A Study on the Development of Medical Robotics Technology Commercialization Model

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***Abstract*—The robot industry is a key field of the Fourth Industrial Revolution. Among them, the interest in medical robotics is increasing due to aging and changes in living patterns. In the medical robotics market, a small number of companies dominate the market, causing problems such as increased costs. To prevent such problems, various companies need to enter the market. In order for new entrants to secure technology efficiently, technology commercialization such as technology transfer is necessary. However, in the field of medical robotics, few companies have major skills and perform most of the technology transfer. In this paper, we propose a model for providing technology commercialization information to new entrants. The experimental data uses patents related to vascular surgery robots registered in the USPTO. As a result of the experiment, high applicants have advanced into various countries in order to secure market power, and have a technique for analyzing the internal image of the body mainly through endoscopy.**

***Index Terms*—robot industry, medical robotics, technology commercialization, data mining**

I. Introduction

After the Fourth Industrial Revolution was announced at the Davos Forum, the world is rapidly changing due to ICT convergence. Among them, the robot industry is a key field of the Fourth Industrial Revolution. The robot industry is growing rapidly due to aging and changes in the manufacturing industry. Therefore, the robot industry will be an important factor to improve national competitiveness in the future. For this reason, it is necessary to establish a R&D strategy to improve the competitiveness of the country or enterprise by analyzing the robot industry.

Robots are largely divided into industrial and service. Industrial robots are fixed or moving devices that are used for industrial automation and are controlled automatically [1]. In addition, service robots provide useful services to human beings, except those used in manufacturing [2].

Medical Robotics is used to provide safe and convenient medical services to humans, and belongs to the field of service robots [3]. In the world, interest in the medical field is increasing due to the increase in the aged population and the changing living patterns. People want to get quality medical care, and they expect robots to make it happen. Medical Robotics is a convergence of robot technology in the medical field to provide safe and convenient medical services.

The medical robotics market is growing and a small number of companies own most of the technology. This situation causes various problems such as 'increase in cost'. To prevent such problems, various companies need to enter the market. However, the field of medical robotics has a high technical barrier.

To enter the market, new companies need to secure technology through R&D activities. However, the company's own R&D activities are expensive and time consuming. To solve this problem, there is a need for technology commercialization to transfer the developed technology. The technology commercialization has various advantages such as diffusion of research results and R&D cost reduction. However, the technology commercialization often fails in the face of intense market competition. Various analyzes have been conducted to reduce the failure of technology commercialization. The technology commercialization is mainly performed qualitatively by some experts. Qualitative methods have the problem that different results are produced according to expert opinion. Recently, a quantitative technology commercialization method applying various machine learning has been proposed. Quantitative methods mainly use the text and indicators of the patent.

In the field of Medical Robotics, few companies have most of the technology and perform many technology transfers. Therefore, it is necessary to understand the technology commercialization characteristics of such a few companies. The identified characteristics can be used as technology commercialization information for new entrants. In this paper, applicants in the field of Medical Robotics are identified and classified by rank. Next, decision trees are used to determine if applicant rank affects technology transfer. Finally, the characteristics of the high applicants group are analyzed and presented. The experimental data uses medical robotics patents related to Vascular surgery registered in the United States Patent and Trademark Office (USPTO).

Manuscript received July 14, 2020; revised January 21, 2021.

doi: 10.12720/jait.12.2.148-152

II. BACKGROUND

A. Medical Robotics

Medical Robotics is largely classified into surgical robot and non-surgical robot. The surgical robot works all or part of the surgical procedure on behalf of the doctor. Non-surgical robots make up the rest of the field except the surgical robot field [4]. Surgical robot is composed of two technologies, Intelligent eye and Intelligent hand. The intelligent eye provides an image of the target lesion for surgery. Intelligent hand includes instruments to increase surgical accuracy [5]. Recently, it is being combined with precise robot operation technology and 3D medical image navigation technology. The field of non-surgical robots involves a relatively large number of technologies. Non-surgical robots mainly include Surgery Simulator, Rehabilitation, and Navigation.

As the medical robotics market has a high barrier to entry, some companies are monopolizing. The monopoly phenomenon causes various problems such as increasing costs through market monopoly and deterioration of technology. Therefore, in order to allow new companies to enter the market, an efficient analysis method capable of sufficiently grasping information on technology is needed. In this paper, the patents related to medical robotics are used to identify the influence of the top applicants in the technical field. In addition, the characteristics of the upper and lower applicants are compared. The proposed model can be used as technology commercialization information for new entrants in the future.

B. Technology Commercialization

Technology commercialization is a process in which the results obtained through R&D are successfully launched and sold on the market [6]-[8]. As global technology competition intensifies, investments in R & D for the predominance of competitive advantage are active. However, unlike R&D costs, which are increasing every year, the ratio leading to technology commercialization is not high [9]. Because technology commercialization is carried out through a complicated process. In addition, even if the technology is successful in commercialization, it is often the case that it is lost in market competition.

Various studies have been conducted for successful technology commercialization. Previous studies related to technology commercialization are divided according to the use of qualitative and quantitative methods. The qualitative method mainly used Delphi technique [10]-[11]. Amadi-Echendu and Rasetlola analyzed the factors and framework of technology commercialization using Delphi technique. Cho and Lee analyzed the factors for commercializing new technologies using Delphi techniques and Fuzzy AHP. Qualitative methods are time consuming and expensive. In addition, there is a possibility that results may differ depending on the analyst. Unlike those using qualitative methods, studies using quantitative methods applied statistical and machine learning techniques to the data [12], [13]. Choi *et al*. developed a technology transfer prediction model using Social Network Analysis (SNA), Regression, and Decision Tree on patent data. Lee *et al*. Proposed a model for predicting sustainable technology transfer using Topic modeling and Ensemble. In this paper, the applicants' ranks are derived and combined with the patent quantitative indicators to build a technology commercialization analysis model. In addition, the characteristics of high applicants are derived and analyzed.

III. EXPERIMENTAL DATA

The following patent data are used to test the model proposed in this paper. The patent data was registered with the USPTO for vascular surgery robot technology, totaling 109. Vascular surgery is a technology belonging to the field of surgical robot among medical robots. Table I below is a search formula for the patent collection. Collect the data from the patent database WIPS using the corresponding search formula. The search formula is prepared by extracting keywords from related studies and expanding synonyms and similar words.

TABLE I. VASCULAR SURGERY ROBOT PATENT SEARCH FORMULA

Patent search formula
((robot* or humanoid* or man-maid*) and (surg* or medic* or health* or care or cure or therapy) and (blood adj vessel) or vein or intravascular or capillar* or endoscop* or angioscop*))

IV. PROPOSED MODEL AND EXPERIMENTAL

In this paper, we propose a model to assist in the commercialization of new entrants in the field of medical robotics technology. The proposed model reflects rank information and quantitative indicators of the patent applicants. In addition, the characteristics of high applicants are derived and analyzed. Fig. 1 below shows the proposed model.

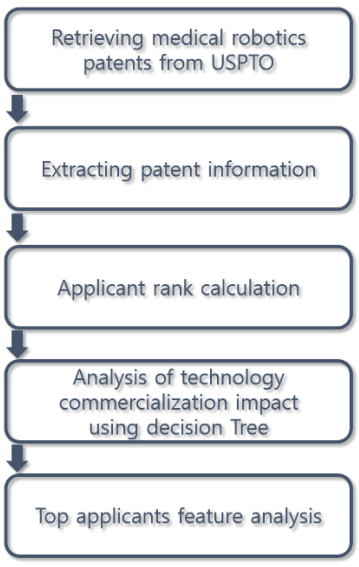

Figure 1. Proposed model.

As shown in Fig. 1, first collect the medical robotics-related patents. Applicant and quantitative indicator information is extracted from the collected patent data. Next, an applicant rank is calculated in the order which applied many patents. Since a patent refers to a developed technology, the more patents applied, the higher the competitiveness in the field. The applicant's rank and the quantitative index are calculated as input variables, and the output variables are determined as technology transfer. Finally, the characteristics of the top applicants are analyzed to help commercialize medical robot technology. To do this, use Decision Tree, which can provide explanations for data classification.

Table II below is given the rank with the top applicants extracted from the collected vascular surgery robot patent data. A total of 35 applicants were derived, of which the highest number of patents were filed in Intuitive Surgical, a total of 33 patents. As in Table II, a total of 8 ranks are assigned for each number of patent applications. Applicants with the same number of applications have the same rank.

TABLE II. VASCULAR SURGERY ROBOT APPLICANTS RANK

Applicants	Number of application	RANK
Intuitive surgical	33	A
Auris surgical robotics	9	B
Hansen medical	9	
Ethicon	6	C
Atricure	5	D
Auris Health	4	E
Siemens	4	
Karl storz gmbh	3	F
Modular surgical	3	
Veebot systems	3	
Avateramedical gmbh	2	G
Boston scientific scimed	2	
Columbia university	2	
National cancer center	2	
Samsung electronics	2	
others	20	H

Table III below shows the quantitative indicators of patents applied to decision trees. A total of 7 quantitative indicators are used as input variables with the applicant rank. Residual.time indicates the remaining right date, so it is possible to measure the value of the patent. Backward_citation and Forward_citation can measure the influence of technology. Claims indicate the scope of patent rights. Inventors represent patent fidelity and development sustainability. Family and Family_nation have applied for the same patent in various countries, indicating marketability.

TABLE III. PATENT QUANTITATIVE INDEX

Index	Explanation
Residual.time	Number of days left to retain rights
Backward_citaions	Number cited prior art
Forward_citations	Numbers cited by other patents
Claims	Number of claims
Inventors	Number of Inventors
Family	Number of family patents
Family_nation	Number of family patent countries

Fig. 2 below shows the technology transfer prediction model constructed by inputting applicant rank and patent quantitative index. In Fig. 2, the lower rank of the applicant, the worse the technology transfer was derived. Therefore, there is a need to analyze the characteristics of high rank applicants.

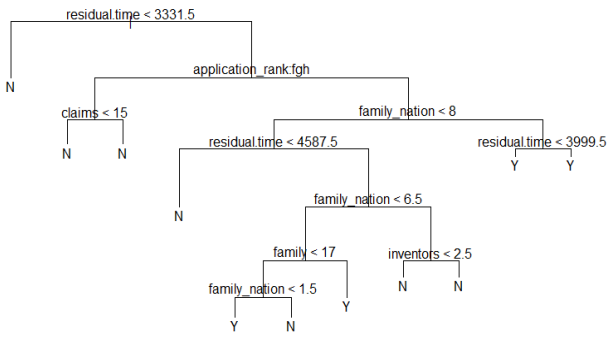

Figure 2. Technology commercialization model.

Table IV below compares the average value of patent quantitative indicators of the ranks of the upper and lower applicants. In most indicators, applicants with higher ranks had higher values. In particular, the largest difference in the number of family patent applications was derived. This means that companies leading medical robotics technology also have high market power. Therefore, new entrants will need to advance their technologies to various markets.

TABLE IV. PATENT QUANTITATIVE INDEX FEATURE COMPARISON

Quantitative index	High rank group	Low rank group
Residual.time	5273	5611
Backward_citaions	317	41

Quantitative index	High rank group	Low rank group
Forward_citations	61	23
Claims	18	15
Inventors	3	2
Family	109	7
Family_nation	6	3

Fig. 3 below is a Word cloud analysis of the abstracts of patents filed by the high rank group. For this, Textmining technique is applied to the abstract of the patent to pre-process it. Also, stopwords that reduce the efficiency of the analysis are removed. Through this, high applicants have a technique for analyzing the internal body image mainly through endoscopy. Therefore, new entrants should try to avoid R & D and commercialization by avoiding the technology.

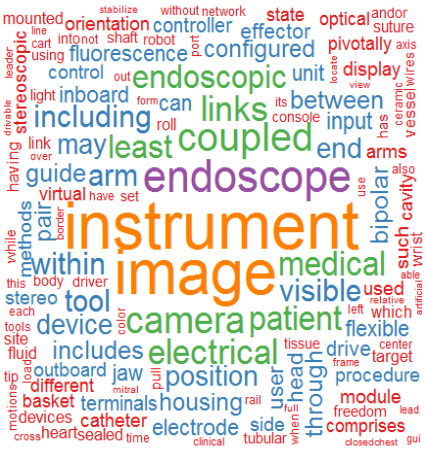

Figure 3. Word cloud analysis of high rank group.

Developing a patent that can complement the image analysis technology through an endoscope can also be an important strategy. This can help the technology of the top-ranked applicants, and new entry into the market is possible.

V. Conclusion and Future Works

In this paper, applicant's rank was derived and characteristics were analyzed for successful commercialization of medical robotics. For this purpose, a decision tree model was applied to patent data related to vascular surgery robots registered in the USPTO. As a result of the experiment, it was confirmed that the applicant rank influences the technology commercialization. In addition, high rank groups apply family applications to various countries to secure high market power. They mainly possessed techniques related to the analysis of internal body images through endoscopy. Therefore, new entrants should go ahead with R & D and commercialization by avoiding the technology, and need to actively apply for family patent. In addition, it is considered that new entry is possible by developing a patent that can assist with the technology. In future studies, it is necessary to construct a technology commercialization prediction model including various machine learning techniques and text information. For this, it is necessary to apply a Textmining technique that can reflect technical information. In addition, it is necessary to review the application to various classification algorithms such as deep learning and ensemble.

Conflict of Interest

The authors declare no conflict of interest.

Author Contributions

Youngho Kim, Junseok Lee, Jiho Kang, and Sangsung Park conceived and designed the experiments; Dongsik Jang, Junseok Lee analyzed the data to show the validity of this study; Youngho Kim wrote the paper and performed the entire research step. In addition, all authors have cooperated with each other in revising the paper.

Acknowledgment

This research was supported by the MOTIE (Ministry of Trade, Industry, and Energy) in Korea, under the Fostering Global Talents for Innovative Growth Program (P0008749) supervised by the Korea Institute for Advancement of Technology (KIAT).

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