home is a vision confronted by the mundane realities of domestic life. From instrumental perspective, smart home is an optimally managed building energy system allowing information and price-responsive adjustments to behavior. [10]

#### D. Privacy and Security challenge

While the smart home systems are in development toward the considerable reliability and lower costs, the privacy of the devices raised as concerns similar to those of targeting on other wireless systems. For the storage of data in smart home systems, the processing of data been classified into data ownership, data transferring, data storage & processing and data access. For the data transfer, integrity and confidentiality needed for ensuring the security of transfer, the possible solutions include VPN and cryptography. The solution for data storage, according to *Privacy Preserving Data Analytics for Smart Homes*, in which the developers shall replacing the personally identifiable information with randomized placeholders and the process shall be Independent to the sensitive datas. Additionally, the accessing to the data shall be secured under proper authentication and authorization[11]

Based on the information from *Senior residents' perceived need of and preference for "smart home" sensor technologies*, the elder individuals involved in the investigation generally pointed out the accessing of the information shall be limited in the range of close family members, healthcare providers, and patients themselves[12]. In another example from *Forecasting the behavior of an elderly wireless sensor data in a smart home*, the overall structure of the smart home system consists of

two important modules: (1) wireless sensor network, (2) intelligent home monitoring software system(collect sensor data and perform data analysis for detecting behavioral changes of an elderly). Additionally, a trial system suppose to run in the system for collection of datas[13].

#### E. Other Concerns

At this moment, even with the most current technologies of Amazon Echo, Google Home or the newly released Apple HomePod, everything will be just in reach, while the students are facing a problem in calculus curriculum, 5 years ago, these students would use a calculator, but the only thing students need to do now is consent with one of these voice-interface devices; with a simple command of: "Alexa, what is the anti-derivative of two X square?" Then the answer is captured by their ears. From the simple example above, we can see the future of our home, in which everything will be in easy reach; our citizens no longer need the face-to-face interactions with other individuals.

Based upon Dr. M. Chen, other major concerns about smart home includes: (1)User needs, acceptability, and satisfaction, (2)reliability and efficiency of sensory systems and data processing software (3)Ethical issues and (5)legal issues[14]. Currently, the under-developed surrounding markets of voice-interface products contributed to the overestimation of real-world benefits of the devices, which lead to limited user needs and acceptability. For the data communication system(smart grid, as explained in section C) have not fully developed, electrical furnitures are unable to connect each other with home Wi-Fi signals, with the fact that other signal technologies(ZigBee, PLC etc.) have yet adopted into home environment. From legal perspective, regulations are far away from completed due to lack of law cases and policies. The ethics of smart home technologies are also been concerned as shall the devices obtain human emotions and personalities.

## II. Research Object Comparison

In this research, we'll compare the functioning, utility, and the current adoption rate of these two devices in America market. From the function level, this research will compare the modules and kits by using the Google Home model and Amazon Echo of the first generation. If allowed, the research will use generation two of Amazon Echo.

### A. Structure of Smart Home System

However, smart home devices is different from smart home system. In this section, we'll specifically explain the structure of smart home system. From the existing researches, the structure of the smart home system shall include: data collector(transfer data from sensor to cluster at regular interval), data receiver(receive data from collector, transfer into 2 sets), de-identified sensor data(coding data), and result provider(the module controls the user accessing)[15]. Smart home devices including Google Home and Amazon Echos are part of the Smart Home System. Based upon its definition, smart home system can obtain multiple devices with unique functions.

### B. Google Home

The first generation of Google Home released in November, 2016, which is two years late compare to Amazon Echo. Compare to Amazon, Google have more products surrounding the Home devices. According to the official website for Google Home, the Home family contains Google Home Mini, Google Home, and Google Home Max. However, based on the fairness of the research, this research will compare Google Home(regular product) with the Amazon Echo(regular product). Also, based on the Smart Home & Entertainment on Google's official webpage, the Home family devices can connect to devices including Google WiFi, Chromecast family(Ultra, Chromecast, Audio), Nest Thermostat, Nest Protect, Nest Secure Alarm System, Nest Cam IQ Indoor, and Nest Cam Outdoor. For mobile applications, Google published Pixel as for the phone market, the

phone can be connect to each part of the smart home system(in which are the devices). Counting on the availabilities of connection of Google Home to other devices, other than the products from Google mentioned above, Google also collaborate with other technology corporations including Philips, LG, SONY, VIZIO, TP-Link, Samsung Smart Home, Hui Smart Home, Hook Smart Home, iHome, etc.

### C. Amazon Echo

The Echo family products were first released in 2014, until right before the releasing of Google Home(March 2016), The Amazon Echo family took 26% of unit sales and 42% dollar sales of the overall profit of Amazon Inc.. In the next year, the sales from Amazon Echo took half of the Amazon profits. With data analyzing, Echo family products been adopted as smart home devices by customers from all incoming groups and diversified age groups. With comparison to other similar products, Amazon sold 2.3 times of smart home devices than combination of all other smart home hubs[16]. Based on informations collected from Amazon's official website, the Echo family products includes Echo Dot, Echo(regular), Echo Plus, Echo Spot, Echo Look, and Echo Show. Amazon Inc. also chose to collaborate with other technology companies including SONY, Wemo, Nest, and TP-Link. For the remote connection, Amazon have mobile applications on both App Store and Google Play Store. From the published information, Amazon Echo devices obtain 7 speakers, can receive voice commands from any angle. While the Amazon Echo obtains the largest market in the field of voice-interface devices, costumers can choose 6 themes of colors for their devices.

### D. Apple HomePod

Apple Inc. released the first generation of Apple HomePod on January, 2018. Due to the short period of the time between this research is conducted and the time the HomePod have been released to the market. Datas and informations are rare. More research can be done when the

Apple HomePod took enough market and have maturer development.

#### *E. Hardware Setting for Smart Home*

As been mentioned earlier in the paper, the hardware settings for each model of voice-interface devices are mostly similar; however, differences exist from model to model.

### III. Research Methodology

#### *A. Goal and Gap*

As the voice-interface smart home devices have released for no more than 3 years and the market have been rapidly developing, so in the field there's no research on the detailed analysis of real-world performance of functioning about these voice-interface smart home devices. The goal for this piece of research is form a comparison the existing models in the market(i.e. Google Home, Apple HomePod, and Amazon Echo) by analyze the utility, marketing, adoption rate and hardware structures.

#### *B. Survey*

Survey is considered as the most direct solution on collecting the mass opinions regarding a issue. This research designed the survey on Google Form and use the printed out copies as well. The links are published online for people to take. The household in the area of Wyomissing, PA have been included in the research. Survey samples are chosen randomly from the households in the targeting region. The amount of family households in Wyomissing 3900. The survey amount should be representing 10% of the sample. The sample size of 53 will have a 5% error margin and 90% of the confidence. The survey was given out on February 14<sup>th</sup>, 2018. All surveys have be provided with the consent form, the survey takers have been told of the following: (1)The information collected in this survey will only be used on this research. (2)Your personal information will be kept confidential. (3)My decision on participating in this survey will be

kept confidential. A brief introduction of the purpose of the research is given.

The survey takers are been asked about the (1)Family income? (2)What smart phone do people in the family currently bear? (3)Have they heard of the concept of smart home? (4)Their opinion regarding the development of smart home? (5)What function does they consider as a use of smart home? (6)Or what is their concern if they choose to disagree with the

development of smart home? (7)Is there a security system for their household? (8)Does their security system allow for remote control? (8)Which model of the device does the household adopt(i.e. Amazon Echo, Google Home)? (9)What is the specific function of the device? (10)Is the device connect to other devices or not?

#### *C. Expert Interview*

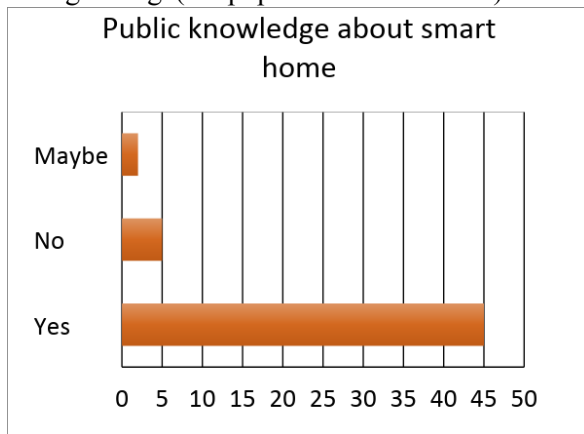
The expert interview will include the responses from 3 experts, the responses and conversations will be done by emails. The experts will be asked about their opinions regarding the existing models of the voice-interface devices. The experts are from Oracle Corporation and Kulike & Soffa Industries Inc. The experts are been asked for their specific opinions regarding the smart home concept, the development of Google Home and Amazon Echo, their opinions of adopt artificial intelligence technologies into regular households, their prediction of settings of the future household, the considerations of a completed smart Holme system, the experts'

opinions of how civilian used technologies improve with the process of smart home technologies.

#### IV. Result and Data Analysis

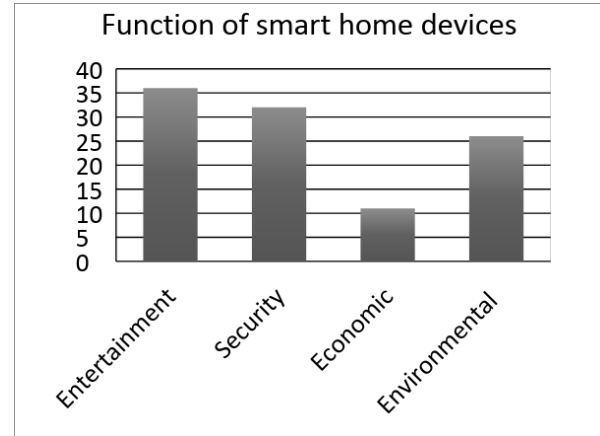
##### A. Survey Result

In total, 53 households responded to the survey, based on the consent form, the overall response amount for each question are very. In 52 survey responses, 45 have said they heard about concepts of smart home, with 5 said that they didn't heard about smart home and 2 chosen maybe. From the data collected in the survey, 86% of the population have obtain some level of understanding to the concept of smart home. These informations about smart home concept can be dominantly adopted from written articles from mass media. Data from the table above positively proved the population in the Reading sub-urban area have its base for the development of smart home. However, due to the limitation of enough survey responses, the data above and presented later may not be relevant enough to represent the population to a larger range(i.e. population of America).

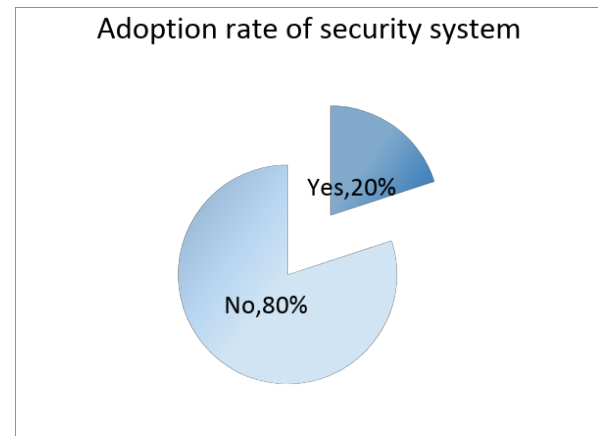


In the following question, the question asked the survey takers if they support the current developments of smart home. Among the 50 whom answered this question, 40(80%) of them supporting the existing and continuing development of smart home technologies. In which about 80% of the people who heard about the smart home have agree that the development

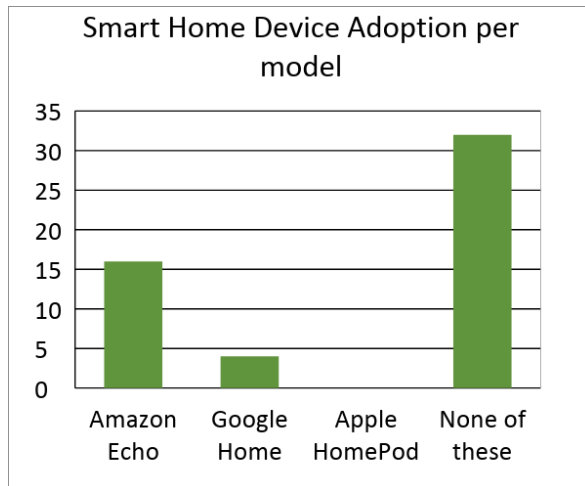
of the smart home technologies are going to benefit back to our households. However, from the graph above, 20% of the survey takers disagree with the concepts and advancing of smart home. The survey also collected the reasonings of disagreement. Relevant reasons



including: privacy, unnecessary, security, preferring traditional method and create environment in which people will be less rely on human interactions. These concerns certainly have their stands and they are the fields the future researches may focus on. The smart home devices using the signal technologies like Wi-Fi, so certainly the devices have possibilities of



been hacked. Additionally, although the premature smart home solutions may seems unnecessary to certain population, however, the development of smart home have no major harm to the society thus conform to the flow of technological developments. Additionally, as the companies working on smart home solutions publish new solutions regarding the concerns of

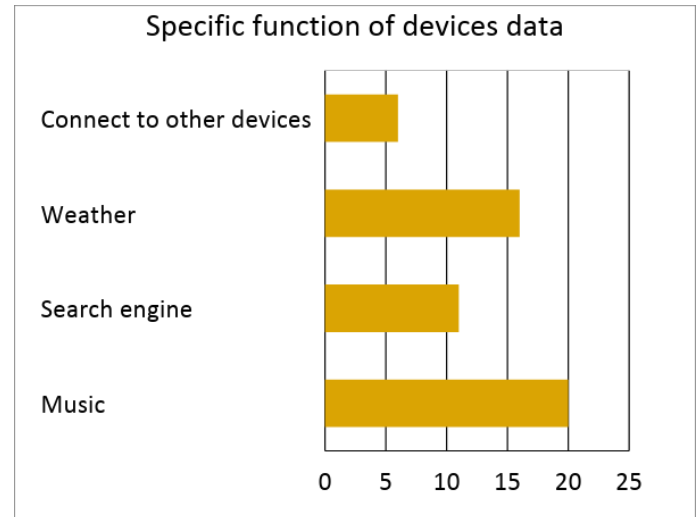


security and privacy, the developing smart home will meet the public expectations. As mentioned earlier, smart home devices can have functions of entertainment, economic, environmental, and security. The survey consented the opinion of people on which functions do they think the smart home devices should have. Survey takers can choose more than one choices. The information collected have been presented in the graph above. Collectively, 36 survey takers considered entertainment is one of the function of smart home devices, 32 of them chose security, economic and environmental are 11 and 26 respectively. Among all four possible functions, economic is been least considered, while the entertainment have been considered the most. Currently, most existing smart home devices on the market are dedicating for the home aid of the elder generations, include personal health monitors, motion detectors, etc. The function of security is also been highly concerned for the common appearance of home security systems in countless households.

However, only 20% of the households in Wyomissing, PA have installed completed security systems in their household. From the practical perspective, the overall smart home adoption in this area is underdeveloped compare to initial hypothesis of this research.

Among 47 survey takers whom answered the question, 15 of them adopted Amazon Echo and 3 adopted Google Home. Apple HomePod have seen no adoption due to the short time after publish and the existing

marketing influences of Amazon Echo and Google Home. Worthy noticing that 30 of them have neither Amazon Echo and Google Home. The data have further proved the conclusion that the smart home in Wyomissing, PA need more developments. However, based on existing adoption data, Amazon Echo took 5 times of the market approximately when compare to Google Home devices. The households who have no smart home devices doubles the amount of



households adopted the Amazon Echo.

Diversified functions of smart home devices can decrease the complexity of household life. From the survey takers whom adopted either Amazon Echo or Google Home about the use of their devices in categories of (1)connect to other devices, (2)weather, (3)search engine, (4)music and the data is shown below. Based on the result, 20 said they used their device for music, 11 considering to use the device as a voice searching engine, 15 used the device for weather check and only 5 considered to use their device for the connection with other devices. From the survey responses, Amazon Echo devices have developed real world connections with Fire TV, Fire Sticks.

From the point of time when this research have been conducted, most com consumers of voice-interface devices have focused on the fundamental functions of the devices. From the overall data collected, the smart home development remained on the primary level. Imagine the existing

voice-interface devices on the market as the controlling centers for the future smart home system, the connections from the center to other devices in the system can be incredibly improved within the next decade. Positively speaking, more technological products have emerged functions for the inter-connections of devices. With limitations, these inter-connections remained on the level of connecting to the devices with different functions from the same technology company of their own. This situation also reflected by the survey, the survey takers who adopted Amazon Echo would choose to connect the device with Amazon Fire TV instead of AppleTV, although these TVs both obtain eligibility of inter-connections with other devices.

### *B. Interview Highlight*

To obtain necessary credibility of this research, experts were selected and interviewed randomly. All the experts the research have interviewed are holding at least Master Degree in technology related majors, one expert received his Ph.D in the field of computer engineering. Because of privacy agreement, the specific office name, job name, and personal informations(name, address, email etc.) will not be published in this paper. The experts are being asked about their opinions regarding the development of smart home and their opinions of targeting models of this research(except Apple HomePod).

From the responses of experts, results are vary. Positively speaking, all experts obtain understandings and opinions regard the smart home concept. Additionally, all the experts interviewed responded that artificial intelligence shall be adopted into civilian households. According to the response from an high official of Philadelphia IEEE Conference, including all the products in the field of smart home as whole, Amazon Echo and Google Home are classified as “personal assistant” devices. Opinions from expert show that AI technologies shall be adopted in particular for homes with elder or otherwise less mobile people. Another expert from Oracle Inc. stated that “often, the inability

to cope with these things can lead elderly people to enter more costly facilities when they would prefer to live independently. Technology can help with these simple routine tasks, supporting such things as on-line weekly grocery ordering, medical reminders(such as when to take medications), anticipating transportation needs(such as contacting Uber services), and scheduling(of medical appointments or social engagements).”

The development of current technologies are the base of the technologies in the future; as mentioned by experts, the smartphone technologies can push the capability of home. For the future of the home environment, households will contain a network of various safety devices, daily-use entertainment devices like speakers, televisions, cleanliness devices, administered by either a centralized humanoid manager or a smart—decentralized home system. In overall, although the current developments of smart home remained to the level of individual devices, the next step development will be systematic connection of smart home devices, the voice-interface devices that occupying the major markets will be the center of the future smart home system.

This research also asked for comments to Amazon Echo and Google Home separately. All experts gave opinions regard Amazon Echo, while only one expert commented on Google Home due to lack of awareness. With prior knowledge Amazon Echo have a lower price, earlier publishing date, and well-developed connections with products both inside and outside Amazon, the market of Amazon Echo has absolute advantage compare to the market volume of Apple HomePod and Google Home. However, reported by one expert that Google Home device is slightly better than Amazon Echo on identifying voices.

## **V. Conclusion & Limitation & Further Research**

### *A. Limitations*

Despite the achievement, this research has countered few limitations in the process. Due to the limitation of time, this research collected limited responses regard to both survey and interviews. The current population in Wyomissing, PA is 10,410, and people per households is 2.7. So there will be approximately 3,800 households in the area, 5% of the sample should be 190 households(1 survey per household), this research only collected 52 survey responses. As the result, the margin of error for this piece of research may contribute a negative impact to the overall research.

The interview only included 3 experts from various corporations, more interview responses can significantly increase the credibility of the research.

### B. Conclusion

In conclusion, households in Wyomissing, PA are ready to adopt primary smart home devices, but the research had overestimated the progress of market developments of smart home devices. The reasons of overestimation can be follow: the area of Wyomissing, PA is considered as wealthy sub-urban areas. The metropolises households may have higher adoption rate, however, the overall situation of Wyomissing, PA can certainly represent population of average United States for its neutral culture and value consideration. Another reason for the relatively low adoption rate is that smart home technology is not an necessary civilian using technology yet. The current household environment, based on technical perspective, have remained the same compare to a decade before, so after a decade of living, the general public may not ready for a new life style.

### C. Further Research

From the result of the research, the general public have shown supportive attitudes toward the developments of smart home despite few concerns. Issues of privacy and security can lead to further researches. Due to the premature markets of smart home device, similar researches can be further draw when the market

is further developed. This research only focused on the attitude of public to smart home concept, comparison of markets of each of the voice-interface devices, and smart home functions; further researches can be done with the real-world benefits of these voice-interface devices or complete smart home systems if possible.

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*Interview Question*

1. Do you consider the technology of artificial intelligence shall be adopted into civilian households?
2. What is your prediction of future household setting?
3. What function do you think shall a completed smart home have?
4. How do you think shall the civilian use technology been improved to associate with future smart home technology?
5. How would you comment on Amazon Echo device?
6. How would you comment on Google Home device?

*Survey Questions*

1. What is the approximate overall income of the family?

\_\_\_\_\_.

2. What smart phones do you have currently?

A. iPhone

B. Samsung

C. Google Pixel

D. Others(please identify)\_\_\_\_\_

3. What is your opinion regarding the development of smart home?

A. Support(goes to question 4)

B. Not Support(goes to question 5)

4. If you agree with the smart home development, for which function does you consider as a use of smart home?(Can choose more than one option)

A. Entertainment

B. Security

C. Economic

D. Environmental

E. Other(please specify)\_\_\_\_\_

5. If you disagree with the development of smart home, what is the reason?

\_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_.

6. Is there a completed security system for the house?

Yes

No

7. If the security system exist, does the system allow for remote control on phone?

Yes

No

8. Does your home have a smart home device?

A. Google Home

B. Amazon Echo(Alexa)

C. My home don't have any smart home devices

9. What is the specific functions of the smart home

Music

Search Engine

Weather

Connect to other devices

10. If the smart home device connects to another device(i.e. Fire TV, Apple TV), please specify: