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A Case Study Of Research Trends Of Internet Of Things

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A CASE STUDY OF RESEARCH TRENDS OF INTERNET OF THINGS

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ABSTRACT

In recent years, the technologies of Internet of Things (IoT) have been catching the focus of researchers from academia, industry, and government. Applying bibliometric method, this paper begins to explore the status of IoT from 1992 to 2015 by locating heading "Internet of Things" as topic in the SSCI database. This paper surveys and classifies IoT articles using the following eight categories – publication year, citation, document type, country/territory, institute name, language, source title and research area – for different distribution status in order to find the difference and how IoT technologies and applications have developed in this period. Furthermore, the paper performs the K-S test to check whether the distribution of author article production of IoT follows Lotka's law or not. Finally, conclusion and limitation of IoT will be addressed.

Keywords: Internet of Things, IoT, research trend.

INTRODUCTION

The Internet of Things (IoT), also called Internet of Everything [1] or Network of Everything [16], is the network of physical objects or "things" embedded with electronics, software, sensors, and connectivity to enable objects to exchange data with the production, operator and/or other connected devices based on the infrastructure of International Telecommunication Union's Global Standards Initiative [9]. The Internet of Things allows objects to be sensed and controlled remotely across existing network infrastructure [4], creating opportunities for more direct integration between the physical world and computer-based systems, and resulting in improved efficiency, accuracy and economic benefit [2][20][. Each thing is uniquely identifiable through its embedded computing system but is able to interoperate within the existing Internet infrastructure. Experts estimate that the IoT will consist of almost 50 billion objects by 2020 [8].

The term "Internet of Things" was coined by British entrepreneur Kevin Ashton in 1999 [23]. Typically, IoT is expected to offer advanced connectivity of devices, systems, and services that goes beyond machine-to-machine communications [12] and covers a variety of protocols, domains, and applications [7]. The interconnection of these embedded devices (including smart objects), is expected to usher in automation in nearly all fields, while also enabling advanced applications like a Smart Grid [15], and expanding to the areas such as Smart city [10][24].

Things, in the IoT, can refer to a wide variety of devices such as heart monitoring implants, biochip transponders on farm animals, electric clams in coastal waters [14], automobiles with built-in sensors, or field operation devices that assist fire-fighters in search and rescue [22]). These devices collect useful data with the help of various existing technologies and then autonomously flow the data between other devices [3][5]. Current market examples include smart thermostat systems and washer/dryers that utilize Wi-Fi for remote monitoring.

Besides the plethora of new application areas for Internet connected automation to expand into, IoT is also expected to generate large amounts of data from diverse locations that is aggregated very quickly, thereby increasing the need to better index, store and process such data [6][21].

RESEARCH ARCHITECTURE

Applying a bibliometric approach, the paper intends to explore the position of IoT in Taiwan by comparing universal research trends, forecasts and citations from 1992 to 2015 by locating heading "Internet of Things" in topics in the SSCI database. The bibliometric analytical technique was used to examine these two topics in SSCI journals from 1992 to 2015, we found of 65 articles in Taiwan and 1566 articles in universe. This paper surveys and classifies IoT articles between Taiwan and universe using the following eight categories – publication year, citation, document type, country/territory, institute name, language, source title and research area – for different distribution status in order to find the difference and how IoT technologies and applications have developed in this period. Besides, the study investigates the relationship between publications and citations in Taiwan and universe. Furthermore, the paper performs the K-S test to check whether the distribution of author article production of Taiwan and universe follows Lotka's law or not. Finally, the study will analyze IoT technology trends, forecasts and citations under the above results.

RESEARCH RESULTS

Distribution by Publication Year and Citation

Regarding the relationship between article production and citations in IoT, the citations also follow the article production ranking accordingly in IoT (Figure 1).

Distribution by Country/Territory

According to Figure 2, we can find out that the PRC is at the top with 405 (25.86%) in IoT, following by US with 375 (23.95%) and England with 138 (8.81%) respectively. Behind them, Spain, Italy, South Korea, and Germany are also major academic providers in the field of IoT. Taiwan ranks No. 8 with 65 (4.15%).

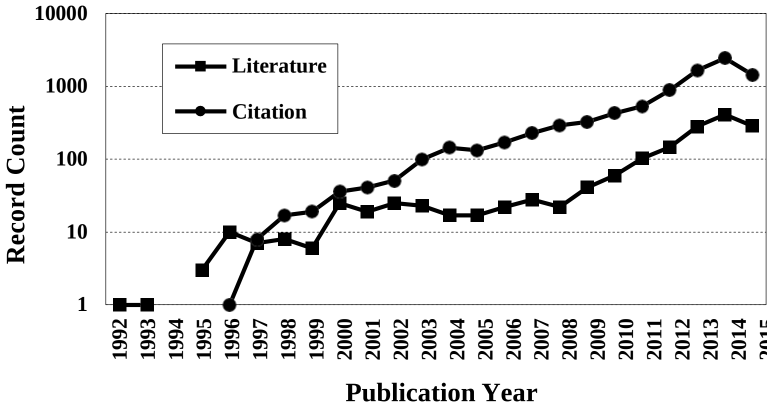

Figure 1. Literature and citation distribution of publication year of IoT (Source: SSCI database on 2015/08/06)

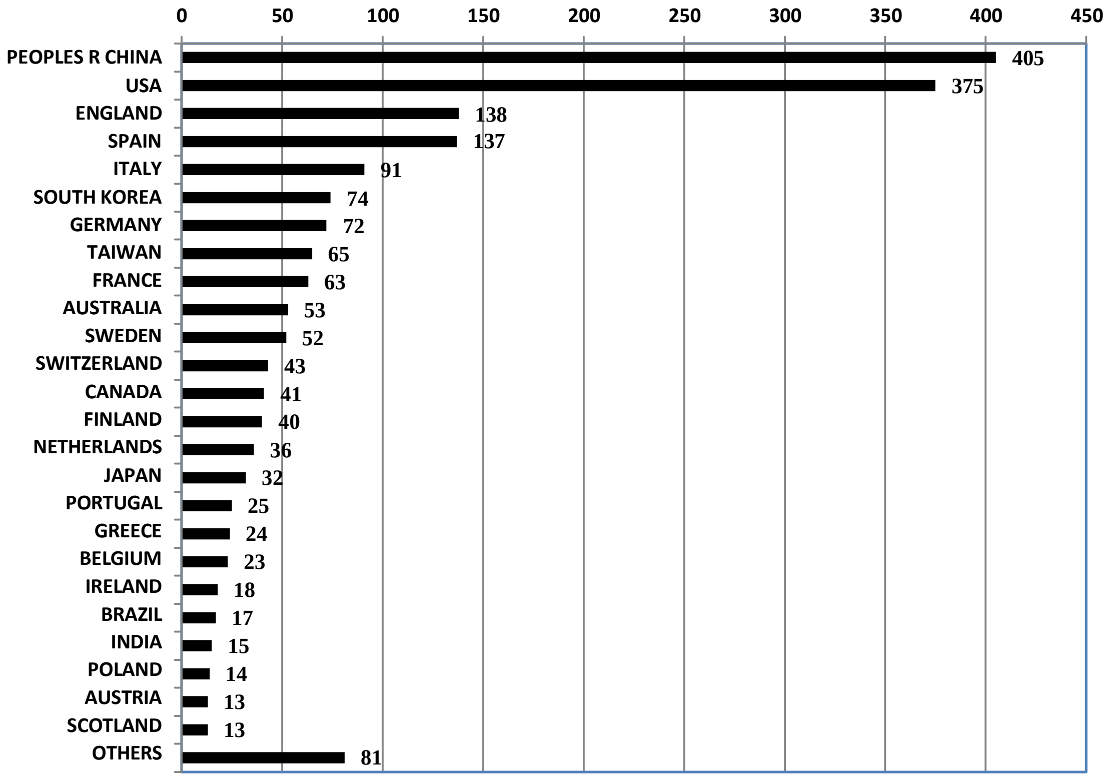

Figure 2. Distribution of top 25 countries/territories of IoT (source: SSCI database on 2015/08/06)

Distribution by Institution Name

As Figure 3 indicates, it is easy to indicate that the PRC is now the most productive country within the research aspect of IoT.

Distribution by Document Type and Language

In Table 1, the distribution of document types from 1992 to 2015 indicates that the most popular publication document type is "Article" (1406 articles, 89.78%). The result demonstrates that the article is the major tendency of document type in IoT research domain. In addition, the majority language for IoT researchers is English with 1527 articles (97.51%). Clearly, English is still the main trend in IoT research domain.

Distribution by Research Area

The top three for IoT research domains are computer science (696 articles, 44.44%), followed by telecommunications (466 articles, 29.76%) and engineering (427 articles, 27.27%). Analysis reveals that there are many additional research domains for IoT article production, such as instruments & instrumentation, business economics, chemistry, electrochemistry, physics, automation control systems and information science and library science (Figure 4).

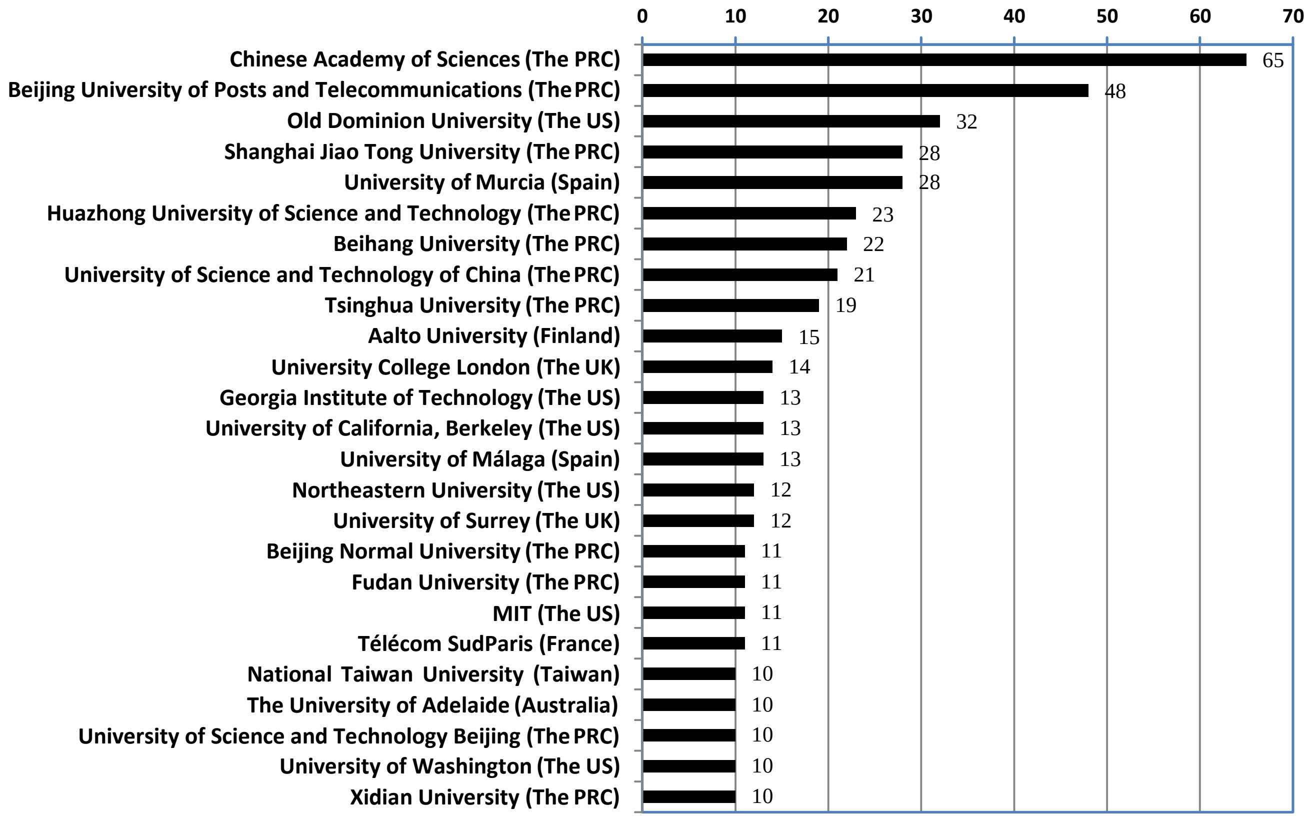

Figure 3. Distribution of top 25 institutions of IoT (source: SSCI database on 2015/08/06)

Table 1. Distribution of document types for IoT (source: SSCI database on 2015/08/06)

Language	NP	% of 1566	Document Type	NP	% of 1566
English	1527	97.51%	Article	1406	89.78%
Spanish	13	0.83%	Editorial Material	91	5.81%
German	6	0.38%	Proceedings Paper	54	3.45%
Portuguese	4	0.26%	Review	44	2.81%
Chinese	3	0.19%	News Item	16	1.02%
French	3	0.19%	Book Review	4	0.26%
Dutch	2	0.13%	Correction	3	0.19%
Swedish	2	0.13%	Book Chapter	1	0.06%
Turkish	2	0.13%	Discussion	1	0.06%
Czech	1	0.06%	Meeting Abstract	1	0.06%
Polish	1	0.06%			
Slovenian	1	0.06%			
Welsh	1	0.06%			
Total	1566	100%	Total	1566	100%

NP = number of publication

Distribution by Source Title

The top three IoT research journals are *Sensors* (67 articles, 4.28%), followed by *International Journal of Wireless Personal Communications* (56 articles, 3.58%) and *China Communications* (36 articles, 2.30%). Moreover, it also find out that there are a lot of research sources for IoT article production such as *AD HOC Networks*, *IEEE Sensors Journal*, *Wireless Personal Communications*, *IEEE Transactions on Industrial Informatics*, *IEEE Internet Computing*, *Computer* and *Personal and Ubiquitous Computing* (Figure 5).

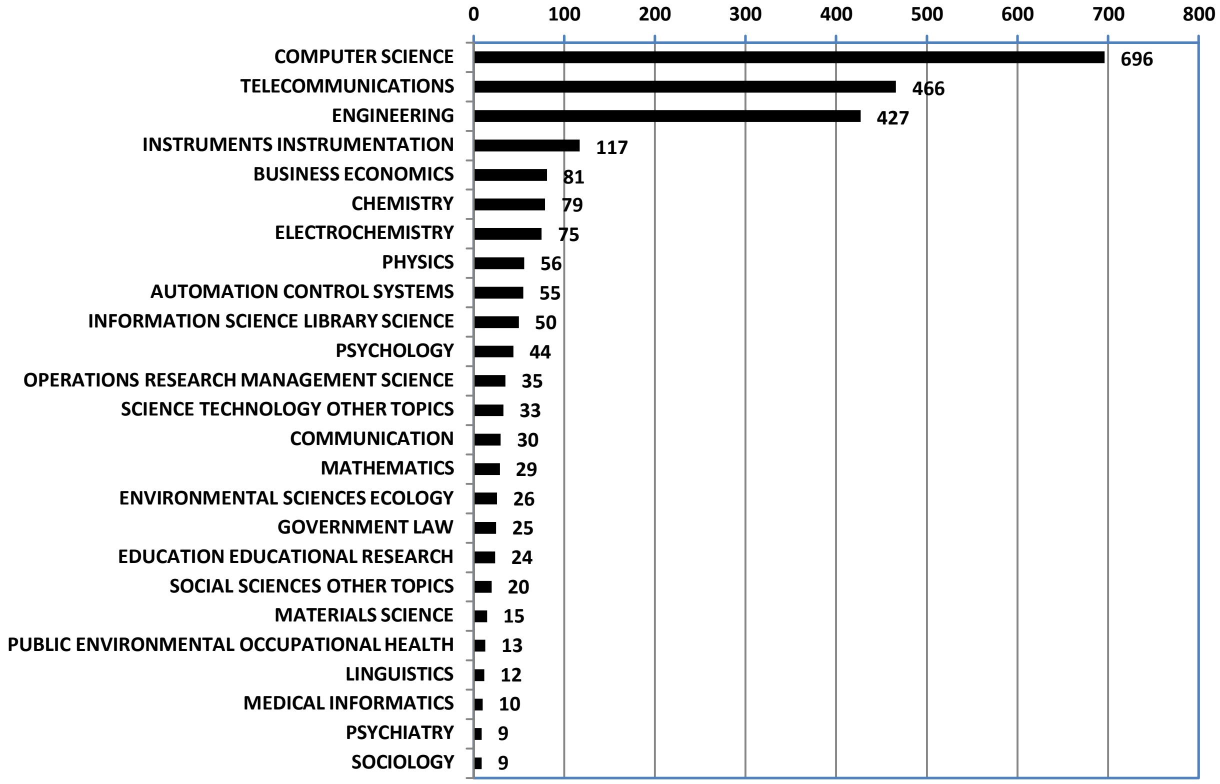

Figure 4. Distribution of top 25 research areas of IoT (source: SSCI database on 2015/08/06)

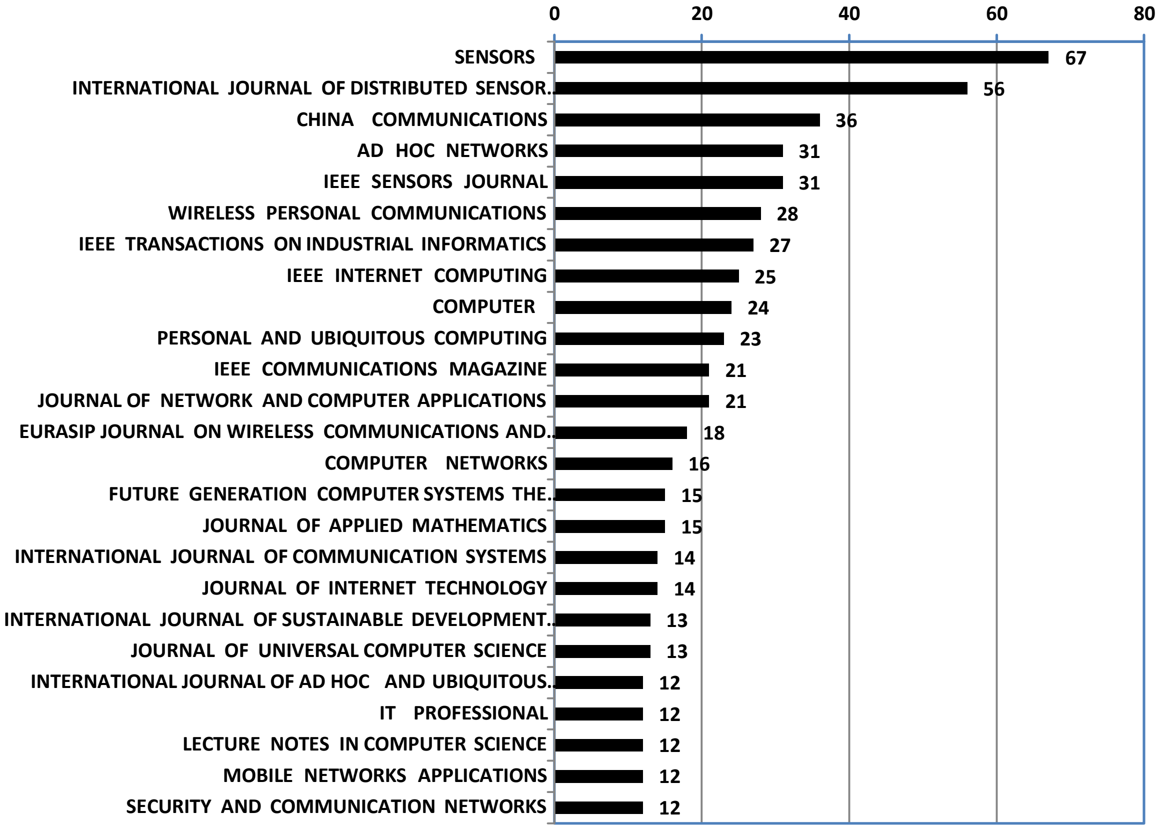

Figure 5. Distribution of top 25 source titles of IoT (source: SSCI database on 2015/08/06)

DISCUSSION

The section implements the steps to verify whether the distribution of author article production follows Lotka's law in IoT research domain.

(1) Collect data and

(2) List author & article distribution table
Author quantity is calculated by the equality method from 1566 articles retrieved by the SSCI index. Altogether, 4123 authors on IoT in universe are included. See Table 2 for reference.

(3) Calculation the value of n (slope)
In Table 3, we list the number of authors and the number of publications by one author for calculation of the exponent n with topic as "Internet of Things" in SSCI database. The results of the calculations in Table 3 can be brought into the Equation (1) to calculate the value of n:

$$n = \frac{30(7.35)-(32.42)(15.48)}{30(39.00)-(32.42)^2} \quad (1)$$

Then we can find n = -2.36966

Table 2. Calculation of author productivity of IoT

NP	Author (s)	(NP) * (Author)	Accumulated Record	Accumulated Record %	Accumulated Author(s)	Accumulated Author(s)%
30	1	30	30	0.55%	1	0.02%
20	1	20	50	0.92%	2	0.05%
18	1	18	68	1.25%	3	0.07%
11	2	22	90	1.66%	5	0.12%
10	1	10	100	1.84%	6	0.15%
9	5	45	145	2.67%	11	0.27%
8	7	56	201	3.70%	18	0.44%
7	11	77	278	5.12%	29	0.70%
6	15	90	368	6.77%	44	1.07%
5	17	85	453	8.34%	61	1.48%
4	87	348	801	14.74%	148	3.59%
3	125	375	1176	21.64%	273	6.62%
2	408	816	1992	36.66%	681	16.52%
1	3442	3442	5434	100.00%	4123	100.00%

NP = number of publication

(4) Calculation the value of c
The value of c is calculated by using the Equation (2), where P = 20, x = 1~19 and n = 2.36966, then we can find c = 0.71561867.

With n = -2.36966 and c = 0. 71561867, the Lotka's law equation of IoT is:

$$f(x) = 0.71561867/x^{2.36966} \quad (2)$$

When the result is compared to Table 2, we can see that authors with only one article account for 83.48% (100%-16.52%=83.48%), which closes to the primitive c value 71.56% generated by Lotka's law. The values for n and c can be calculated by the least squares law and then brought into further analysis for Lotka's law compliance.

According to [17], the absolute value of n should be between 1.2 and 3.8, as given by the generalized Lotka's law. The result indicates that n (=2.36966) is between 1.2 and 3.8 and is matched the reference data by observation. The detail distribution chart is shown in Figure 6.

Table 3. Calculation of the exponent n for IoT

x (NP)	y (Author)	X=log(x)	Y=log(y)	XY	XX
30	1	1.48	0.00	0.00	2.18
29	0	1.46		0.00	2.14
28	0	1.45		0.00	2.09
27	0	1.43		0.00	2.05
26	0	1.41		0.00	2.00
25	0	1.40		0.00	1.95
24	0	1.38		0.00	1.90
23	0	1.36		0.00	1.85
22	0	1.34		0.00	1.80
21	0	1.32		0.00	1.75
20	1	1.30	0.00	0.00	1.69
19	0	1.28		0.00	1.64
18	1	1.26	0.00	0.00	1.58
17	0	1.23		0.00	1.51
16	0	1.20		0.00	1.45
15	0	1.18		0.00	1.38
14	0	1.15		0.00	1.31
13	0	1.11		0.00	1.24
12	0	1.08		0.00	1.16
11	2	1.04	0.30	0.31	1.08
10	1	1.00	0.00	0.00	1.00
9	5	0.95	0.70	0.67	0.91
8	7	0.90	0.85	0.76	0.82
7	11	0.85	1.04	0.88	0.71
6	15	0.78	1.18	0.92	0.61
5	17	0.70	1.23	0.86	0.49
4	87	0.60	1.94	1.17	0.36
3	125	0.48	2.10	1.00	0.23
2	408	0.30	2.61	0.79	0.09
1	3442	0.00	3.54	0.00	0.00
Total	4123	32.42	15.48	7.35	39.00

x = number of publication; y = author; X = logarithm of x; Y = logarithm of y

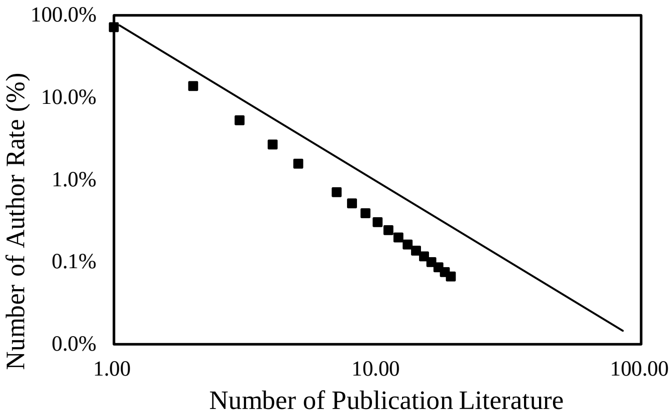

Figure 6. Distribution of literature productivity of author on IoT research aspect

(5) Utilize the K-S test to evaluate whether the analysis matches Lotka's law

From Table 4, we can find D (D = Max | Fo(x)-Sn(x) |) = 0.3463. According to the K-S test, the critical value at 0.01 level of significance is calculated by using the Equation (4):

$$1.63/\sqrt{4123} = 0.02539 \qquad (3)$$

Table 4. The K-S test for IoT

NP	Author (s)	IoT (Observed)	Sn(x)	IoT (Expected)	Fo(x)	D
1	3442	0.8348	0.8348	0.7156	0.7156	0.1192
2	408	0.0990	0.9338	0.1385	0.8541	0.0797
3	125	0.0303	0.9641	0.0530	0.9071	0.0570
4	87	0.0211	0.9852	0.0268	0.9339	0.0514
5	17	0.0041	0.9893	0.0158	0.9496	0.0397
6	15	0.0036	0.9930	0.0103	0.9599	0.0331
7	11	0.0027	0.9956	0.0071	0.9670	0.0286
8	7	0.0017	0.9973	0.0052	0.9722	0.0251
9	5	0.0012	0.9985	0.0039	0.9761	0.0224
10	1	0.0002	0.9988	0.0031	0.9792	0.0196
11	2	0.0005	0.9993	0.0024	0.9816	0.0177
12	0	0.0000	0.9993	0.0020	0.9836	0.0157
13	0	0.0000	0.9993	0.0016	0.9852	0.0140
14	0	0.0000	0.9993	0.0014	0.9866	0.0127
15	0	0.0000	0.9993	0.0012	0.9878	0.0115
16	0	0.0000	0.9993	0.0010	0.9888	0.0105
17	0	0.0000	0.9993	0.0009	0.9875	0.0118
18	1	0.0002	0.9995	0.0008	0.9882	0.0113
19	0	0.0000	0.9995	0.0007	0.9889	0.0106
20	1	0.0002	0.9998	0.0006	0.9895	0.0103
21	0	0.0000	0.9998	0.0005	0.9900	0.0097
22	0	0.0000	0.9998	0.0005	0.9905	0.0093
23	0	0.0000	0.9998	0.0004	0.9909	0.0088
24	0	0.0000	0.9998	0.0004	0.9913	0.0085
25	0	0.0000	0.9998	0.0003	0.9916	0.0081
26	0	0.0000	0.9998	0.0003	0.9920	0.0078
27	0	0.0000	0.9998	0.0003	0.9923	0.0075
28	0	0.0000	0.9998	0.0003	0.6535	0.3463
29	0	0.0000	0.9998	0.0002	0.6701	0.3297
30	1	0.0002	1.0000	0.0002	0.6795	0.3205

NP = number of publication; IoT = author productivity of IoT; Sn(x) = observed cumulative frequency; Fo(x) = theoretical cumulative frequency; D = maximum deviation

CONCLUSION

The results in this paper have several important implications. From the distribution of publication year, IoT has more potential to grow up and becomes more popular. The article and English are the main tendency of document type and language in IoT research.

On the basis of the countries/territories, the PRC, the US and England are the top three countries/territories in IoT research. Besides, Spain, Italy, South Korea, Germany and Taiwan are also the major academic article providers in IoT.

Regarding the institutions, analysis of the locations of these affiliations shows that the PRC is now the most productive country within the research aspect of IoT.

Judging from the research area, the most relevant disciplines in IoT research categories provided by computer science, telecommunications, engineering, instruments & instrumentation, physics, chemistry, electrochemistry will become the most important categories for IoT researchers.

Based on the sources, the most enthusiastic supports for IoT scholarly publishing enterprise come from AD HOC Networks, IEEE Sensors Journal and Wireless Personal Communications which are repeated in IoT research domain and will turn into the most critical journals for IoT researchers.

According to the K–S test, the result shows that the author productivity distribution of IoT can't be predicted by Lotka' law [18]. The reason why IoT does not fit Lotka's law is the amount of authors who published one article is too large. The result causes that the difference between observed value and expected value becomes greater than the K–S test critical value. The outcome diverges IoT distribution from the slope of Lotka's law.

According to the analyzing results, this paper provides the IoT roadmap, abstracts technology trend information and facilitates knowledge accumulation for future researches. Therefore, the researches of IoT can follow and concentrate their attentions on the right countries, institutes, research categories and core journals, and create the research potentials in the near future.

Limitation of the Study

The results and conclusion are limited and not intended to be exclusive. SSCI journals adopt stringent journal reviewing criteria, the articles might take one to two years from submission to publication. Besides, the SSCI database does not collect SCI and conference proceedings, the findings in this study may not reflect the most recent research trends. Furthermore, this study used only one search term each ("Internet of Things") to analyze IoT publications from 1992 to 2015 collected in the SSCI databases. Future studies with greater resources, using more search terms, are needed to expand these findings.

REFERENCES

[1] CISCO, the network (2015) 'Internet of everything', available at http://newsroom.cisco.com/ioe(accessed 26 June 2015).

[2] Cognizant Reports (2014) 'Reaping the benefits of the Internet of Things', available at http://www.cognizant.com/ InsightsWhitepapers/Reaping-the-Benefits-of-the-Internet-of-Things.pdf (accessed 26 June 2015).

[3] Farooq, M. U., Waseem, M., Khairi, A. & Mazhar, S. (2015), 'A critical analysis on the security concerns of Internet of Things (IoT)', *International Journal of Computer Applications (IJCA)*, Vol. 111, No. 7, pp.1-6 (accessed 26 June 2015).

[4] Harvard Business Review analytic report (2015) 'The Internet of Things: Science fiction or business fact?', available at https://hbr.org/resources/pdfs/comm/verizon/18980_HBR_Verizon_IoT_Nov_14.pd. (accessed 26 June 2015).

[5] Hendricks, D. (2015) 'The trouble with the Internet of Things', London Datastore, Greater London Authority, http://data.london.gov.uk/blog/the-trouble-with-the-internet-of-things/ (accessed 26 June 2015).

[6] Hogan, M. (2014) 'The Internet of Things database', *Data Management Requirements, ScaleDB.*, http://www.scaledb. com/i nternet-things-database.php. (accessed 26 June 2015).

[7] Höller, J., Tsiatsis, V., Mulligan, C., Karnouskos, S., Avesand, S. & Boyle, D. (2014) 'From machine-to-machine to the Internet of Things: Introduction to a new age of intelligence', *Elsevier*, ISBN 978-0-12-407684-6 (accessed 26 June 2015).

[8] Howard, P. N. (2015) 'How big is the Internet of Things and how big will it get?', *The Brookings Institution*, available at http://www.brookings.edu/blogs/techtank/posts/2015/06/8-future-of-iot-part-1 (accessed 26 June 2015).

[9] ITU-T (2015a) Internet of Things global standards initiative, available at http://www.itu.int/en/ITU-T/gsi/iot/Pages/ default. aspx (accessed 26 June 2015).

[10] ITU-T (2015b) 'Smart cities Seoul: A case study', ITU-T technology watch report, available at https://www.itu.int/ dms_pub/itu-t/oth/0b/15/T0B150000153301PDFE.pdf (accessed 26 June 2015).

[11] LOPEZ research LLC (2013) 'An introduction to the Inter of Things (IoT)', http:// www. cisco. com/web/ solutions/ trends/iot/introduction_to_IoT_november.pdf (accessed 26 June 2015).

[12] M&M Research Group (2012) 'Internet of Things (IoT) & M2M communication market: Advanced technologies, future cities & adoption trends, roadmaps & worldwide forecasts 2012–2017, technical report', Electronics.ca Publications.

[13] Mattern, F. & Floerkemeier, C. (2010) 'From the Internet of Computers to the Internet of Things', *Infor-matik-Spektrum*, Vol.33, No. 2, pp 107–121, available at http://www.vs.inf.ethz.ch/publ/papers/Internet-of-things.pdf (accessed 26 June 2015).

[14] Molluscan Eye (2015) available at http://molluscan-eye.epoc.u-bordeaux1.fr/index.php?rubrique=accueil&lang=en/ (accessed 26 June 2015).

[15] Monnier, O. (2014) 'A smarter grid with the Internet of Things', *Texas Instruments*, http://e2e.ti.com/ blogs_/b/ smartgrid/archive/2014/05/08/a-smarter-grid-with-the-internet-of-things (accessed 26 June 2015).

[16] Open interconnect (2015) 'Network of everything', http://openinterconnect.org/join/ (accessed 26 June 2015).

[17] Pao, M. L. (1989) *Concept of information retrieve*, Libraries Unlimited, Englewood, Colorado.

[18] Potter, W. G. (1981) 'Lotka's law revisited', *Library Trends*, Vol. 30, No. 1, pp.21-39, Summer.

[19] Santucci, G. (2015) 'The Internet of Things: Between the revolution of the internet and the metamorphosis of objects', available at http://cordis.europa.eu/fp7/ict/enet/documents/publications/iot-between-the-internet-revolution.pdf.(accessed 26 June 2015).

[20] Vermesan, O., & Friess, P. (2013) 'Internet of Things: Converging technologies for smart environment and integrated ecosystems', *River Publishers*, http://www.internet-of-things-research.eu/pdf/Converging_Technologies_for_Smart_Environments_and_Integrated_Ecosystems_IERC_Book_Open_Access_2013.pdf (accessed 26 June 2015).

[21] Violino, B. (2014) 'The Internet of things will mean really, really big data. InfoWorld', available at http://www.

infoworld.com/article/2611319/computer-hardware/the--internet-of-things--will-mean-really-really-big-data.html(access ed 26 June 2015).

[22] Wigmore, I. (2014) 'Internet of Things (IoT), TechTarget', available at http://whatis.techtarget.com/definition/Internet- of-Things (accessed 26 June 2015).

[23] Wood, A. (2015) ‘The internet of things is revolutionizing our lives, but standards are a must’, available at http://www.theguardian.com/media-network/2015/mar/31/the-internet-of-things-is-revolutionizing-our-lives-but-standar ds-are-a-must (accessed 26 June 2015).

[24] Zanella, A., Bui, N., Castellani, A., Vangelista, L., & Zorzi, M. (2014) ‘Internet of Things for smart cities’, *IEEE Internet of Things Journal*, Vol. 1, No.1 (accessed 26 June 2015).