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Sustainable Smart Home and Home Automation: Big Data Analytics Approach

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Abstract

Popularity of information technology not only changes the façade of data management, but powers smart home and city movement. Despite there are many different types of smart home technologies, lots of them share similar goal of sustainable development. Heaps of these tools improve energy generation or save energy and reduce water wastage. Beyond doubt, some of them achieve the win-win-win co-development in environment, social and economics. In this paper, we firstly discuss three generations of smart home: (1) Bluetooth and Zigbee enables smart technologies, (2) smart home with artificial intelligence and (3) smart home robot which can stroll around home. We then adopt big data analytics method to study the popularity of smart home and home automation searches in Google from 2004 to 2016. Finally, we search for the latest smart home technologies that can achieve the goal of sustainable development. The results show that nations which are keen on smart home and home automation devices do not only restrict on the richest countries in the World. All the top three cities with the largest number of Google searches in home automation over the past decade come from India. They are famous information technology (IT) hubs with many IT personnel. We speculate that interests in smart home / home automation are correlated with residents' computer literacy rather than economic wealthiness. Besides, the research shows that many of the sustainable home technologies mainly focus on energy saving. Water saving smart home devices only happen once in a blue moon. That may be reflected in the relative high costs in using electricity as compared to water in many cities around the World. In short, the research offers academic, practical and policy contribution.

Keywords*: sustainable development, computer aided technologies, facilities, smart homes*

1. Introduction

In recent decades, new electrical appliances increase the use of electricity. Electricity grids expand and more fuels are consumed. At the same time, shrinking water resources Worldwide and the rising costs of water prompts residential occupants to adopt conservation tactics (1). Hence, politicians put forward new policies; environmentalists suggest viable solutions and researchers explore new technologies to reduce the use of water and electricity resources. Modern residents call for modern residential facilities to enhance social well-being but at the same time reduce costs. Beyond doubt, smart home apparatus is born at the right time and place to provide sustainable solutions for home owners.

Smart home is often discussed together with the idea of home automation. It distributes commands and information via wireless network to electrical appliances, information

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gadgets and other internet-based applications via an ubiquitous home network (1). Güneş and Akdaş (2) concede that home automation systems allow users to control security, lighting, ventilation and temperature. Balasubramanian and Cellatoglu (3) suggests that home automation saves electricity and protects occupants from intruders. Reaz (4) finds that a friendly user interface enhances home automation efficiency. Benmansour, Bouchachia (5) believes that we need to consider the number and types of occupants in smart home. Collotta and Pau (6) contend that application of Bluetooth Low to manage energy enhances consumers comfort via peak load energy demand reduction and allows more appliances to operate at the same time.

2. Three Generations of Smart Home Technologies

In recent years, various computational methods have been proposed for the advancement and development of sophisticated control systems of Smart Home Environment (7). Smart air-conditioners, security devices, mobile phones and home theatres put theoretical smart home into practice (8). A myriad of them utilize the technology of artificial intelligence (AI), multi-agent systems and automation control.

2.1 The First Generation of Smart Home: Wireless Technology and Proxy Server Home Automation Approach

The first generation smart home devices are used to monitor occupants' activities and operate electrical devices in a predefined pattern. The Advanced Metering Infra-structure, for example, sends time-varying electricity price messages to smart meters in residents' houses. Smart meters issue instructions to adjust power usage (8). Besides, smart home also provides support for paralyzed patient (9). To develop and improve home services, researchers shed light on home automation by introducing Bluetooth home automation system which connect electrical home devices to one Bluetooth sub-controller. The system lowers the needs of electrical wires and intrusive electrical installation via wireless technology. Nevertheless, sharing of one single Bluetooth between large number of devices often lead to an access delay, ZigBee-based home automation network is therefore introduced. The network requires a local proxy server to enable communication between electrical appliances and the internet. Another possible solution to solve the abovementioned problem may involve Internet of Things (IoT) which gears an all-IP solution based on IPv6 Routing over Low Power and Lossy Network (RoLL) (10).

Apart from ivory research, the private sector also realizes the potential of smart home and introduces heaps of relevant new technologies and products. For example, Samsung introduces a SmartThings hub which can monitor and control electrical devices when users are away from their place via android and Apple iPhones (11). NuBryte introduces Touchpoint All-in-One Smart Home Console. It can light switch with Touchpoint. It can control Nybryte App by using different Android and iPhone. It also has different light modes including bedtime mode, dimming mode. NuBryte also has wide-angle camera which can let other mobile phones to receive immediate alert when there are intruders. It can also update weather information, calendar, events, energy monitoring (12).

Smart devices not only include products which can control other smart products but also send reminder to users. Quirky Egg Minder Wink App Enabled Smart Egg Tray notifies users about the number of eggs in fridges and whether the eggs turn bad. The egg tray also has LED lights to distinguish which eggs are the oldest (13).

2.2 The Second Generation of Smart Home: Artificial Intelligence Controls Electrical Devices

It has evolved to the notion of Smart Home Environments (SHE). SHE exhibits various forms of "artificial intelligence" by improving traditional home automation systems with

new "smart functions". It increases comfortableness, lowers operation costs and enhances security. A myriads of computational methods are proposed for the design as well as the sophisticated Control Systems development for SHE with the help from automation, artificial intelligence (AI) and multi-agent systems (14).

Prior 2015, even though it is widely believed that there is close relationship between smart home and artificial intelligence, technology as such mainly operates in laboratory rather than everyday use at home (15). One of the examples is the iSpace in the University of Essex. It is fitted with intelligent devices to detect and learn from users' behaviors an provides suggestions according to users' needs. These devices can communicate with each other, coordinate actions and allow remote access via Internet and GSM (16).

In 2014, Amazon Echo was introduced by the internet bookstore giant-Amazon. It is a sophisticated product unlike other smart home devices only accepts users' instructions, it can listen users' questions and answer them. It reports information about traffic and weather, provides updates about news, sport scores and users' schedule. It also controls lights, thermostats and switches. Moreover, it will become smarter as users interact with it and it processes the ability to learn (17).

2.3 Third Generation of Smart Home: Robot Bubby "who" can Interacts with Human Beings

Integration of service robots with smart home system is the current trend (18). Affordable robots are equipped with artificial intelligence and can respond to human's needs via voice recognition. For example, Zenbo connects to smart home devices, moves freely and independently around home, sees things via its camera, makes video calls, recognizes faces, takes photos and videos. Robots as such not only control smart things but can also be viewed as a buddy "who" can interact with human (19).

Robot Rovio, a mobile robot equipped with a webcam, a microphone and loudspeakers, is one of the symbols of the revolution of the integration. The middleware approach that has been chosen to integrate the Rovio in the smart home is UPnP, which has already been used for this purpose in other works. Rovio can connect with other UPnP devices such as smart home systems or other service robots such as Roomba. Integration of Rovio in a UPnP environment shows how easily service robots can be integrated in smart home and develop new advanced services that illustrate the benefits of interoperability in the smart home (18).

No matter which generations of smart home, they improve people's quality of life. In addition, some experts thought that smart home system could help disabled people to have a better and convenient life. Costa, Carballa (20) realize that people, especially disabled ones' lives become more convenient in presence of home automation.

3. Research Method Previously used in Smart Home Research

Ethnographic approach, surveys and interviews are adopted in smart home research (21). Fieldwork study with contextual interviews at interviewees' homes include role-play, storytelling and artifact walkthrough activities (22). Other novel research methods for smart home are recorded in the following Table.

Table 1. Research Methods for Smart Home Research

Research approach	Results / merits of this research method	References
Diary • Provide diaries to participants to record their experiences and viewpoints when they use the system.	• Participants keep records of their interactions with the system. • It successfully engages participants in the process of evaluation.	(21)
Photographic study • Request the smart home users to take photos of their own home. • Participants were given mission packs to finish tasks at homes.	• It provides understanding on how Smart home technologies are used and identify the roles of technology in people's everyday lives in the future.	(21)
Focus group • Focus groups allow research participants to discuss their needs and viewpoints after using smart home system. • Participant packs are planned and disseminated for the Equipment Management in home trial. • They used resource packs to keep their diaries of experiences, records of interaction and photos for the trial. • Participants are given A5 spiral bound record books, Post-it note pads, emotion stickers and a camera to record their ideas, opinions and state of mind.	• Data collected in these booklets can provide a wide range of variety of information from the households for researchers at each home visit. • The booklet records the interactions between researchers and participants instantaneously.	(21)
Econometric forecasting approach • It forecasts temperature at home with sensors.	• The result shows that over three hours the accuracy is within one fifth of a degree Celsius and when over six hours, the accuracy will be within one half-degree Celsius based on the one or hours of history.	(23)
Two schedule modelling • It analyses the maximum power consumption in smart grid environment based on two scheduling models: online and offline. • It adopts load model with dynamic pricing process	• It studies consumers' incentives in power consumption reduction.	(24)

3.1 Big Data Analytics

In this research paper, we adopt big data analytics which can act as a proxy for studying the popularity of smart home and home automation in different parts of the World from 2004 to 2016. In this section, we firstly provide a brief idea on data analytics, followed by big data analytics.

Data analytics is the use of data collection and analysis to optimize decision making (25). It reviews large amount of raw and unorganized data to identify patterns which help organizations or decision makers to have a better understanding of behaviors. It is a useful tool in gaining meaningful insight on how information, sentiments, as well as opinion are generated (26). Moreover, analysis identifies and determines prevailing trends and issues in the market. Organizations nowadays always use data analytics to infer business intelligence (BI) from social media content for making the decisions and formulate various business strategies for the decision-makers. Data analytics provides opportunities for business intelligence creating a platform for the decision-makers to have a better understanding of the business performance. Business intelligence encompasses the processes and technologies used to obtain timely and valuable insights into business. However, Data analytics and BI are only the aid for the people to make decisions, they should process their analysis based on their analytical thinking skills after getting the results from the data analysis but not to blindly make their decision according to the results from the data analysis.

Nevertheless, there is challenge for the data analysis. One major challenge is data availability, including relevance and integrity of data analysis (27). For many managers and organizations, they may not have the ability to capture data such as computer skills and knowledge, or data may contain noise and asymmetric information problem exists (28). Even if the data can be readily provided and the decision-makers are granted full access, they have to consider the integrity (27), completeness, ambiguity or quality of data.

Big Data Analytics (BDA) applies the idea of data analytics but that aims at handling huge volumes of data to identify trend, patterns and collect invaluable findings. Big Data Analysis often links with a mix of Oracle's Big Data appliance and Cloudera's Hadoop (29).

4. Research Results

Changes in interests of smart home and home automation in google by sheding light on keyword search from 2004 to 2016 is recorded in the following diagram. It shows that smart home has gained in interests over time but there is a decreasing interests in home automation. The largest number of searches country of smart home in Google search engine mainly comes from Philippines, the US and Germany where the largest number of searches of the cities come from Pheonix (the US), Quezon City (Phillipines) and Austin (the US).

With regards to home automation, the largest number of searches countries come from South Africa, India and United Arab Emirates. Cities with the largets number of keyword search come from Bengaluru, Hyderabad and Chennai. All these three cities locate in India and are famous for their information technology development. Bengaluru is known as Indian Silicon Valley, Chennai emerges as another Indian Silicon Valley (30) and Hyderabad is the home of Google, Apple, Facebook Microsoft India. The results to certain extend overthrow laymen viewpoints that home automation and smart home are fancy stuff which are only interested by rich peoeple and countries only. The results show that there is closer relationship between computer knowledge and smart home technologies' interests than economic development.

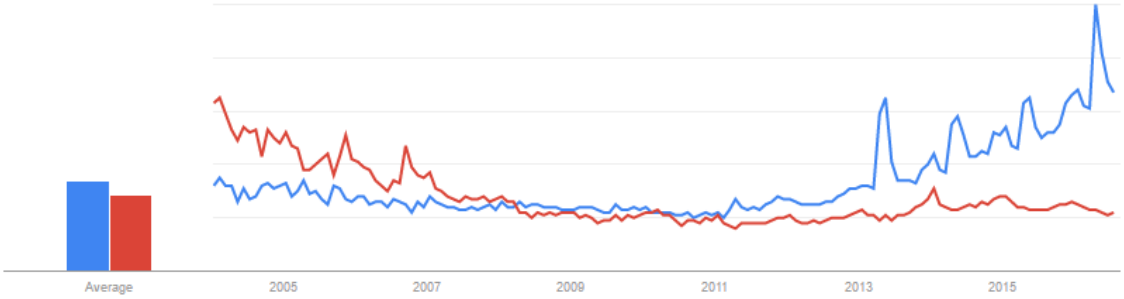

Figure 1. A Comparison between Interests in Home Automation and Smart Home from 2004 to 2016 in Google (Red Line Indicates Home Automation wheras Blue Line Represents Smart Home)

Figure 2. Cities with the Largest Number of Keyword Search for Smart Home in Google (31)

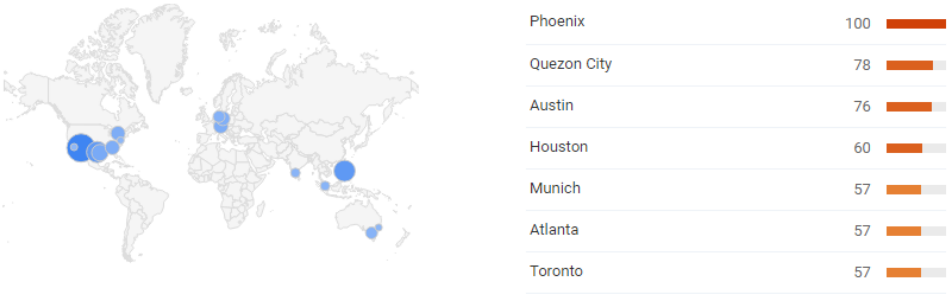

Figure 3. Cities with the Largest Number of Search for Smart Home in Google (31)

Figure 4. Country with the Largest Number of Home Automation Search of Country (31)

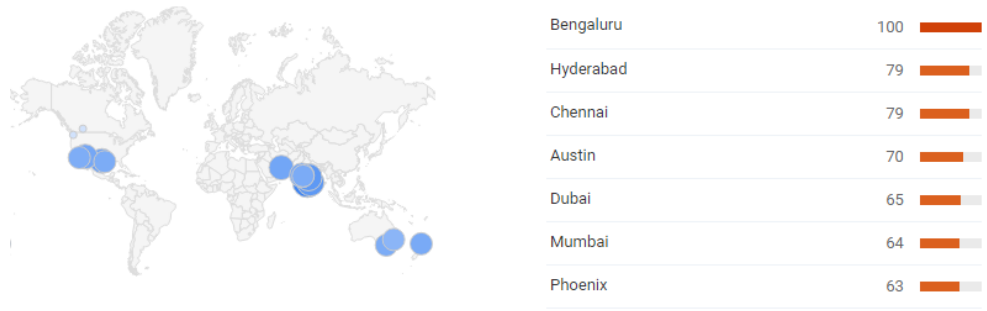

Figure 5. Cities with the Largest Number of Keyword Search for Home Automation in Google (31)

In the second part of the research study, we aim at reviewing various smart home techologies which are now available for sale in market and may achieve the goal of sustainable development (smart home robots are not included in this study yet as many of them which include Zenbo are not yet available for sale in the market til late 2016). The idea of sustainable development can refer to "*development that meets the needs of the present without compromising the ability of future generations to meet their own needs*".(32). It focuses on the co-development of social, environment and economics (33, 34).

In fact, many of the smart home devices in market save electricity or smoothen electricity generation process. For example, EIB-I Bus allows us to use more natural light to reduce energy consumptions and control the products anytime and anywhere (35). Hence, it can achieve the goal of environment development (reduce electricity usage) and economic development (save money of consumers) as well as social development (can be controlled everywhere).

Apart from energy saving and generation devices, some of these save water too. For example, Whirpool's optical water senor determines the water and energy usage which allow user to change the energy usage (36). To save water during fire test, Zone check residential provides The flow-switch tests which negates the need and saves the costs to hire contractors (37). Nevertheless, choices of smart home devices which are related to water saving are a lot less as compared to electricity. Table 2 showcases various smart home devices which may have sustainability applications.

5. Conclusion

Smart home devices have already developed for a couple of decades. However, most of the products are not popular because of the high cost and difficult to install. In 2016, there are several tech giants aware the hidden potential of smart home devices and start to develop state of art devices. We expect that there will be an increase in popularity in adopting smart home devices according to the big data analytics results. Partially because of the fact that smart home technologies can do more things other than simply home automation, *i.e*. the power is stronger than automate a house only, the number of searches for the latter one is getting less. Indeed, smart home devices in the third generation can even tell stories, take photos, and stroll around the home. They do not only control electrical appliances but also improves living quality.

The results also show that many of the devices which are now available for sale in the market can help achieve the goal of win-win-win social, economics and environmental development. Yet, most of these focus on electricity rather than water. We speculate that is mainly a result of economic motive: electricity is more expensive than water in many places Worldwide. Hence, monetary expense remains one of the major motivations in moving towards smart living at home.

All in all, this paper has academic, practical and policy contribution. Academically

speaking, this paper is the first of its kind to adopt big data analytics as a proxy to study the relative popularity of smart home and home automation Worldwide. Practically speaking, this paper overthrows many laymen's perspectives that smart home and home automation is the game of rich people. That also provides useful information for policy makers when they wish to implement smart city policy.

Table 2. Sustainability Analyses on Smart Home Devises

Company which sell the products	Name of the smart home device	Sustainability
Avancetech (35)	EIB–I bus	• Economics: the automation system reduces the running and management cost. • Social: Users can control the products anytime and anywhere. • Environment: it maximizes the natural light to reduce energy consumptions.
Quirky (13)	Aros	• Economics: Aros keeps record of spending on cooling each month and offers settings based on user's budget and later report. • Social: Aros learns users' pattern of cooling. It predicts the temperature in different conditions including wake up, leave for work and return home
GE (13)	GE Link	• Economics: GE Link light bulbs can last over 22 years (3 hour/ day) • Social: Users can control GE Link light bulbs anywhere, schedule to turn on when users awake, turn off when user leave or dim when it is time to bed. • Environment: 80% less power can be saved as compared with other traditional light bulbs
Yoga (38)	Yoga system	• Environment: lights switch off automatically when the room is empty. It integrates energy and heating management by using smart plugs, thermostats and meters, manages temperature and energy usage. • Social: remote control the lighting system to improve security. • Social: there are different lighting styles including party to serene. • Social: it turns on the lights when user arrive home and sets a mimic daily pattern to give outsiders' impression that someone is still inside the house while the user is out of town. • Social: temperature can be adjusted according to home location real- time weather and user behavior.
Whirlpool (36)	Smart system/ Nest system	• Environment: nest system manages the energy usage and control the washing cycles. • Economics: auto delay the washing or drying cycles during energy rush hours. Therefore, it can save electricity costs in some places. • Social: dishwasher has optical water senor to determine water and energy use and let user to change energy use from one cycle to another. • Environment: refrigerator changes energy usage

		according to temperature and humidity inside and outside home. It has energy reports on energy consumptions.
LG	Smart ThinkQ	• Social: it cooks 20% faster without preheat • Social: washing machine can download custom cycles and let user customize his best laundry cycle • Environment: Smart ThinkQ can detect and adjust the power consumption to the lowest level. It has seven sensors to monitor the temperature difference to optimal power mode
Delta Paramax (13)	Solar tracking system	• Environment: Solar Tracking Skylights consist of highly reflective mirror panels move continuously according to the sun's position. By aligning the position of the sun, mirrors reflect light down to the space that would otherwise lose. • Economics: longer duration and generates up to 4x light levels which reduces the initial cost and ongoing expense • Social: it provides a comfortable environment
Delta Paramax (13)	Zone check residential	• Economics: the flow-switch tests which negates the need, provides maintenance benefits and saves the costs to hire contractors. • Environment: Zonecheck saves 100% of the water discharged as waste and reduces carbon footprint. • Social: the entire system is managed from central location which can be configured for automated fire test according to client's needs. It eases testing and an optional Zonecheck printer provides test record with time and date stamped.
Delta Paramax (13)	STEP 3	• Economics: it saves 30% to 50% cost as compared to similar products. • Social: STEP3 is an automated system which provides central air-conditioning and building automation Direct Digital Controller (DDC). It facilitates the engineers to check their design. On-line solidification of the DDC can be downloaded .
PCCW (38)	Philips Hue home-lighting system	• Social: timers can be set according to individuals' habits. Remote control lighting system improves security. Favorable pictures and light scenes, photos and color lights paint the room. 4 pre-programmed light settings are set according to human biological impact. The optimum light shade and varying brightness energizes users and helps us relax and concentrate.

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