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Adoption of AI in Firms and the Issues to be Overcome - An Empirical Analyses of the Evolutionary Path of Development by Firms

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Adoption of AI in Firms and the Issues to be Overcome ~ An Empirical Analyses of the Evolutionary Path of Development by Firms

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Abstract—AI has been through several booms and we have currently reached the 3rd AI boom. Although AI has been evolving over six decades it seems that the current boom is different from the previous booms.

In this paper, we attempt to elucidate the issues for widespread adoption of AI in firms. Through one of the authors work experience related to AI, it appears that although companies are willing to consider adopting AI for various applications, only a few are willing to make a commitment to go for full scale adoption. The main goal of this paper is to identify the characteristics of the current 3rd AI boom and to analyze the issues for adoption by firms.

For this purpose we have put forward 3 research questions.

1) How has the technological performance in AI changed at the national level during the 2nd and the 3rd boom?

2) How have the key technologies and the applications of AI changed over time?

3) How is the companies' perspective on AI and what are the necessary conditions for firms to adopt AI?

Through bibliometric analysis, we were able to extract the important keywords in the 3rd AI boom, which were Machine learning and Deep learning. The main focus of AI research has been shifting towards AI applications. The interviews with firms which were considering adopting AI suggested the existence of a gap between the needs of the company and what AI can deliver at present. AI could be used for finding suitable treatment for genetic illnesses if some issues are solved.

I. INTRODUCTION

Many industries are undergoing radical transformations due to technological paradigm shifts, mega-competition taking place on a global scale. The current AI boom started around 2013 and AI is beginning to affect corporate management and operations. John McCarthy from Stanford University coined the term Artificial Intelligence in 1956 at a conference in Dartmouth. According to McCarthy, AI is the science and engineering of making intelligent machines.[15]

AI is said to have reached its 3rd boom [18]. The first boom which continued up until 1969 was based on search and deductive reasoning. AI programs were able to solve only simple problems. In the 2nd boom which took place in the 1980s, AI was mainly related to expert systems. The knowledge of the experts were used to build the knowledge bases which enabled expert systems to be constructed. For example, one of the authors worked at Schlumberger in the 1980s and was doing research on reservoir modelling systems used in oil exploration. The knowledge of the geologists was used to build the expert system to estimate the exact location and the amount of oil in a reservoir. AI in the 2nd boom was highly specialized in specific domains leading to limit in generalization of applications.

Since 2013, AI has entered a new phase of the 3rd boom, characterized by machine learning and deep learning. Although AI has been evolving over six decades, it seems that the 3rd boom is fundamentally different from the previous booms in certain ways, with definite signs of AI adoption in a broad range of applications, affecting society.

AI is beginning to affect corporate management and operations. IBM carried out a survey on AI adoption and 65% of 600 companies responded that AI will play an important role in corporate management; 58% responded that cognitive computing is essential to digital transformation; 58% responded that having AI capability would be absolutely necessary to remain competitive in the future. [7]

One of the authors has been working at IBM, advising customers and marketing systems based on Watson. From his experience, it appears that although companies are willing to consider adopting AI by implementing prototype applications, few companies are willing to make a commitment to go for full scale adoption.

In this paper, we try to identify the issues behind AI adoption by corporations in the current 3rd AI boom.

For this purpose we have put forward 3 research questions.

- 1) How has the technological performance in AI changed at the national level during the 2nd and the 3rd boom?
- 2) How have the key technologies and the applications of AI changed over time?
- 3) How is the companies' perspective on AI and what are the necessary conditions for firms to adopt AI?

II. METHODOLOGIES AND DATA SOURCES

The methodology is based on a 3 step approach. In the first step, a bibliometric analyses of Artificial Intelligence was carried out to analyze the technological accumulation over the 2nd and the 3rd AI boom. In the first phase, having done the desk work and interviewed several experts on AI, we divided the two AI booms into 2 periods, before and after 2013. In the second stage, a bibliometric analyses based on countries over the 2 periods was followed by co-occurrence analyses of the author keywords in the 2 periods, before and after 2013. In the third stage, interviews were carried out with corporate members to do a qualitative analysis on the possible application areas of AI and identify the issues to be solved for AI adoption.

One of the main challenges in doing an empirical analysis of AI is that the term AI is quite broad and general so that one has to first identify the key technologies underlying AI in order to apply techniques such as bibliometric analysis. We took into account a set of application keywords related to AI made by Jiqiang Niu.[11]

We revised the list of keywords based on a range of information sources searched including a report published by the Japanese Patent Agency in 2015[20] and by studying the practical applications of AI in IBM where one of the authors is employed.[7] In addition we interviewed some experts on AI such as Professor Katsuo Nitta and Professor Takao Terano at Tokyo Institute of Technology. In addition the knowledge of one of the authors was used as she worked as a computer scientist in the field of knowledge based systems in industrial applications.

As a result, we revised the list by adding some keywords, such as Web science, deep learning, machine learning, neural networks, linear classifiers, logical regression, perception, support vector machine, quadratic classifiers, K-Means clustering, boosting, decision tree, random forest, Bayesian networks, and VR (virtual reality).

Bibliometric analysis was carried out using the search term,

("machine learning" or "neural network" or "Linear Classifiers" or "Logical Regression" or "Naive Bayes Classifier" or "Perceptron" or "Support Vector Machine" or "Quadratic Classifiers" or "K-Means Clustering" or "Boosting" or "Decision Tree" or "Random Forest" or "Bayesian Networks" or "Deep Learning" or "reasoning system" or "knowledge base" or "knowledge representation" or "fuzzy reasoning" or "fuzzy control" or "genetic algorithm" or "chaos theory") AND ("speech recognition" or "image recognition" or "facial recognition" or "character recognition" or "natural language processing" or "data pattern recognition" or "visualization" or "auralization" or "Dialogue" or "agent" or "knowledge discovery" or "information retrieval" or "data mining" or "information recommend" or "Monitoring" or "diagnosis" or "control" or "optimization" or "design" or "prediction" or "web science" or "VR")

Using Web of Science Core Collection, between the period 1990 and 2016, 210,576 papers were retrieved in January 2017. Subsequently, a national performance analysis was conducted by dividing the whole period into 2 parts, prior to the 3rd boom (1990-2012), and during the 3rd boom (2013-2016). In the next stage, co-occurrence analysis of the author keywords was carried out over the 2 periods and we were able to extract the application keywords which only existed prior to the 3rd boom and also the new application keywords which appeared in the 3rd boom.

In the third stage we interviewed some people in companies which were considering adopting AI such as in a pharmaceutical company, a life insurance company, or a DNA sequencer maker.

III. FINDINGS

3.1 Country Performance

The trend of AI related publications using the keyword 'artificial intelligence' led to 25,841 publications shown in Fig. 2.

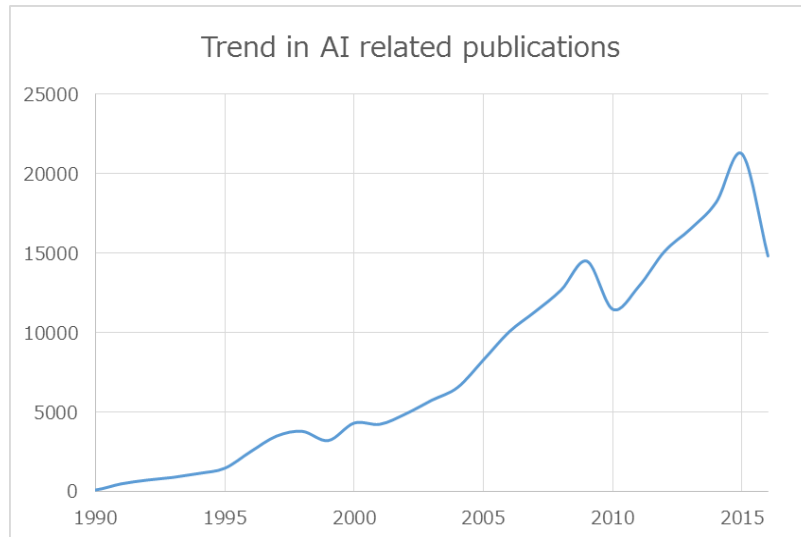


Fig. 1. Trend in publications using the search term defined by the authors

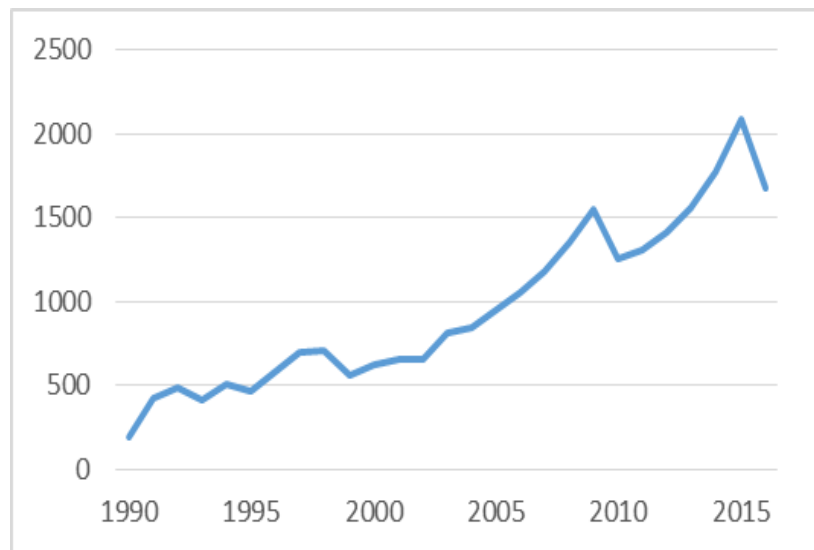


Fig. 2. Trend in publications using the term including 'artificial intelligence'

The trend in publications using the specific search terms defined by the authors resulted in 210,576 publications as shown in Fig. 1. The shape of the trends in publications in Figure 1 and 2 are similar, confirming that the search terms that we defined seem to represent well the field of AI. From Fig. 1 the papers published prior to the 3rd boom were 139,795, compared to the papers published during the 3rd boom (2012-2016) which were 70,781,

indicating that 34% of the publications have been published during the last 4 years, confirming the presence of the 3rd AI boom.

Rank	Country	Papers	(%)
1	PEOPLES R CHINA	20805	28.465
2	USA	11202	15.326
3	INDIA	6705	9.173
4	IRAN	4976	6.808
5	ENGLAND	3262	4.463
6	TAIWAN	2680	3.667
7	CANADA	2340	3.201
8	GERMANY	2337	3.197
9	SPAIN	2321	3.175
10	AUSTRALIA	2233	3.055
14	JAPAN	1969	2.694

TABLE I. COUNTRY PERFORMANCE PRIOR TO THE 3RD AI BOOM (1990-2012)

Rank	Country	papers	(%)
1	PEOPLES R CHINA	32477	23.232
2	USA	26081	18.657
3	TAIWAN	7161	5.123
4	JAPAN	7028	5.027
5	ENGLAND	6768	4.841
6	INDIA	6186	4.425
7	CANADA	5008	3.582
8	IRAN	4806	3.438
9	GERMANY	4639	3.318
10	SOUTH KOREA	4567	3.267

TABLE II. COUNTRY PERFORMANCE DURING THE 3RD AI BOOM (2013-2016)

Tables I, II list the papers published by country. In both periods, the ratio of China is above 20%, showing its strong performance. US, UK are among the top 5 nations.

Japan's ranking used to be No. 4 prior to the 3rd AI boom but in the 3rd boom its ranking has dropped to the 14th position. During the 3rd AI boom, Iran has emerged among the top 5 leading nations, and University of Tehran in the 6th position. Japanese national universities

have lost their competitiveness, as Tokyo University's ranking has dropped to the 107th position (from the 59th) and Tokyo Institute of Technology's ranking has dropped to the 453th position (from the 107th) during the 3rd AI boom. A Chinese scholar has commented in a newspaper that China has vast amount of data and there is a need to use it to solve the problems faced by the Government. In China, AI is considered as a way to analyze the vast amount of data related to a population of 1.3 billion people. The Government has announced in May 2016 that it will allocate 1.68 trillion yen into AI research over 3 years. Among the top 10 institutions in AI in the 3rd boom, 5 are Chinese. Iran's performance has also improved from the 8th to the 4th position. Iran has been gaining strength in research in other high-tech areas such as robotics, biotechnology, satellites, nanotechnology. Although the ranking of 2 universities in Japan has dropped, Japanese government has announced that it will try to accelerate the adoption of AI in society by establishing the AI Technology Strategic Council which will promote the linkage between industry academia and government.

Intelligent control	recurrent neural networks
Nonlinear systems	Fuzzy systems
control	backpropagation
modelling	nonlinear control
Chaos	induction motor
Learning	robustness
Identification	Fuzzy controller
knowledge discovery	bioinformatics
Process control	Predictive control
Tabu search	Fuzzy logic control
robust control	Computer-aided diagnosis
	Heuristics
	Fuzzy Reasoning
	Nonlinear system

TABLE III. KEYWORDS WHICH EXISTED PRIOR TO THE 3RD AI BOOM BUT WERE NOT RETRIEVED IN THE 3RD AI BOOM

NSGA-II	deep neural network
Deep learning	Local search
Support vector regression	multi-objective
ANFIS	Swarm intelligence
random forest	Parameter estimation
Response surface methodology	Regression
Big data	Taguchi method
Cloud computing	Smart grid
Reliability	Wavelet neural network
Extreme learning machine	energy efficiency
Metaheuristics	remote sensing
	Surface roughness
	PID controller

TABLE IV. KEYWORDS WHICH WERE RETRIEVED ONLY IN THE 3RD AI BOOM

3.2 Analyses of key technologies and applications in the 2 periods

The occurrences of the author keywords before the 3rd AI boom and during the AI boom were analyzed. Table III shows the keywords which existed prior to the 3rd AI boom but were not retrieved in the 3rd AI boom. Keywords such as Fuzzy systems, Fuzzy controller, Fuzzy reasoning, Chaos, Knowledge discovery, Nonlinear systems have disappeared in the 3rd AI boom. Table IV contains a list of author keywords which were only retrieved in the 3rd AI boom such as Deep learning, deep neural network. Also, keywords such as smart grid, big data, cloud computing, energy efficiency have emerged, indicating that in the 3rd AI boom, AI is beginning to converge with other fields which are related to applications of AI.

Co-occurrences of author keywords were analyzed and mapped using R's free software called KH Coder. The lines linking the keywords indicate the co-occurrences of the author keywords in a paper. The red nodes indicate a higher degree of co-occurrences with the various keywords than the blue nodes. For example, Genetic algorithm, Neural networks and Optimization are the 3 main keywords which represent the components of AI prior to the 3rd AI boom. On the other hand, Classification has co-occurrences with many different keywords such as Machine learning, Support Vector machine, Decision tree, Feature selection, data mining which represent algorithms underlying AI.

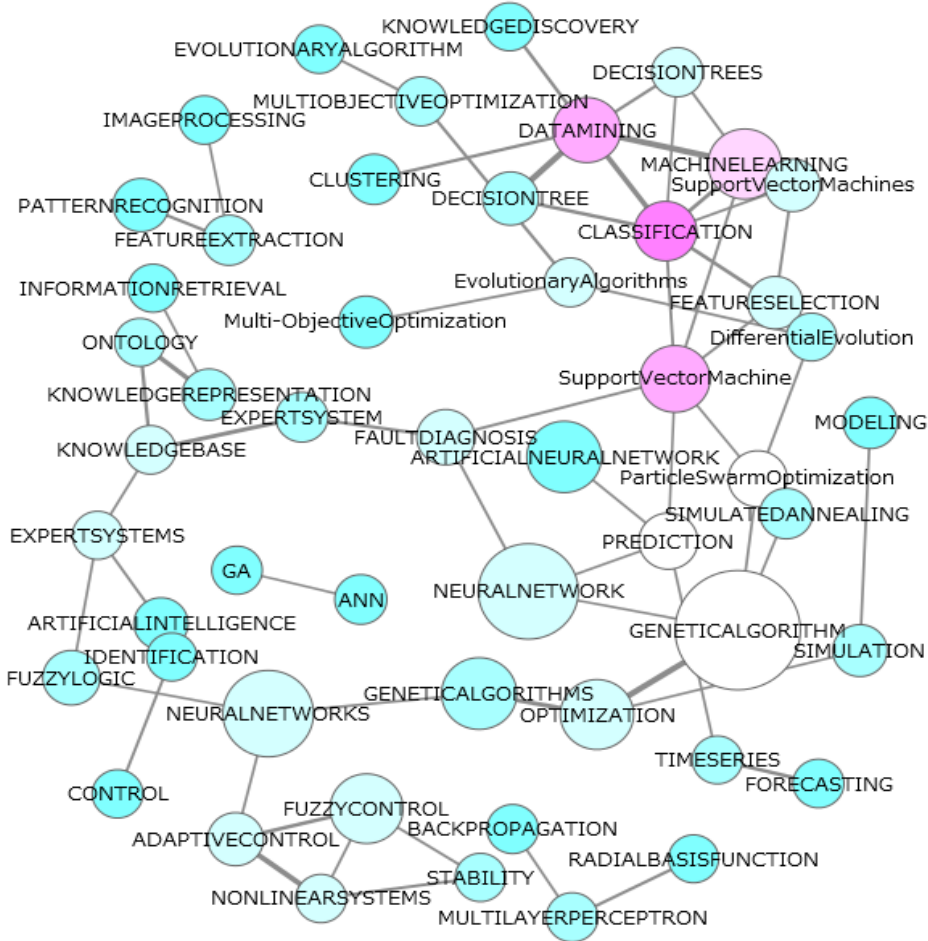


Fig. 3. Co-occurrence Network based on author keywords prior to the 3rd AI boom (1990-2012)

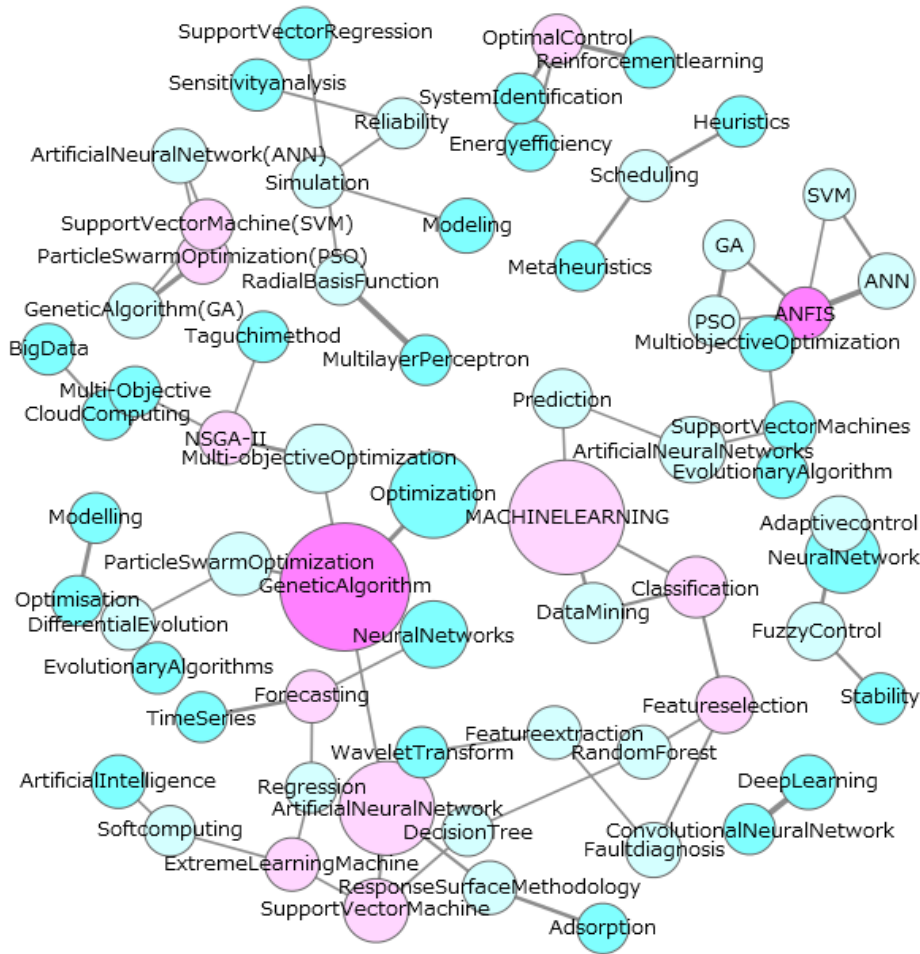


Fig. 4. Co-occurrence network based on author keywords during the 3rd AI boom (2013-2016)

Compared to Fig. 3, Fig. 4 shows the Co-occurrence network based on author keywords during the 3rd AI boom. The size of the circle indicates the frequency of co-occurrence. Machine learning has become as prominent as Genetic algorithm indicating that the 3rd AI boom is strongly linked to Machine learning. We also note that Machine learning is linked with Data mining, suggesting that the two are closely related. The map also highlights the strong connection between Deep learning and Convolutional Neural Network, and ANFIS and ANN. Similar to the previous analysis based on the keywords which existed prior to the boom and during the boom, this analysis also revealed the emergence of new applications related keywords such as Energy efficiency, Big data and Cloud computing, and Scheduling, confirming that AI is beginning to be adopted by different applications.

Application Keywords	stage	The rate of occurrence of keywords prior to the 3rd boom (occurrences/period)	The rate of occurrence of the keywords during the 3rd boom
1.Expert system	0	27.95	34.25
2.Optimization	0	166.68	528.50
3.Prediction, Forecast	1	56.91	174.75
4.Machine learning, Classification, Data Mining, Recognition, Pattern Recognition, Deep Learning	1	191.32	647.75
5.Design	0	15.23	34.25
6.Simulation	0	43.09	84
7.Diagnosis, Fault Diagnosis	1	68.09	150.25
8.Decision support system (DSS)	0	-	-
9.Knowledge-based system(KBS)	0	-	-
10.Case-based reasoning(CBR)	0	-	-
11.Knowledge representation(KR)	0	39.68	60.25
12.Management	1	-	-
13.Identification	1	14.45	^
14.Decision making	1	-	^
15.Navigation, Self-driving	1+2	^	^
16.Game	2	-	-
17.Matching, Scheduling	2+3	-	59.75
18.Robot, Automation, Remote Sensing	2+3	-	29.50
19.Smart Grid, Energy Efficiency	3	-	62.00

TABLE V. THE RATE OF OCCURRENCE OF APPLICATION KEYWORDS PRIOR TO THE 3RD AI BOOM AND DURING THE 3RD BOOM

In the next stage, the list of applications keywords was revised, by 1. Taking into account the suggestions by the experts interviewed 2. IBM's cases of cognitive adoption [7], and also using the results of the analyses in the previous section where keywords related to

applications such as Smart Grid, Energy efficiency, Remote sensing, Scheduling were identified. The final list is shown in Table V. The keywords in bold letters are the newly added keywords. Stage 0, means that the keyword existed in the original applications keyword list put forward by Jiqiang Niu[11]. Stage 1 refers to the keywords which were suggested by the experts interviewed. Stage 2 refers to the keywords found in IBM's cases of cognitive adoption or in the news; Stage 3 refers to the newly identified keywords in the previous section. The figures in Table V in the right hand column indicate the rate of occurrence of keywords prior to (or during) the 3rd boom, which is the total number of occurrences divided by the number of years.

The analyses of keywords has confirmed that during the 3rd boom, applications such as Optimization, Prediction, Forecasting, Machine learning, Classification, Data mining, Pattern recognition, Deep learning have become high priority applications. Less important applications include Fault diagnosis, Knowledge representation, Expert systems.

3.3 Perspectives on AI Adoption by companies

Interviews were carried out in some companies which were considering adopting AI (IBM's Watson). The interviewee was asked to comment on 1) one's perspectives and expectations on AI and 2) what would be the necessary minimum conditions for adopting AI.

A. The case of a pharmaceutical company

Mr. Otsuka from Takeda pharmaceutical company, who is in charge of the digital unit, considers that until recently AI was still in the academic domain. But he thinks that AI has finally reached the stage it could be used in firms. For a pharmaceutical company, AI could be used in drug development, especially for speeding up the drug development process, by increasing the efficiency of operational processes. In other words, in drug development, AI would not lead to product innovation, but process innovation. Another possible application of AI can be found in a call center, which handles enquiries by customers. At present, operators answer the calls but AI could be used to answer the calls automatically by transferring the knowledge related to FAQ and apply deep learning. Mr. Otsuka did not think that AI can solve all problems. FAQ feature of Watson uses natural language processing so it would be an advantage.

One needs to have evidences and data for discovery and decision making. But for applying AI in FAQ, it should be possible to link the input with the output so he considers that the adoption hurdles would be low. It is important to have high quality data for implementation. Mr Otsuka considers that there should be applications or cases where AI could be applied within a pharmaceutical company but the company has to make effort to search for them. The timing of the successful search and the pricing structure would be important criteria for adopting AI.

On the other hand, for a company selling AI based products, it should clearly present the ROI due to AI adoption, for example by carrying out simulations, using the number of potential users. A company could show how much the service will improve by using AI in

call centres, even though it might not directly lead to increase in sales. Such provision of data is necessary. In this case, AI may be considered to have a positive effect on operational efficiency.

B. The case of a DNA sequencer maker

Thermo Fisher Scientific Inc. is one of the leading makers of DNA sequencer. Dr. Satoshi Murakami, a Field Application Scientist was interviewed. The company is a maker of next generation DNA sequencer which analyzes human genome data. In order to search for genomes which are related to specific illnesses, it would be necessary to analyze a massive amount of genomic data and collaborations with IT companies such as Google, Amazon, and IBM will be needed. AI could be used for the analysis of genomic data. Ideally, AI may lead to tailor made healthcare. For curing cancer, human genome data as well as other data, such as publications, previous cases of medical treatment of cancer, could be used to find the most suitable treatment for a patient but that would require about 600 G data for a single patient.

Deep learning is based on improving the learning algorithm but it works in an environment when a correct solution exists. For the treatment of cancer, the connection between irregularity of DNA and the occurrence of cancer has not been identified so technological challenges still remain. In addition, the genomic data formats by different makers are not standardized, causing somewhat of a problem for inputting it into Watson. Dr Murakami thinks that within 9-10 years AI could be used for the treatment of genome related illnesses such as cancer. There is another issue related to incompatibility of the formats used by different DNA sequencers.

C. Other cases

AI is beginning to be used in companies for many applications such as help desks, call centres, quality control, marketing, product development to improve operational efficiency as well as to look for new market opportunities. AI is also being used in higher educational institutions. At Kanazawa Institute of Technology, AI is used to provide students with better, personally oriented guidance and education based on in-depth analyses of the students' capabilities and motivations.

At Hitachi which has a corporate history of over 100 years, and is involved in a range of businesses in energy, manufacturing, distribution, railways, healthcare, electronics, computers, finance, the company has been actively building capabilities in AI. Hitachi has built capabilities in optimization through AI in the 1st AI boom, and expert systems in the 2nd boom and in recent years, the company has been developing technologies related to deep learning and Neural Network/Machine learning [23]. With cloud computing, social media, and sensing technology, the amount of data a company has to manage has been exploding. For example, in the field of marketing, AI can be used to offer customers products or services that match the customers' preferences or to identify the factors which may trigger changes in the customers' purchasing behavior. [24]

D. Recommendations to firms considering adopting AI

The potential adopters of AI will have to identify the knowledge related to their domains and build a knowledge database. As an example, at a leading automobile maker, AI is used to analyze huge amount of customer feedback and claims data in the form of free form text. According to the IBM website, the company used IBM's Watson's Explorer not only to improve their quality control and operational efficiency but also to classify the different categories of claims and identify the problems effectively. The result was then used as a feedback to other functional units such as those related to components and production units. For such an application of AI, the company had to prepare a comprehensive database of components, standard cases of claims and other related information.

IV CONCLUSIONS AND DISCUSSION

The goal of this paper was to explore the issues related to the adoption of AI by firms in the current 3rd AI boom. For this purpose, the research was carried out in 3 steps, 1) a bibliometric analysis to analyze the performance at the national level 2) analysis of the key technologies and main applications in the 2 periods 3) a qualitative analysis of the kind of applications to emerge in the future and the issues for full scale adoption of AI in firms. We devised a scheme for distinguishing the new applications before and after 2013.

In the 3rd AI boom, through a bibliometric analysis and co-occurrence analysis, we were able to detect the important key technologies of Machine learning and deep learning. The main focus of the companies has been shifting towards AI applications in the 3rd boom, such as Energy efficiency, and Scheduling. Interviews with experts in companies which were planning to adopt AI pointed out the existence of a gap between the needs of the companies and what AI can offer at present. Companies should make effort to search for cases within their companies to find applications where AI can be applied. Companies could start from simple applications where the adoption hurdle is low, such as call centres.

The analysis has shown some keywords which were only retrieved in the 3rd AI boom. Among them were big data and cloud computing. Compared to the previous AI booms, the current AI boom is beginning to have a real impact on companies and society. In a companion paper [25] we have developed a framework to track knowledge convergence in big data and have pointed out that big data will have a significant impact on AI. AI is a technology (or a group of technologies) which could be adopted in a variety of sectors and applications. For an effective adoption of AI, one has to consider all aspects of adoption including a significant amount of effort required by the adopting unit and the impact it will have on the organization's business processes and human resource development. Since companies face resource constraints, companies should strategically plan AI adoption by considering other technologies which will also have to be integrated, such as cloud, or big data.

As the different cases of AI adoption have shown, AI can be used in many applications depending on the purposes. AI has been used in optimizing, in the 1st boom, expert systems in the 2nd boom and in the current 3rd boom, AI has evolved to the stage of using machine

learning and deep learning creating capabilities in sensing, learning, identifying, tracking, forecasting by combining with other technologies such as big data and cloud. It will continue to evolve, having a significant impact on our society.

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