CSCanada
Management Science and Engineering
Vol. 10, No. 1, 2016, pp. 67-75
DOI:10.3968/8220

ISSN 1913-0341 [Print]
ISSN 1913-035X [Online]
www.cscanada.net
www.cscanada.org

The Application of Patent Mining in the Forecast of Smart Home Industry

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Received 2 November 2015; accepted 18 January 2016
Published online 16 March 2016

Abstract
With the rapid development of the Internet, the Internet of things and the intelligent terminals, Smart Home has caused the great attention. This paper applies data mining method into patent analysis, and creates a visual-based patent mining analytical framework. We carry on the statistical analysis of the invention patents of Smart Home in China, and point out the development of smart home-related products and technologies, the main patent applicant and the corresponding type. Besides, we find out the technology hot spots and patent vacancies of Smart Home through Patent Network and Patent Map, to provide reference for the related research field.

Key words: Smart home; Patent mining; Patent network; Patent map

Lai, C. A., & Xu, C. L. (2016). The Application of Patent Mining in the Forecast of Smart Home Industry. *Management Science and Engineering*, *10*(1), 67-75. Available from: URL: http://www.cscanada.net/index.php/mse/article/view/8220
DOI: http://dx.doi.org/10.3968/8220

INTRODUCTION
Smart Home is such a way of life that various subsystems related to household life are integrated by advanced computer technology, network communication technology and integrated wiring technology, to make household life more comfortable, safer and more effective through the overall management (Jiang, Liu, & Yang, 2004). Compared with ordinary household, Smart Home not only has the traditional residential function, providing safe, high grade and pleasant comfortable family life space, but also changes from passive static structure into a dynamic intelligent tool, provides a full range of information exchange function, helps families keep smooth communication with external, optimizes people's life style, helps people to arrange time effectively, enhances the security of home life, and even saves for a variety of energy cost savings. Smart Home is also known as Home Automation, Electronic Home (E-home), Digital family, Home net/Networks for Home, Network Home, Inte1ligent home/building, etc..

With the publication of "Chinese twelfth five-year" development plan, as well as the national network security and information construction unceasingly, Smart Home has become one of the nine key areas of application and demonstration projects, and brought the dawn for intelligent household industry and related accessory industry. Intelligent household also ushers in unprecedented opportunities for development; to meet the needs of digital home of intelligent terminal products such as smart TV, relevant patents also reveal rapid growth. Compared with Europe, the United States and other countries, the development of Chinese Smart Home started later. If we want to have substantial progress in the emerging industries to enhance international competitiveness, we must attach importance to technology development and patent layout, and master the core technology (Lai, Gao, & Chu, 2013). Patents can reflect the context of technology development fully, and this paper applied to data mining method into patent analysis. We carried on the statistical analysis of the invention patents of Chinese Smart Home to discover the development trend of products and technologies related to Smart Home. By calculating the distance between each patent (Koivisto, Wessberg, & Eerola, 2009), we pointed out the technology hot spots and patent vacancies of Smart Home through patent network and patent map (Lee, Kang, & Shin, 2014), to provide reference for the related research field.

1. RESEARCH METHODS AND DATA SOURCES

This paper focuses on the analysis with Chinese Smart Home patents, and we had statistics about the invention patents related to Chinese Smart Home based on the published literature from CPRSABS database, and the retrieving deadline was December, 2014. We chose CPRSABS database because it contains all the Chinese patent information with rich data items, and its data coverage is comprehensive, containing the summary, classification and etc. And invention patent has the higher technical level and the higher commercial value compared to utility model patent and appearance patent, and it can reflect the development of related technology more authoritatively (Wang, 2009). What's more, the number of invention patents related to Chinese Smart Home is increasing rapidly in recent year, so we did the analysis in Smart Home industry. Considering that there are many patents involved in this filed, we made the combination with patent title and summary to retrieve through keywords, reduced the impact of patents which are not closely to Smart Home. The keywords included: Digital Home, Smart Home, Electronic Home, home gateways, automatic control, flexible, wearable, data storage and etc. The analysis process of this paper contains: first, we carried on the statistical analysis of the invention patents of Smart Home in China, and then we made the combination with patent analysis and data-mining, pointed out the technology hot spots and patent vacancies of Smart Home through Patent Network and Patent Map.

2. ANALYSIS OF DEVELOPMENT STAGE OF SMART HOME IN CHINA

We retrieved 624 patents in CPRSABS (the retrieving day was December 31, 2014, and the patents does not contains the appearance patents), the number of invention patent (including public invention) is 274, accounting for 43.89%, the number of utility model patents is 350, accounting for 56.09%, and the number of all the authorized patents is 183, accounting for 29.32% of total patent.

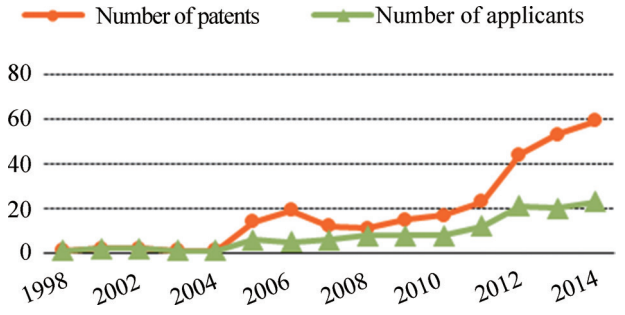


Figure 1
Distribution of Patent Application and Applicants of Smart Home Industry

Figure 1 is the distribution of patent application and applicants of Smart Home industry, we can know that Smart Home development in China mainly divided into four stages.

(a) Stage of concept proposed (year 1998-2004): Smart Home began to rise in overseas in the1980s and 1990s. In 1998, the patents related to Smart Home appeared in China, the annual number of them had been very low, and the number of patents and applicants was same. The early Smart Home products in China completely copy foreign mode, because the domestic residential apartment-style is different from the western single-family villas, such application couldn't adapt to the state and the development of Smart Home in China was slow.

(b) Stage of infancy (year 2005-2006): With the development of the Internet, Smart Home entered into the stage of trial and popularization. From 2005 to 2006, the related patents of Smart Home was increasing rapidly, and the number of patents was greater than the number of applicants significantly.

(c) Stage of boom subsided (year 2007-2010): Due to the lack of unified standard in the industry, the high cost, and the dislocation between product value and the public demand, the development of Chinese Smart Home arrested. From 2007, the number of patents began to decline, and the number of patents was consistent with the applicants. In addition, with the impact of the global economic crisis, there were more than 20 Smart Home native enterprises withdraw from the market until 2010.

Stage of growing again (year 2011-2014): Smart Home became a hot point concerned once again. Smart Home patents began to grow rapidly in 2011, and the number of patents was much greater than the number of applicants. Related companies increased investment in patent research, leading enterprises upgraded intelligent of strategic height, and parts manufacturers also had rapid development. IT vendors, intelligent control manufacturers, and Internet firms had started to enter this competition field, to form new competition trend.

The legal status of patents includes authorization, review, invalid, and etc. The legal status of the patent and the quality of patents are closely related, the quality of patent reflects the strength of the technology competitiveness (Lai, Zhu, & Liu, 2007). In the 174 invention patents of Chinese Smart Home, more than half of them are in the review stage, and have not been authorized; only 51 invention patents have been authorized. It suggests that the Smart Home is a sunrise industry which is in a stage of vigorous development with broad prospect. The invalid patents mainly are rejected and withdraw, we think this phenomenon is due to the rapid update iteration in the field, and the value patents rapidly reduce or the application value of patents is not high enough.

3. ANALYSIS OF ALL KINDS OF APPLICANTS

According to the nature of the patent applicants, the types of applicants include: Company (including "club" or "plant"); University (including "College"); Cooperation (more than two applicants); Individual (except the above types of applicants). Figure 2 shows the proportion of all kinds of applicants of Smart Home.

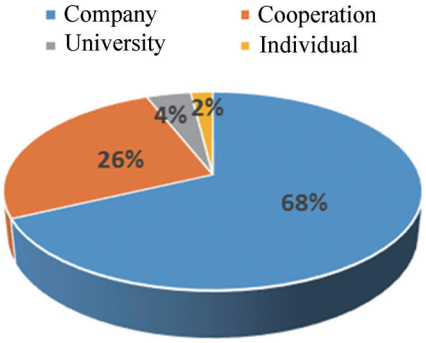


Figure 2
The Proportion of All Kinds of Applicants

The number of applications from companies accounts for the majority, and they invest more to Smart Home industry mainly because companies conduct related researches for profit. Besides, Smart Home is in a high content of science and technology, it achieves intelligent control of home appliances through high-tech hardware and software, involving many aspects such as communications and automation, and it needs to do test design and research with larger equipment, so there are more researches from companies and less from personal researches. The main of cooperation are between enterprises or between enterprises and colleges. The reasons include: Smart Home involves multiple technologies (cooperation between enterprises); it needs to combine technology research and development with theoretical research (cooperation between enterprises and universities). The gradually increasing of university application proves that the research demand for universities is increasing under the impetus of technology research and development of practice with enterprises. A big brand companies typically have several molecules, then they usually apply for a patent respectively. The applicants with same brands are counted as one applicant in order to gain more accurate conclusions in further analysis.

The proportionof patents from different applicants merged by brand is shown in Figure 3. The core enterprises in the industry are mainly appliance suppliers (Haier, TCL, Konka), mobile terminal enterprises (Huawei, Samsung) and universities (Sun Yat-sen university, Peking University). The main cause is that mobile terminal provides a portable interface for smart home, television set at the center of the family provides the big and natural display screen, and the air conditioning with great power and function of energy storage becomes the energy center of Smart Home.

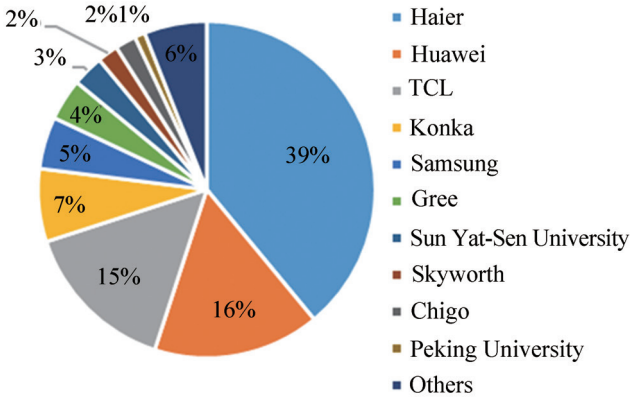


Figure 3
The Proportionof Patents From Main Brands

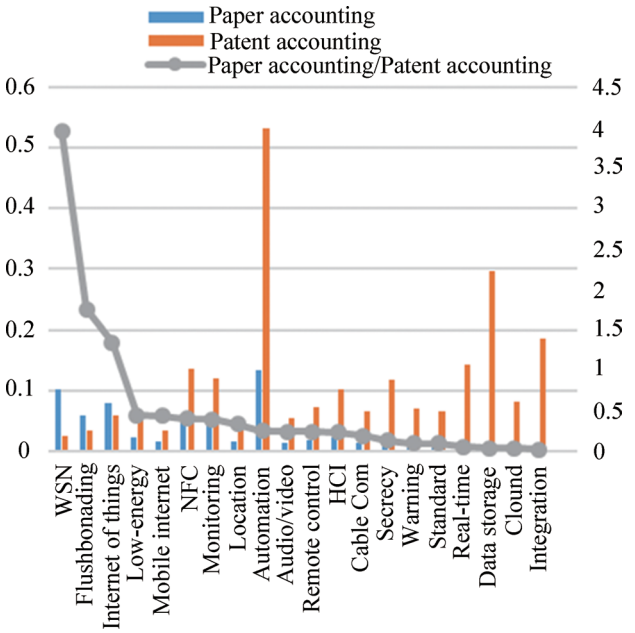
4. ANALYSIS OF TECHNOLOGIES DEVELOPMENT

4.1 Analysis of Patent Network

Analysis based on keywords (keyword-based analysis, KWA) is one representative method for patent analysis (Yoon & Kwangsoo, 2012). This method is used to calculate distances between two patents according to the occurrence frequency of selected keywords in patents, or to citation information and patent summary information (Koivisto, Wessberg, & Eerola, 2009; Lee, Kang, & Shin, 2014), then illustrate core patents at the center of the visual patent network and the overall scene, further analyze patent vacancy and technology hot spots in the visual patent map, finally, forecast high-tech development trend by mapping high-dimensional data to two-dimensional data, moreover, discover new technological opportunities from the patent data, or anticipate new technical concepts, and depicts technology roadmap. By reading literatures and patents related to Smart Home, 20 technology keywords with the highest appearing frequency were selected, as automation, data storage, integration and etc.. We took the Boolean Combined Search to the patents abstract with these 20 technology keywords and their synonyms, and the proportion of patent which contains one keyword at least is 100%, it shows the accuracy and the representativeness of these technology keywords.

Paper is the carrier and sign of the theoretical research, and patent is the result of the technology practice. To compare the difference between theoretical research and technology practice, to find out the advanced theory has not been widely applied as the development direction, we retrieved the papers related to Smart Home in CNKI, and counted the corresponding number of papers according to the 20 technology keywords. Figure 4 shows the paper accounting and the patent accounting of each technology

keyword. Wireless sensor network, Flushbonading, Internet of things have obviously higher paper accounting than patent accounting, we think that university and other research institution have carried out a more in-depth theoretical research, while the technologies development and practical application in business is still less, so that the related personnel can seize the time window to do further technology research and development, and apply for related patens to occupy the initiative. Warning, Standard, Real-time, Data storage, Cloud and Integration have a higher patent accounting than paper accounting, we think these technologies have been widely used in enterprise, but the relevant theoretical study is not sufficient, so that they may become the direction theory research in the future.



Figurer 4
The Paper Accounting and the Patent Accounting of Each Technology Keyword
(WSN means Wireless sensor network, NFC means Near field communication, HCI means Human-computer interaction, Cable Com means Cable communications)

The common patent network contains: patent network based on the keywords co-occurrence frequency and patent network based on co-citation relations. Compared with patent network based on co-citation relations, patent network based on keywords co-occurrence frequency searches for industry themes that current patents focuses on, it reflects the technology hotspot after the formation of trend, and it is more suitable to search for innovative technologies in common. However, patent network based on co-citation relations shows the focus of attention at present, through analyzing the reference of previous published patents, and it is more suitable to search for mature industrial technology. Because innovation technology research often is large in number but not focus, and related patents are so scattered that their reference are unstably. But keywords are well reflected study and research hotspot and focus in the industry, they can reflect the development direction of this emerging field, and help to find the technical features of the industry.

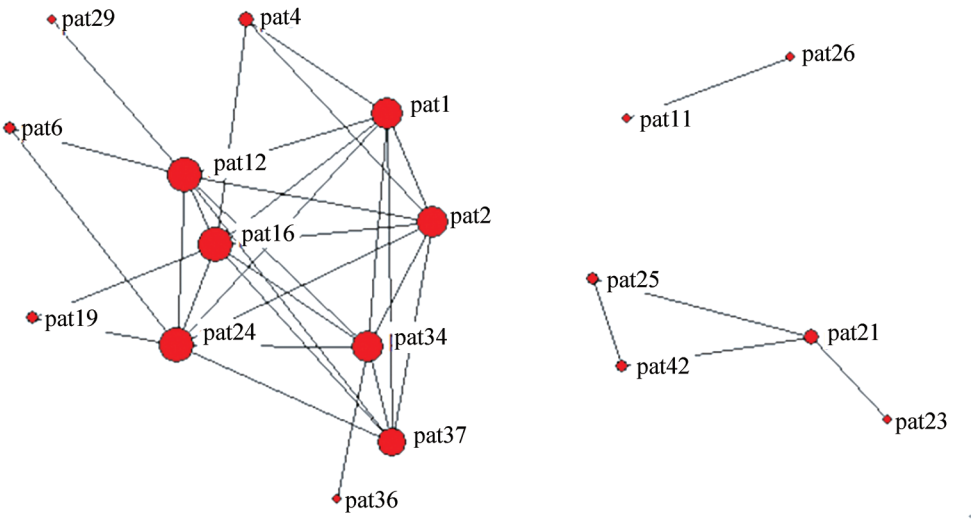
This paper calculated the patent difference correlation matrix through Euclidean distance, to construct the patent network based on the keywords co-occurrence frequency. Firstly, we got the vector N of keyword occurrence by counting the number of times that each keyword appear in each patent. The vector of keywords occurrence in patent i is $N_i = (n_{i1}, n_{i2}, n_{i3} \ldots n_{ik})$ and that in patent j is $N_j = (n_{j1}, n_{j2}, n_{j3} \ldots n_{jk})$, where k is the serial number of keyword; n_{ik} is the number of times keyword k appears in patent i; the difference f_{ij} (Euclidean distance between patent i and patent j) is calculated as the Formula (1) (Yoon & Park, 2004).

$$f_{ij} = \sqrt{\frac{(n_{i1} - n_{j1})^2 + (n_{i2} - n_{j2})^2 + \ldots + (n_{ik} - n_{jk})^2}{k}} . \quad (1)$$

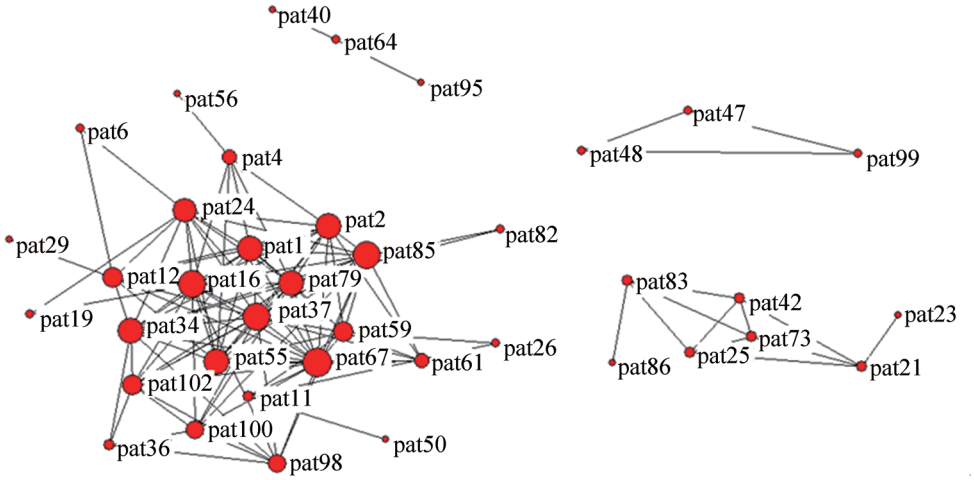
We provided a unique number for each patent (patent 1 ~ patent 274) according to the date of application, and we got a symmetrical patent difference matrices with 274 × 274 dimensions by calculating the distance between any two patents, to generate the patent network through Ucinet software. According to Figure 1, in order to observe the development of patent technologies better, we divided three time periods and generate the corresponding patent network. They are the year 1998-2006 (beginning to the stage of infancy cultivation), the year 2006-2010 (beginning to the stage of boom subsided) and the year 2010-2014 (beginning to the stage of growing again). By adjusting the threshold, we got Figure 5, the points greater than threshold are not shown in network. The larger the point, the higher centrality it has, and the influence of the corresponding patent on the other patent in the network is greater.

Table 1 shows the network concentration of different time periods. Overall, year 1998-2006 is the time of initial development of Smart Home in China, there was less research direction due to the limitation of technologies, so that the patent concentration is higher. With the continuous innovation and development of the Internet, terminals and other technology, the direction of Smart Home technology became increasingly diverse, the patent concentration decreased. In 2014, the technology development of the Internet of things, cloud, big data broadened the research area, and the patent concentration further reduced.

(a) year 1998-2006 (beginning to the stage of infancy cultivation)



(b) year 2006-2010 (beginning to the stage of boom subsided)



(c) year 2010-2014 (beginning to the stage of growing again)

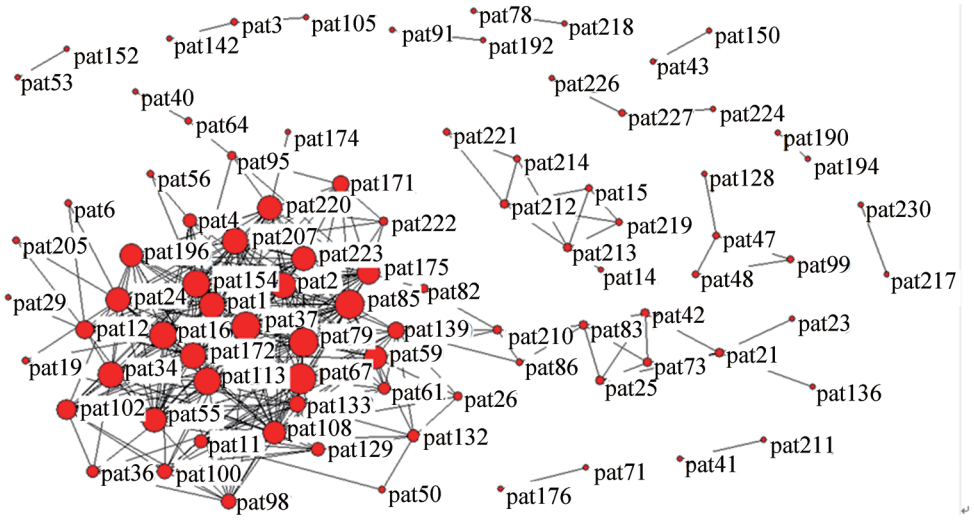


Figure 5
Patent Network of Smart Home

Table 1
Network Concentration of Different Time Periods

	1998-2006	1998-2010	1998-2014
Number of network nodes（patent）	42	98	274
Network ties	35	128	369
Network density	0.0185	0.0124	0.0059
Network concentration	high	ordinary	low

The patents with higher concentration are core patents in each patent network of different periods. By reading the text of core patents, we found out that in the early time, Smart Home focused on the detection of working status of home appliances, and the centralized control of multiple appliances through short distance recognition technology like radio frequency or cable transmission. Furthermore, the Smart Home patents mainly related to home gateway, network communications optimization, and protocol conversion technologies, to improve network communication experience. Currently, the core patents turned attention to connections with mobile phones and other intelligent terminal, wireless transmission technology (ZigBee, Z-Wave, etc.), battery, and interactive based on touch screen, it gradually improved the user experience to the further development of a more diversified and more intelligent direction, and expanded the application scenarios technologies. Besides, the research of data storage technology ran through the whole developing stage of Smart Home. With the advent of the big data era, data storage capacity needs were growing, the data storage technologies developed from traditional database to the cloud server storage.

4.2 Analysis of Patent Map

Based on a patent differential matrix or similarity matrix, patent map makes the high dimensional matrix data to a low-dimensional target space visually by mapping algorithm, so the patents distribute in two-dimensional space based on the similarity to display the abnormal patents, patent vacancy, and technology hot spots of different periods. The common mapping algorithm contains self-organizing feature maps (SOFM) and multidimensional scaling (MDS). As a kind of clustering technique, SOFM is an adaptive implementation of discrete mapping input signal to one dimension or two dimensions. It can classify the enter patents automatically according to its learning rule. Namely in the unsupervised case, it does self-organizational learning with enter patents by repeatedly adjusting the weight coefficients of input and output, ultimately it makes these coefficients reflect distance relationship between enter patents, and the classification results are in shown competition level. While MDS makes patents to distribute on a two-dimensional space based on patent difference matrix, and represents them with the point of space. Point interpersonal distance represents a degree of similarity between the patent, that the closer the distance, the higher the degree of similarity patents. When the network size is small and the dimension of input space is low, we can calculate directly with original input vector space based on SOFM, but it needs to reduce the dimension to huge network. But the amount of patents is large, SOFM is difficult to adapt to high-dimensional size. So this paper chose MDS to generate the corresponding Smart Home patent map (Hyunseok, Kwangsoo, Choi, & Yoon, 2013). MDS makes patents to distribute on a two-dimensional space based on patent difference matrix, and represents them with the point of space. Point interpersonal distance represents a degree of similarity between the patent, that the closer the distance, the higher the degree of similarity patents. Pressure Index (Stress) can show the reliability of MDS analysis, and it can measure the degree of fit between spatial structure and input data, by calculating the difference between the spatial distance and the actual distance between the patents. Pressure Index is calculated as Formula (2).

$$S = \sqrt{\frac{\sum_{ij}\left(\delta_{ij} - d_{ij}\right)^2}{\sum_{ij} d_{ij}^2}}. \quad (2)$$

δ_{ij} represents the degree of similarity between patent i and patent j (the actual distance derived from the input data), d_{ij} represents the spatial distance of patent in the multidimensional scaling analysis structure. Figure 6 shows the patent map of Chinese Smart Home, and the corresponding pressure index is 0.164, the fitting degree is acceptable.

4.2.1 Analysis of Abnormal Patents

In Figure 6, points marked with red coil represent abnormal patents, which is far away from many patents and almost no other patents around it. The areas marked with orange coil represent the patent vacancies that no related patent appears there. Abnormal patents generally appear at the marginal areas of patent map, and the level of them is normal. The invention frequency of the technologies they proposed is very low, but they may have the hidden possibilities to become a major trend in the future. By reading the instructions of abnormal patents, we found out the main reason they appear as follows.

a) New scenes applications. For example, patent 157 “Automotive equipment, home device, automotive, system and method for monitoring home appliances” in 2012 realized the control of home appliances with car terminal, it integrated car with home appliances to make the car networking and smart home monitoring each other.

b) Introductions of new technology. With the combination of cloud technique and wireless communication, patent 238 “The method, system and device of home appliances control” in 2014 realized multiple bindings with cloud server and user terminal to

control home appliances. The concept of cloud technology was very early to put forward but not universal, the combination with cloud technique and Smart Home in this patent belonged to technological innovation. Besides, the application of cloud technique to Smart Home has got rapid development in recent years.

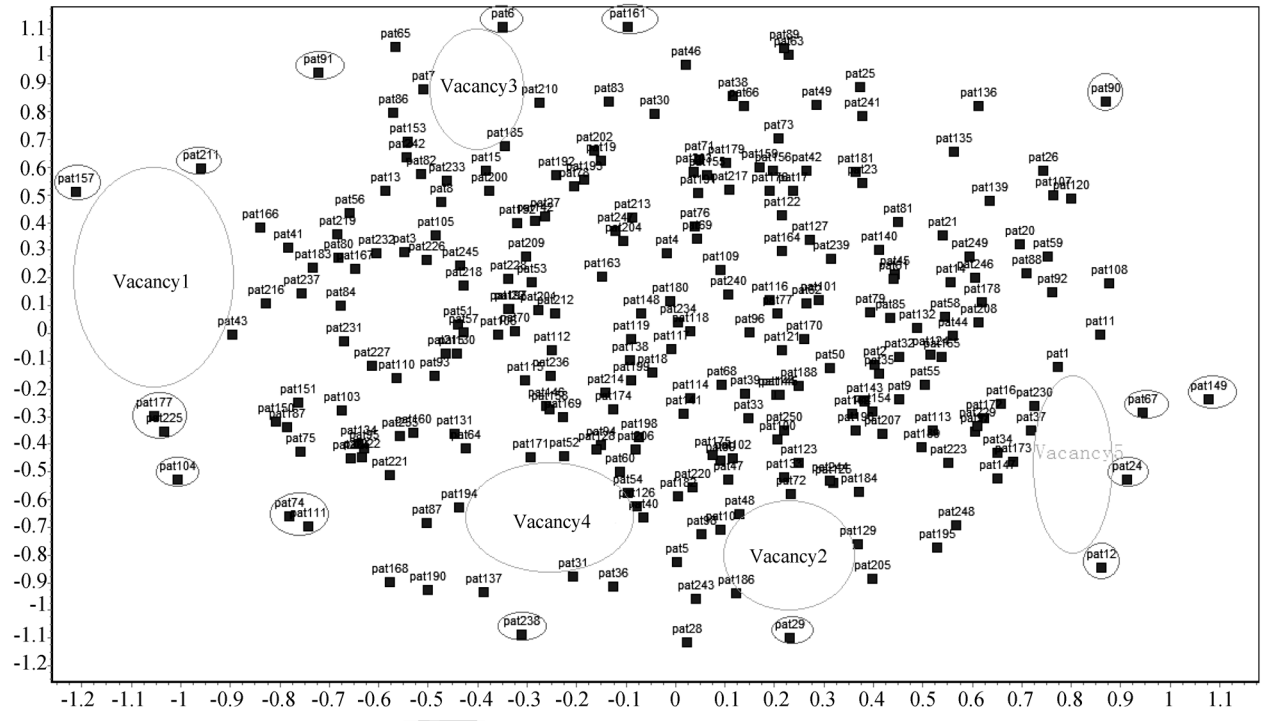


Figure 6
Patent Map of Smart Home (274 Patents)

4.2.2 Analysis of Patent Vacancy

The vacancy areas in patent map may represent the opportunities of patent layout, or may represent the technologies which is not suitable to development at the present stage. We read and analyzed the patents around the vacancies in patent map, and with the judgments of technical and industrial value, we finally divided five patent vacancies which are more critical and more important with higher development value as follows.

(a) Vacancy 1: Remote management and control of multi-terminal. The mainstream Smart Home devices achieve remote control to home appliances mainly through smart phones, "Smart Home devices with mobile phone app" usually means the majority of Smart Home, but the Smart Home which integrates with multi-terminal like traditional remote controller, mobile phone, PC, ipad and cloud server is rarely seen in market. For example, patent 41 "Device and method in home network system to send control commands" in 2006, invented the intelligent remote control device to control household devices, but this terminal is dependent with mobile phone and PC that they are not interconnected unified; patent 166 "The method, system, mobile terminal and home management center for household devices control" in 2012 related to the remote management of home system with mobile terminals, like phones, computers, POS machines, pad and etc.. Patent 157 "Automotive equipment, home device, automotive, system and method for monitoring home appliances" in 2012 only realized the control of home appliances with car terminal. With the continuous development of various intelligent terminals, people hope to achieve the remote management and control of home appliances through the integration with different terminals. For example, people can monitor home appliances through PC or mobile phone, and they can do this through car terminal while driving , so they can not only avoid security risk causing by the use of mobile phone, but also control home appliances quickly, to implement the interconnection and unified supervision with different terminals for the same appliances.

(b) Vacancy 2: Multi-dimensional interactive model based on image or motion capture. From the original SMS notification and audible alarm, the interactive modes for Smart Home gradually develop into multimedia interactive with variety of intelligent terminals, just like mobile clients and remote monitoring television screen and so on, and it gradually evolved from the key board to touch screen. For example, patent 48 "Method for home monitoring system to achieve remote monitoring with mobile phone" in 2007 realized the remote monitoring for home appliances with mobile phone client; patent 205 "Intelligent real-time monitoring systems for minors away from home or go home" in 2013 implement the monitoring about minors activities through SMS

notification; patent 186 “Smart home control method and system based on sensor technology” in 2013 identified the actionfeature of current user, and match with the custom actions user pre-stored to execute control commands to the corresponding home appliances. The interactive model for Smart Home will develop to gesture recognition, voice recognition and other multi-dimensional interactive mode in the future. For example, the identity recognition for security module in Smart Home may change from account/password model to two-dimensional code scanning, voice recognition or face recognition mode, and improve recognition accuracy by simultaneous acquisition and integration of multi-dimensional information. It is the patent vacancy for Smart Home in China.

(c) Vacancy 3: Data acquisition and optimization of transmission mode**.** Due to the variety and the large amount of Smart Home data, the control of data flow is still a big problem so far. For example, patent 6 “Method of seamless handoff with mobile IPv6 home agent” in 2003 reduced traffic by the router cache; patent 210 “A method of active anti-theft family by using mobile voice and light” in 2013 used wireless coordinator as the mediation of data transmission, and improved the efficiency of data storage and transmission; patent 242 “A kind of intelligent old-age care system” in 2014 monitored the old man’s blood glucose and pulse through the infrared sensor and care equipment. Therefore, how to collect multiple data, optimize the way of data transmission and reduce traffic of the data transmission, will become the patent research direction in the future. For example, we can combine Smart Home with mobile medical, install medical sensor on wearable device (such as watch, wristband, headphones, etc.) or intelligent terminal, and install related medical sensors on the appropriate furniture at home (such as sofa, bed, toilet or car), to collect the physiological parameters of family members, such as heart rate, blood pressure, and blood fat through multi-channel of data acquisition and make home health care become reality.

(d)Vacancy 4: Intelligently processing and Analyzing data based on cloud, to strengthen the forecasting function of demand. The importance of smart home is humane and facilitation. If people want to realize the humanized and facilitation through the intelligent device logic and the function of artificial intelligence, it can’t depart from the support of data, but the number of patents with the combination of mobile Internet, cloud computing and Smart Home is relatively rare. For example, patent 87 **“**Smart Home system” in 2009 proposed regional service according to the user’s position at home, forecasted the demand for home appliances near the area, and realized the function such as automatic startup; patent 126 “Control system and method of Smart Home TV” in 2011 realized automatic adjustment of TV programs, TV volume and TV switch with autonomously learning based on the user habit; patent 168 “The Smart Home which has the function of intelligent housekeeper with cloud application” in 2012 used cloud technology for data storage, and carried on the simple analysis to help professional personnel to provide users with specific butler service; patent 238 “Home appliance control method, system and devices” in 2014 established multiple connections between home appliances and user terminals. Therefore, how to transmit the information collected to all kinds of intelligent terminals and store it to cloud server at the same time, and intelligently analyze big data to forecast user’s demand based on the knowledge base and user data uploaded in the cloud data server, will become the technology trends and hot spots in the future.

(e)Vacancy 5: Reduce energy consumption and the use of new energy supply. Energy problem is the major problem for Smart Home. It will bring new development opportunities if Smart Home can further reduce the energy consumption on wiring process and devices (such as electrical appliances and intelligent terminal) in technology. For example, patent 173 “Intelligent USB charging into the wall socket” in 2012 offered a new kind of USB charging outlet, which can reduce household wiring and the cost; patent 230 “The smart reminder device for babies infants care” in 2013 proposed using lithium-ion batteries to power smart devices, and it is rechargeable for use; patent 147 “The method and system for power supply control of intelligent household system in community micro grid” in 2012 proposed to take advantage of solar energy and wind power, and achieve power supply for e intelligent household system by generation equipment. Combined with the practical perspective, the patents which contain the application of wireless power transmission for intelligent household is rarely at present, and it is in the initial stage. In addition, we also can combine with the kinetic energy of motion, the lithium battery and solar new energy to provide power for home appliances, and transfer the power section to the location with the available solar energy or fixed power, to reduce the battery replacement and improve the battery life.

CONCLUSION

Overall, Smart Home is a sunrise industry in China. And it is in the flourishing stage, the number of related patents grows rapidly, and update iteration of related technologies is fast. At present, the patent technologies of Chinese Smart Home gradually develop toward diversification and automation, and expand the application scenario. The core patent focuses on areas such as home security, data storage, and wireless transmission at present. Remote management and control of multi-terminal, multi-dimensional interactive model based on image or motion capture, intelligently processing and Analyzing data based on cloud, and new functional mode of devices are currently patent vacancies and the development

opportunities. China should provide full support to patent highland enterprises and potential enterprises of Smart Home in policy, funding and personnel, and take advantage of patent vacancies to get international leading position and form the core competitiveness in the international arena. For domestic enterprises and universities, they should be timely track the development of the relevant technology of smart home, make use of existing advantages to explore innovative ideas innovative ideas, and pay great importance to the patent layout for the valuable research direction. In addition, enterprises and universities should strengthen further cooperation with each other to realize the complementary advantages. Enterprises can focus on the basic research of universities, develop key technologies jointly to develop new products and new markets; universities can actively communicate and corporate with enterprises, and solve the problems enterprise meet in the practical application, to improve the conversion rate of patent products.

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