A Study on Research Trends of Technologies for Industry 4.0; 3D Printing, Artificial Intelligence, Big Data, Cloud Computing, and Internet of Things

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Abstract In this paper, the current trends of five technologies are analyzed. The target technologies are 3D printing, artificial intelligence, big data, cloud computing and internet of things, which are significant for industry 4.0. The trends are analyzed to figure out the current researching situation of the selected five technologies and predicate the leading country in the era of industry 4.0. USA and China are the most leading countries. UK, Germany, France, and Italy in Europe and India, Japan, and Korea in Asia are following. Most researches are carried out in universities or national laboratories. Therefore, the political intention of the government, and the well-performed system which manages and supports the research projects are the most significant features that determine the competitive power of each nation. The quantity and quality of researches are analyzed using Elsevier's Scopus database from 2012 to 2016.

Keywords 3D printing · Artificial intelligence · Big data · Cloud computing Internet of things · Technology trends

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1 Introduction

Technology is always a key which defines the human civilization [1]. Until now, the human civilization goes through three revolutionary changes. The first revolution was made by the agricultural technologies. With these technologies, new era of the human civilization had begun with settlement. The second revolution was made with the steam engine. The technology changed the source of power from animals to machines. Industry had begun with the power of engines. The era of industry has its own revolutions [2]. With the help of mass production system such as conveyor belt, the aspect of industry had changed drastically. When the material prosperity was satisfied, the human race moves to the next level of civilization. The next revolution was born from the desire for the information. The right to access the origin of knowledge had been a privilege of the upper class citizen. Education, which was the way of acquiring knowledge was regarded as a ladder of success. However, technology changed this rule. After the Internet was invented, information and knowledge were open to the public. More than 20 years passed since the last revolution which was made by information technologies. It is a time to prepare for the next revolution. It is called as '*the fourth wave*' following the Neolithic revolution, industrial revolution, and information revolution [3]. It is also called as '*the fourth industrial revolution* (*industry 4.0)*' following steam-powered engine, mass production system, and information technology [4]. According to the world economic forum, technologies are converged with not only societies but also each human in *industry 4.0* [2]. Therefore, technologies which make the convergence possible become the core technologies.

In this paper, we choose five technologies which are 3D printing, artificial intelligence (AI), big data, cloud computing (CC), and internet of things (IoT) as core technologies for industry 4.0. Then analyze the current trends of these five technologies to figure out the current researching situation and prepare for improving the national capability to be a leading country in the era of *industry 4.0*. To analyze the technology trends, we collected data from Elsevier's Scopus database [5] using SciVal Analytics Engine [6]. The quality of researches are compared with three criteria which are the number of published journal, the number of citation, and field weighted citation impact (FWCI).

2 Five Technologies of Industry 4.0

2.1 3D Printing

In the era of mass production, Pareto principle, which means that roughly 80% of the effects comes from 20% of the causes, reigns the world [7]. To maximize the efficiency of production system which is the originated from the economies of scale,

Table 1 Trend of 3D printing research results during last 5 years

	2012	2013	2014	2015	2016	Total
# of journals	13,117	14,209	15,854	16,747	18,310	78,237
# of citation	139,122	120,494	93,751	63,020	25,782	442,169
FWCI	1.15	1.22	1.20	1.22	1.19	1.20

variety should be sacrificed. However, 3D printing technology successes in expelling the Pareto principle. Small quantity batch production can be realized with low cost [8]. Table 1 shows the trends of researches on 3D printing technology.

2.2 *Artificial Intelligence*

AI is a technology for representing, reasoning, and managing knowledge. Smartness can be achieved in various services with AI [9]. In order to be smart, services should be able to recognize the context of the environment where they are deployed, and astronomically decide what to do in the given situation to achieve the given goal. Main topics in AI are enhancing knowledgebase (KB) by symbolic and statistical approaches, reasoning implicit knowledge from KB, and applying KB to make services intelligent. Table 2 shows the trends of researches on AI technology.

2.3 *Big Data*

Big data is a fundamental technology for realizing AI. In order to enhance the knowledge by machine learning methods, the database where the patterns are hidden should be provided. Depending on the scale of data, more reliable and explicit knowledge can be extracted. Big data is a method for collecting and

Table 2 Trend of AI research results during last 5 years

	2012	2013	2014	2015	2016	Total
# of journals	50,537	53,338	56,115	57,282	63,435	280,707
# of citation	522,622	427,796	323,575	192,470	63,893	1,530,356
FWCI	1.23	1.21	1.30	1.30	1.26	1.26

Table 3 Trend of big data research results during last 5 years

	2012	2013	2014	2015	2016	Total
# of journals	668.9	72,967	79,915	83,798	88,459	391,948
# of citation	905,351	720,915	537,883	311,618	109,724	2,585,491
FWCI	1.49	1.43	1.41	1.35	1.36	1.41

managing data in large scale [10]. This technology is similar to data warehouse except that the data warehouse focuses on the architecture of data to make it reliable, accessible, and believable, whereas big data focus on the way of storing and managing the volume, variety, and velocity of data. Table 3 shows the trends of researches on big data technology.

2.4 Cloud Computing

CC is based on the distributed computing and client-server architecture [11]. The cloud services work as server systems. Therefore, the service users can get their working environment regardless of time and place while they are online. However, as the number of the service users increases, the computing load for servicing them also increases. Therefore, cloud services are composed of distributed computing objects. The way of managing distributed computing objects to provide reliable services to massive users is the main research topic in CC. Table 4 shows the trends of researches on CC technology.

2.5 Internet of Things

IoT is a method of embedding and managing communication capability into computing objects [12]. Therefore, the way of managing networks such as registration of computing objects, dynamic configuration of the network architecture, providing securities in data communication, and managing limited resources of each computing objects are the main topic to be researched in IoT. Table 5 shows the trends of researches on IoT technology.

Table 4 Trend of CC research results during last 5 years

	2012	2013	2014	2015	2016	Total
# of journals	41.334	44.282	46.755	47.182	48.717	228.270
# of citation	33.443	287.403	205.773	122.650	39.485	988.754
FWCI	1.22	1.23	1.18	1.17	1.15	1.19

Table 5 Trend of IoT research results during last 5 years

	2012	2013	2014	2015	2016	Total
# of journals	13,927	14,628	15,286	16,338	19,492	79,671
# of citation	78,075	68,050	55,535	35,364	12,440	249,464
FWCI	1.16	1.18	1.24	1.26	1.28	1.23

2.6 Research Results of Major Nations

The quantity of five technologies have been increased constantly for last 5 years. Pareto principal is still valid in the quantity of researches. As shown in Table 6, the number of researches from top 9 nations holds 80% of the whole researches. USA is second to none not only in quantity but also in quality. Chain is in the second place, and the research of USA and Chain occupies over 50% of the total amount of the research result. In Asia, China, India, Japan, and Korea are in the leading group of the selected technologies. The ratios of highly qualified researches, which are in Top 1 percentiles, over total quantity of China, India, Japan, and Korea are 1.11, 0.62, 1.40, and 1.29%, respectively.

3 Public Policy for Supporting 5 Technologies in Korea

As shown in Table 6, technologies are attached to the nation where technologies are invented. Because technologies requires abundance of resources, the governmental supports becomes the incubator where the technologies can be invented. The rank of countries in Table 6 is similar to the rank of the national economy. However, the strategic plan for managing the national resources can make the reversion that even the minor nation can overtake the major nations. Even though Korea is in the last rank in GDP and population [13], there is a possibility to overtake and lead the world.

National Research Foundation of Korea (NRF) is a quasi-governmental organization established in 2009 as a merger of Korea Science and Engineering Foundation, Korea Research Foundation, and Korea Foundation for International Cooperation of Science and Technology [14]. The role of NRF is to provide supports for improving national capability in science and technology. Table 7 shows the number of projects and total fund size which are managed and supported by NRF. Therefore, the role of NRF is the key for Korea to promote its rank shown in Table 6.

Table 6 Research results of top 9 nations for 5 technologies from 2012 to 2016

Nation	# of journals/# of journals in top 1 percentiles									
	3D Printing		AI		Big Data		CC		IoT	
USA	17,833	453	71,919	216	122,535	3759	53,470	1118	11490	187
China	15,763	233	54,986	604	61,931	842	41,626	329	19221	155
UK	4086	126	19,050	561	35,978	1576	15,601	376	3319	58
Germany	5620	110	16,186	385	33,159	1286	17,924	389	4134	44
India	3335	28	15,807	82	16,009	162	11,931	51	7714	21
France	3429	77	10,104	193	21,650	867	10,912	198	3583	34
Italy	2824	56	10,254	167	20,013	753	10,585	182	3608	66
Japan	3884	48	12,403	109	14,662	352	9714	77	2377	20
Korea	3201	59	6246	86	9107	154	6812	49	3885	31

Table 7 The number of projects and total fund size which are registered and managed by NRF from 2012 to 2016. The unit of fund size is KWR Billion

		2012	2013	2014	2015	2016
3D printing	# of project	13	16	35	59	97
	Fund size	21.0	34.7	38.0	72.9	120.8
AI	# of project	43	47	58	90	228
	Fund size	36.8	33.1	50.1	79.7	238.9
Big Data	# of project	20	62	102	162	200
	Fund size	21.8	47.5	112.2	182.3	235.7
CC	# of project	70	94	106	107	117
	Fund size	59.4	72.1	84.7	84.4	93.0
IoT	# of project	6	8	36	92	149
	Fund size	3.4	4.9	23.6	77.3	124.4
Total	# of project	145	211	315	458	702
	Fund size	134.6	180.3	286.7	442.4	733.6

4 Conclusion

In this paper, we select 3D printing, artificial intelligence, big data, cloud computing and internet of things as core technologies for *industry 4.0*. Then the trends of each technology are analyzed using statistical approach. The current research papers are mined from Elsevier's Scopus database with selected keywords, and analyzed according to the quality of the result and the leading subject of the research.

From the trends analysis, the researches of the selected 5 technologies have been increased constantly and these tendency is predicted to be kept. There are 10 countries which lead these technology trends. The rank of these countries are similar to the rank of GDP. However, there is a possibility of upheaval in the rank. In *industry 4.0*, technologies are closely related and converged with societies. Therefore, to lead the technology trends for *industry 4.0*, government-level support is required. In order to expand the quantity of researches without losing the quality, managing and supporting the large-scaled research projects become the most significant fundamentals. Hence, the role of NRF can be the key of Korea to become the leading country in the era of *industry 4.0*.

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