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ANALYSIS OF ARTIFICIAL INTELLIGENCE TECHNOLOGY BASED ON THE REQUIREMENTS OF COLLABORATIVE ROBOTS THROUGH PATENT ANALYSIS

Hong Joo Lee*, Ji Su Kim and Hyun Woo Kim

Department of Industrial and Management Engineering
Kyonggi University
154-42, Gwanggyosan-ro, Yeongtong-gu, Suwon-si, Gyeonggi-do 16227, Korea
*Corresponding author: blue1024@kgu.ac.kr

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Abstract. *Since the manufacturing market has been declining lately, many companies are paying greater attention to more-efficient production methods. The research on collaborative robots based on Artificial Intelligence (AI) technology, in particular, has become diversified as interest in "smart factories" has been receiving greater focus recently. This study analyzed the requirements and technology needed for using collaborative robots at industrial sites. Currently, Korea is one of the major countries in the global patent market along with China, the United States, Japan and Europe. Korea is the fourth largest country with 7.9% of the global patent market. Therefore, considering the amount of patent data that is registered in Korea, the data collection and analysis for this study are meaningful. Thus, we collected data from abstracts of patents based on the AI (G06Y) technology classification table provided by the Korea Intelligent Property Office (KIPO). In addition, we extracted words based on the reference of co-operating robot requirements by referring to KS B 7313 and conducted an analysis through a matrix that matched the requirements of AI technologies and collaborative robots. Furthermore, the statistical analysis program SPSS 24.0 was used to perform factor analysis and regression analysis. As a result, the 11 factors of the collaborative robot were grouped into two mega-factors. We were also able to identify the cause and effect relationships between the two factors. In addition, to improve the productivity and safety of collaborative robots, ergonomic design must be improved, and there are five factors that must be considered for the ergonomic design of collaborative robots. Furthermore, it was found that, in order to influence these five factors, it was necessary to recognize events of situation recognition among AI technologies, to recognize objects and places of visual recognition, to judge the map learning tree, to classify self-study, and to have deep trust network technology of deep learning.*
Keywords: AI, Collaborative robot, Patent information analysis, Matching analysis matrix

1. Introduction.

1.1. Research background.

As the global economy has slowed, international manufacturing is entering a phase that can be characterized as a slump. Also, this slowing down of the global economy has had a huge impact on the Korean manufacturing sector as well, which is heavily dependent on exports. In order to overcome this crisis, Korea and other countries pay attention to the concept of the smart factory.

Currently, with the development of ICT (Information and Communication Technology), the role of the smart factory is increasing with the advent of the fourth Industrial Revolution. The smart factory was designed to collect and analyze information about the entire production processes of manufacturing facilities and resources and to develop automatic production [2].

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In order to operate the smart factory efficiently, it is necessary to collect and analyze manufacturing data, and research on the rational use of collaborative robots should be conducted. Because collaborative robots are an element that helps the effective operation of smart factory, this paper analyzed the requirements and AI technology for collaborative robot development through patent analysis. Also, the paper analyzed the major technologies of AI for developing collaborative robots based on AI technology and how it is used to improve the efficiency and productivity of manufacturing processes using smart plants. To accomplish this, it was necessary to systematically analyze the previous research on this topic. As a result, we collected keywords from 11,052 registered patents for AI from Korea Intellectual Property Rights Information Service (KIPRIS) and analyzed them through text mining using the R-Programming. Through this, we have studied AI technology required for collaborative robot research for productivity improvement of smart factory.

1.2. **Research process.** This paper is organized in the following order. In Section 2, we study the theoretical background on importance of patent analysis and artificial intelligence technology. Section 3 explains the procedures for data analysis and describes methods for data collection and analysis. Section 4 presents the research results and Section 5 presents the conclusions of the research and the significance and limitations of the research.

2. Theoretical Background.

2.1. **The importance of a patent analysis.** A patent is a document containing specific technical and scientific information, and it is known that patents contain more than 90% of the technology information that exists in the world [4]. Analyzing patents is very important because it allows us to understand trends, levels of technology, and the commercial value of the technology [5]. In this regard, researchers analyze technology changes and development patterns through patent analysis and apply them to national technical policies as well as technical analysis and industrial analysis. Gang studied the prediction of promising fusion technologies by calculating the fusion index and promise indexes from patent information [6].

2.2. **AI technology.** First-generation AI involves a simple rule of computing (1950-1960). Second-generation AI involves machine learning that is regular or knowledge under a given algorithm (1980-1990). Third-generation AI is referred to as deep learning (2012), which involves learning input itself and creating and using features [7]. AI has repeatedly stagnated up until the second generation, but now AI has evolved in earnest due to the rapid growth of IT technology and the rapid production of data from the third generation of AI. With the growing industrialization of AI technologies, greater productivity and efficiency are being provided in a wider range of areas than ever before. This third-generation AI is also expected to bring about structural changes in the economy and labor through unmanned and automated operations [2].

3. **Research and Analysis Procedures and Methods.** In this study, we investigated the requirements of collaborative robots first and then investigated the patents of AI in Korea. The research and analysis procedure is shown in Figure 1.

3.1. **Procedure of research analysis.** The Korean Intellectual Property Office gives the G06Y to technologies in the field of AI. In this paper, the patent data were collected through KIPRIS after classifying the AI technologies that could be applied to collaborative robots through G06Y. Furthermore, data were collected only for patents registered before November 2016 because since May 2018, patents have generally been released 18 months after application [5]. Through this, 11,052 registered cases were collected between January

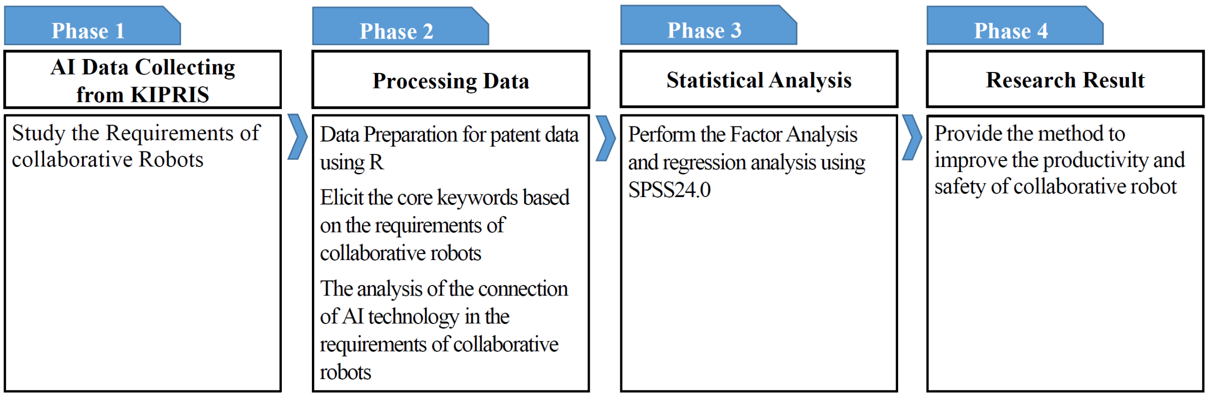

Figure 1. Research process

2012 and November 2016, which represents the start of third-generation AI and the data collection process of the collected patents was analyzed and the data extracted through single text mining. We also extracted words related to safety and productivity, which are requirements of collaborative robots, by referring to KS B 7313 of the Korea Agency for Technology and Standards. In addition, the extracted words were searched in the data frame, and word frequency was analyzed in conjunction with the requirements of collaborative robots and AI technology. The validity of the factor analysis was analyzed using the KMO and Bartlett's test, and the causality between the factors was studied through regression analysis.

3.2. **Measurement tools.** This study was data preparation with the statistical package R and factor analysis and regression with the statistical package SPSS 24.0.

4. Research Results.

4.1. **The requirements of collaborative robots and the analysis of AI technologies.** This study analyzed the requirements of collaborative robots at production sites through KS B 7313. In other words, the core keywords for the requirements of a collaborative robot were analyzed in Table 1.

In addition, based on the data collected by KIPRIS, the results of a collaborative robot's requirements and AI were analyzed by organizing the frequency as shown in Table 2. The horizontal axis number is the number of the vertical axis of Table 1 (the requirements of the production site).

4.2. **Factor analysis.** This study presents results such as those shown in Table 3 through factor analysis based on the results from Table 2. In other words, Table 3 analyzes the requirements for the development of technology-based collaborative robots according to two factors: productivity increases and ergonomic design. According to Table 1 and Table 3, issues of increased productivity require devices with process improvements (detail factor: Process + Improvement + Process + Time + Efficiency + Services) and emergency shutdown functions (detail factor: Motion permit + Emergency stop), reduced defect rate (detail factor: Yield + Defect), improved quality (detail factor: Quality + Process plan + Improvement), and shorter delivery dates (detail factor: Management + Shortening). In addition, issues of ergonomic design require the ability to automatically detect, warn, and stop by itself in unusual situation (detail factor: Warning + Sense + Detector + Stop), control of speed depending on the user's position (detail factor: Action + Position + Speed + Acceleration + Deceleration + Deceleration control + Detection + Monitoring), should be no danger when switching modes (detail factor: Transition + Risk), should have protection stop function and safety function (detail factor: Protection + Stop +

TABLE 1. Deriving keywords according to the requirements of collaborative robots at production sites

No.	Requirement	Keywords
1	Collaborative robots should have protective shutdown and safety features.	Protection, Stop, Safety
2	A device with emergency stop function is required.	A motion permit, Emergency stop
3	There should be no danger when switching modes.	Transition, Risk
4	Speed control is required depending on the user's position in the manufacturing process.	Actions, Position, Speed, Acceleration, Deceleration, Deceleration control, Detection, Monitoring
5	Contact with users should be limited.	Contact, Area, Limit
6	A feature that can automatically detect, warn, and stop by itself in unusual situations is required.	Warning, Sense, Detector, Stop
7	Increase productivity	Labor, Production, Growth, Productivity
8	A reduction in due date	Management, Shortening
9	Process Improvement	Process, Improvement, Process, Time, Efficiency, Service
10	Quality Improvement	Quality, Process planning, Improvement
11	Defect Rate Reduction	Yield, Defect

Safety), and should limit areas of contact with users (detail factor: Contact + Area + Limit).

This study also assessed the appropriateness of the correlation matrix through a review of the appropriateness of the sample through KMO (Kaiser-Meyer-Olkin) and Bartlett's test of sphericity to determine the suitability of factor analysis. The closer the value of the KMO is to 1, the better the correlation of the sample to apply to factor analysis is. If one is 0.9 or more, it is excellent; 0.8 is good, 0.6 or 0.7 is normal, and 0.5 or less is poor [8]. The KMO value in this study was 0.670 and therefore normal, and Bartlett's spherical form validation was 513.818, df = 55, $p < 0.05$, which makes it appropriate for the analysis of the factors. This study used a commonness value to remove the inadequate variables. Song recommended removing questions if the commonality was less than 0.4 [9]. In this study, we analyzed the results of the rotational component matrix for each factor through the Varimax rotation and derived factors with a result of 0.6 or more. All procedures for validation were performed using the SPSS 24.0 statistical package.

4.3. **Reliability.** Cronbach's α coefficients were analyzed to verify the reliability of the factors [10]. Table 3 shows that Cronbach's α coefficient of productivity improvement is more than 0.6. In addition, the coefficient of ergonomic design is 0.8 or more, which indicates that it has high reliability.

4.4. **Causal relationship between factors.** This study demonstrates regression by selecting ergonomic design as an independent variable and productivity improvement as a dependent variable based on factors derived from factor analysis and summarizes the relationship in Table 4.

Table 2. Analysis of the requirements of collaborative robots and the linkage between AI technologies

	1	2	3	4	5	6	7	8	9	10	11
Judgment tree	495	11	319	1206	901	57	103	539	2367	697	177
Random forest	10	1	2	21	21	2	2	8	14	7	0
k-nearest neighbors algorithm	2	0	0	23	50	0	6	5	31	10	3
Naive Bayesian	13	0	33	127	52	3	1	60	139	53	2
Linear logistics regression	77	0	87	299	216	20	65	84	386	120	19
Support vector machine	38	2	57	203	172	8	3	100	168	67	72
Clustering based on partition	66	16	53	538	421	55	58	209	795	178	35
Hierarchical clustering	360	100	261	1499	1426	69	33	1091	4272	743	125
Markov decision process	2	2	9	72	14	1	18	11	68	20	7
Slope descent algorithm	13	0	6	54	31	9	2	4	29	7	2
Error reverse wave algorithm	6	0	3	124	52	1	2	15	120	24	10
Deep learning	10	0	29	55	11	5	1	17	37	4	13
Object recognition	243	0	239	2306	1496	437	34	244	700	227	18
Action recognition	74	0	100	868	503	108	6	253	689	134	1
Place recognition	423	0	208	2069	1071	296	55	611	1490	294	47
Event, accident recognition	684	2	350	2039	707	618	32	417	728	247	24
Instructive study	28	0	59	389	215	54	2	103	240	41	0
Unsupervised study	19	0	24	166	76	20	3	56	137	28	0
Intensive study	37	0	17	266	111	23	16	55	288	54	10
Automatic cumulative noise rejection	45	0	12	453	144	34	23	30	245	59	10
Convolution nerve network	13	0	6	40	21	6	5	19	78	5	14
A circular neural network	7	0	6	43	50	2	6	28	46	23	1
Deep trust network	691	84	242	583	1289	119	49	1331	3537	714	172

The analysis above shows that the ergonomic design of collaborative robots affects productivity improvements. Table 5 presents the technical requirements for ergonomic design, based on the results of the analysis of the collaborative robots and AI according to Tables 2 and 3.

As a result of the analysis, the features most closely matched with the detailed variables of ergonomic design in AI technology are event recognition, object recognition, and location recognition of visual recognition, hierarchical clustering of autonomous learning, and the deep trust network of deep learning. Therefore, we could have known that productivity can be improved by matching the problem of design based on ergonomics with improvement using the above techniques.

TABLE 3. Factor analysis

Factor	Detailed factor	Factor analysis			Reliability
		Factor loading	Commonness	Characteristic values	Cronbach's α
Productivity increases	Process + Improvement + Process + Time + Efficiency + Services	0.948	0.972	5.656	0.664
	Motion permit + Emergency stop	0.916	0.84		
	Yield + Defect	0.915	0.872		
	Quality + Process plan + Improvement	0.914	0.982		
	Management + Shortening	0.893	0.933		
Ergonomic design	Warning + Sense + Detector + Stop	0.966	0.937	4.038	0.826
	Action + Position + Speed + Acceleration + Deceleration + Deceleration control + Detection + Monitoring	0.936	0.929		
	Transition + Risk	0.807	0.956		
	Protection + Stop + Safety	0.709	0.88		
	Contact + Area + Limit	0.687	0.889		

TABLE 4. Regression between factors

	Nonstandard factor		Standardization factor	p-value
	B	Standardization error	Beta	
Constant value	155.800	363.919		0.673
Ergonomic design	0.770	0.179	0.684	0.000

5. **Conclusions and Further Research.** This study examined 11 requirements and 23 AI technologies by analyzing Korea's AI field (G06Y) and the requirements of collaborative robots. Based on this, two factors were analyzed for productivity improvement and ergonomic design through factor analysis. We also studied the causal relationship between these factors through regression analysis. As a result, we were able to analyze the importance of the ergonomic design factors of collaborative robots in order to improve productivity; in addition, the detailed AI technologies needed to develop ergonomic robots were analyzed. The significance of this study is that, while not many patents have been used in the field of AI technology for collaborative robots, one of the early studies has focused on matching the requirements of collaborative robots and AI technologies and exploring ways to solve requirements using AI technologies. However, there are two limitations of this study. One is that it is difficult to eliminate noise from the data during text mining and the other is that of the researchers' subjectivity in regard to the extraction of keywords from the requirements of productivity and safety.

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Table 5. Analysis of AI technologies based on the requirements of collaborative robots

Requirement	Keywords	Technology with high frequency of analysis		
		1	2	3
A feature that can automatically detect, warn, and stop by itself in unusual situations is required.	Warning + Detection + Detector + Stop	Event, Accident recognition	Object recognition	Place recognition
Speed control is required depending on the user's location.	Action + Position + Speed + Acceleration + Deceleration + Deceleration control + Detection + Monitoring	Object recognition	Place recognition	Event, Accident recognition
There should be no danger when switching modes.	Transition + Risk	Event, Accident recognition	Judgment tree	Deep trust network
Collaborative robots should have protective shutdown and safety features.	Protection + Stop + Safety	Deep trust network	Event, Accident recognition	Judgement tree
Contact with users should be limited.	Contact + Area + Limitation	Object recognition	Hierarchical clustering	Deep trust network

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