Patent Trend of Unmanned and Automated Agricultural Production
- Open Field Operation -

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Abstract This study was conducted to determine the major patent and analyze the patent trend of unmanned and automated agricultural production for the open field operation. As a result of conducting a search for patent applications related to these technologies, 1,080 valid patents were selected by evaluating the relevance of the patents and removing noise patents. As a result of the country-based analysis using the selected valid patents, it was found out that the largest number of patent applications were filed in the United States with 541 cases, followed by Japan with 326 cases, the European Union with 128 cases, and Korea with 85 cases. Upon classifying the valid patents into core technology, the path generation and tracking technology accounts for 33% with 353 cases; the implementing control with environmental condition technology accounts for 22% with 236 cases; the robot design technology accounts for 21% with 228 cases; the plant and environment sensing technology accounts for 19%

with 206 cases; the yield and quality monitoring technology accounts for 5% with 58 cases. Finally, 10 core patents were selected by performing a patent index evaluation. The United States registered all of the 10 core patents. The results showed that Korea falls behind in the open field-related unmanned and automated agricultural production, compared to other developed agricultural countries.

Keywords Patent, Unmanned, Automated, Agricultural Production, Open Field

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1 Introduction

The food shortage period comes because the grain average production could not meet the consumption amount such as the lack of 7 million tons of agricultural production in the standard of the year 2000 all over the world, and this situation has become more serious due to the production slowdown etc. caused by the climatic damage after the year 2006 (Park et al., 2011). Additionally, the production shortage increased the international grain prices along with the world grain stocks plunge. According to the long term predictions of OECD and FAO, for the next 10 years the agricultural production growth rate will stop at 1.7%, which is lower than 2.6% of that of the past 10 years, and it is predicted that the international grain prices will increase more than 20% comparing to the past 10 years. Because Korea is the fourth largest grain-importing country in the world and depends on more than 80% of the grain import from small numbers of grain-exporting countries such as the U.S., France, Argentina, Australia, Canada, Brazil, etc., it is necessary to prepare the plan against the price instability caused by the grain price plunge in case of a world grain supply shortage as well as the food mineralization situation.

The Korean agriculture has continuous problems such as business condition deterioration, aging, etc., with the worldwide grain shortage situation. The arable land area in Korea decreased by about 8.4% from 1.888 million ha

in 2000 to 1.730 million ha in 2012, and the agriculture portion in GDP decreased from 4.2% in 2000 to 2.3% in 2012. In case of a farm household debt, it increased by 35% for the last 10 years, and the farm household income ratio comparing to the urban household income decreased from 80.6% in 2000 to 57.6% in 2012.

In addition, the aging speed among the OECD countries is the fastest due to the world's lowest birth rate level; therefore, the 4.5 of the total birth rate of Korea in 1970 rapidly dropped to 1.23 as of 2010 (Park et al., 2014). Recently, the elderly population ratio of more than 65 years old in the total population increased from 3.1% in 1970 to 11.3% in 2010; it was the worst problem (4.9% in 1970 to 31.8% in 2010) in the agricultural area. Korea is going to enter the super-aged society, from more than 14% of aged population in 2018 to more than 20% of aged population in 2026, and by the gradual increase of the more than 65 years old farm household population ratio, the aging in the rural society is expected to become extreme by reaching to 43.5% in 2022.

Therefore, to solve the business condition deterioration, aging problem, etc., it is necessary to break the existing agricultural production way, to make a breakthrough in agriculture such as the cost down, minimizing the environmental contamination, value added provision, etc., by using advanced technology such as ICT, etc., and to maintain the productivity efficiently through the unmanned and automated agricultural production system. Because the unmanned and automated technique for the agricultural production has a high marketability through high efficiency, the world-leading companies are developing and selling the related products. As being related products, the leading companies of North America and Europe such as John Deere, AGCO, etc., sell a navigation and automatic steering system which allows the drive path tracking with the degree of precision of the 5cm level by installing the RTK-level of high-precision GPS and controller which is additionally manufactured; related to the automatic harvest, the Carnegie Mellon University in the U.S. developed the harvest system which recognizes the clippings and non-clippings of the crops automatically by installing DGPS, inertial navigation system, and camera into the Holland combine. Additionally, at the same time, there is a research case about the technology controlling the driving by sensing the obstacle using a camera.

The purpose of this study is to provide the basic data for the gradual strategy establishment of the source technology development related to the domestic agriculture unmanned and automated system by investigating and analyzing the main patent trend of the world's major countries in a open field area primarily for the unmanned and automated technology application.

2 Analysis method

For the unmanned and automated patent analysis about a open field, the search formula was made by selecting the main keywords, and the core patents were selected by using the patent analysis index after analyzing the patent trend of each country and each technology. The Figure 1 showed schematic diagram of the patent analysis process.
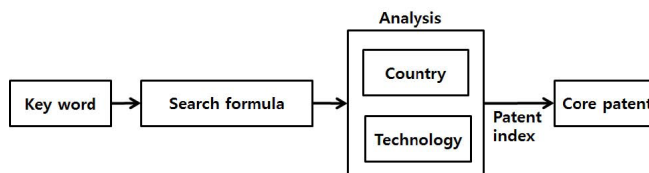

Fig. 1 Schematic diagram of the patent analysis process.

2.1 Patent search

The search formula was made by targeting the core keywords related to the unmanned and automated production system for a open field area shown in Table1. The patent search was conducted by applying the web services including the patent information search service (www.kipris.or.kr) and wipson (www.wipson.com) and searching the patents of Korea as well as the major countries of the world including the US, Japan, and the European Union for the search period from 1973 to June, 2014.

Table 1 Patent search formula using key word of unmanned and automated agricultural production

agricultur* orrice* oropenorfarm* orplantorcrop* orupl andordryland)and(((((soiladjanaly*)or(soiladjmesur*) or(soiladjrecogni*)or(soiladj percept*) or (soil adj environment) or (soil adj condition) or (soil adj status) or (soil adj sensor) or (soil adj strength) or (soil adj water) or (soil adj organic) or (soil adj nutrient) or (plant adj recogni*) or (plant adj percept*) or (plant adj analy*) or (plant adj growth) or (plant adj information) or (plant adj detect*) or (plant adj status) or (tree adj detect*) or (environment adj analy*) or (environment adj measur*) or (environment adj recogni*) or (environment adj percept*) or (disease adj detect*) or (disease adj sensing) or (disease adj monitor*) or ((harvest or ingather*) adj3 monitor*) or (detect near10 (growth adj status))) and (unman* or manless or automation or automated))) or (((course or path*) near10 (creat* or generat* or form* or search* or track* or explor* or investigat* or observat* or seek* or trace* or plan* or follow*))) or ((((autonomous or intelligence) adj5 (control or system)) or navigat* or landmark or GPS) and (vehicle* or (harvesting adj machine) or combine* or planter or cultivator or harvester or seeder or tractor or (planting adj machine) or transplanter))

2.2 Analysis method

The searched patents were analyzed in three methods depending on the country, core technology, and country-core technology. In the patent analysis depending on each country, the patent registration status was selected by classifying into four countries including Korea, the U.S., Japan, and the European Union by targeting the overall patents searched. In the core technology patent trend, after grouping all of the patents based on its similarity of the technology, the core technology that represents the technology of each group was selected, and its trend was analyzed; at the same time, by performing the country-core technology patent analysis, the registration status and the trend of the core patents were analyzed depending on each major country.

2.3 Core patent selection

To select the core technology related to the unmanned and automated agricultural production for a paddyopen field, the core patent was selected. As a selection method, by considering the research development entry possibility, pre-market development possibility, technology protection possibility, etc. about the overall patents searched, the three indexes including Cites Per Patent (CPP), Patent Impact Index (PII), and Patent Family Size (PFS) were calculated, and the highest index was selected as a core patent by normalizing and adding them up.

2.3.1 Cites Per Patent (CPP)

Equation 1 is Cites Per Patent, the index to analyze the US registration of a patent. Cites Per Patent presents the number of citations quoted by the other patents with different registration patents; as this value increases, it means that there is a high possibility to possess a high quality patent.

$$CPP = \frac{\text{Citation number of the registered patent}}{\text{Number of the registered patent}} \quad \text{......... ....(1)}$$

2.3.2 Patent Impact Index (PII)

The Patent Impact Index is calculated by using the Cites Per Patent in Equation 2; it is an index to relatively evaluate the patent quality level possessed by a certain country or company like the Cites Per Patent. The technology level of the target for analysis is measured by comparing the average technology level; if the score of the Patent Impact Index is one, the quality level is on the average level, and if it is more than 1, it means that the quality level is higher than the average level.

$$PII = \frac{\text{Cites Per Patent of the target object for the analysis}}{\text{Total Cites Per Patent}} \quad \text{..............(2)}$$

2.3.3 Patent Family Size (PFS)

The Patent Family Size is the index to find the research development area targeting the global market using the patent family shown in Equation 3. Here, the patent family presents a patent applied in each country about a technology; when the number of patent families is high, it can be judged that the marketability through the patent will be high.

$$PFS = \frac{\text{Relevant applicant (Owner) of average patent family number}}{\text{Overall average patent family number}} \quad \text{..............(3)}$$

3 Result and discussion

3.1 Patent analysis result

3.1.1 Trend depending on each country

The total of 1,080 patents were searched after searching for the patents related to the unmanned and automated technology for a paddyopen field based on the patent data opened until June, 2014.

As a result of the analysis depending on each country, the U.S. possessed the most patents with 541 cases compared to Korea with 85 cases, Japan with 326 cases, and the European Union with 128 shown in Figure 2. The patent-possessing status in Korea was the fourth following Japan and the European Union, and was also the lowest. Particularly, because the possessing status of Korea is 20% less than that of the U.S., it is urgent to secure the unmanned and automated technology for a paddyopen field.

The result of the patent trend analysis about the unmanned and automated technology for a paddyopen field depending on each country and each year began to increase mostly after the year of 1973 as shown in Figure 3, and increased rapidly around the year of 1998. As a result of the analysis depending on each country, in case of Korea, it has gradually increased starting from the year 1998 to now; particularly, the registration increase became distinct after the year 2008. In case of the US, it was investigated that the registration has gradually increased from the late 1990s to now; as similar to the U.S., in case of Japan, it was known that the registration has increased after the 1990s continuously. On the other hand, in case of the European Union, it was shown that there were no registration increases after the mid 1990s but it was maintained within a similar range.
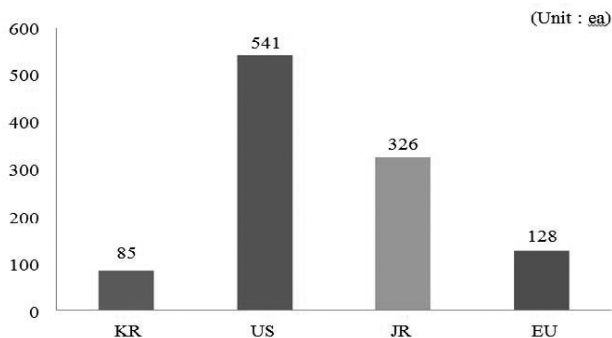
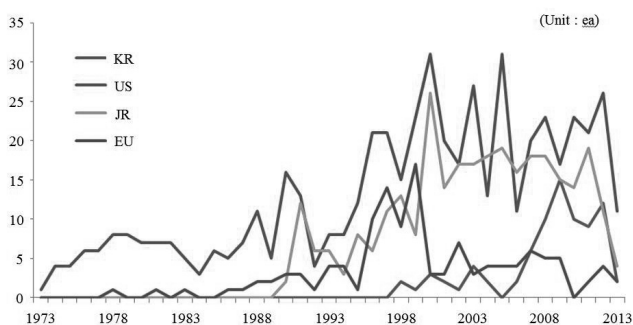**Fig. 2** The number of patent registration for major countries.

Fig. 3 Trend of the patent registration for major countries.

3.1.2 Trend depending on each core technology

In the analysis result depending on the similar technologies about the 1,080 patent cases searched related to the unmanned and automated technology for a paddyopen field area, it was possible to classify into the five core technologies shown in Figure 4. The patent depending on each core technology has a higher share in the order of the 353 cases of the path generation and tracking technology (33%), 236 cases of the operation machine control technology through the environmental recognition (22%), 228 cases of the robotic agricultural operation system design technology (21%), 206 cases of the crop and environment sensing technology (19%), and 57 cases of the yield and quality monitoring technology (5%). Particularly,
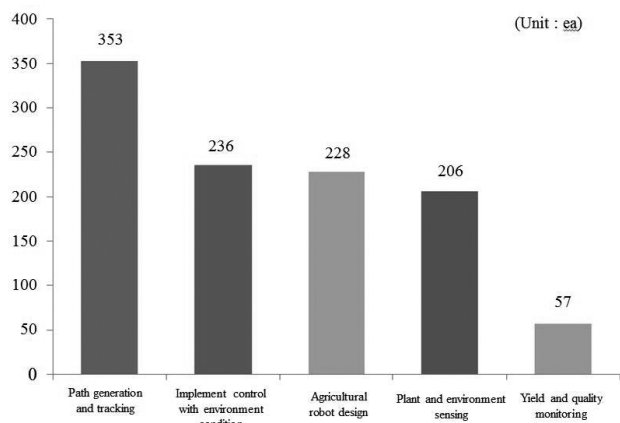

Fig. 4 The number of patent registration for major technologies.

the yield and quality monitoring technology had an overall of 5% of the share, and its technology development progress was lower than the other four technologies.

3.1.3 Trend depending on each country-core technology

As a result of analyzing the unmanned and automated technology for a paddyopen field area depending on the countries and core technologies, the U.S. showed the most active patent registration in all of the areas as shown in Figure 5 followed by Japan, the Europe Union, and Korea in order.

The Korean patent showed relatively very low patent activities compared to the other countries with 28 cases of the path generation and tracking technology (33%), 18 cases of the operation machine control technology through the environmental recognition (21%), 15 cases of the robotic agricultural operation system design technology (18%), and 7 cases of the yield and quality monitoring technology (8%).

The U.S. registered a total of 541 cases of all of the major technologies which were registered by showing the distribution of 178 cases of the path generation and tracking technology (33%), 134 cases of the operation machine control technology through the environmental recognition (25%), 106 cases of the robotic agricultural operation system design technology (20%), 93 cases of the crop and environment sensing technology (17%), and 30 cases of the yield and quality monitoring technology (5%). The major technology registration of the U.S. was the highest ratio in the path generation and tracking technology, and the operation machine control technology through the environmental recognition and robotic agricultural operation system design technology are next. Meanwhile, the yield and quality monitoring technology was observed as the relatively lowest number of registration by recording the overall of 5% of the share.

In case of Japan, among the 326 cases registered, the distribution ratio was shown as follows: 113 cases of the path generation and tracking technology (35%), 62 cases of the operation machine control technology through the environmental recognition (19%), 97 cases of the robotic agricultural operation system design technology (30%), 41 cases of the crop and environment sensing technology (12%), and 13 cases of the yield and quality monitoring technology (4%). The portion of the registration about the path generation and tracking technology was the highest, the robotic agricultural operation system design technology and the operation machine control technology through the environmental recognition were next; therefore, in case of Japan, it was known that the investment about the robotic technology was higher than that of the U.S. or Korea. Meanwhile, the portion of the production amount and quality monitoring technology was recorded as a total of 4% of the share that is similar to the US, European Union, and

Korea, and it was investigated that the investment about the technology was relatively insufficient.

As a result of checking the registration distribution depending on each major technology area about 128 cases registered in the European Union, the distribution was as follows: 48 cases of the path generation and tracking technology (37%), 28 cases of the operation machine control technology through the environmental recognition (22%), 16 cases of the robotic agricultural operation system design technology (13%), 29 cases of the crop and environment sensing technology (23%), and 7 case of the yield and quality monitoring technology (5%); it was shown that the highest portion of the registration was the path generation and tracking technology like the other countries. Next, the registrations were high in order of the crop and environment sensing technology, operation machine control technology through the environmental recognition, and robotic agricultural operation system design technology; it was verified that the crop and environment sensing technology area took a high portion unlike the U.S. and Japan. On the other hand, the yield and quality monitoring technology showed an overall of 5% of the share similar to the U.S., Japan, and Korea, and it was observed that the investment about the technology was relatively inadequate.
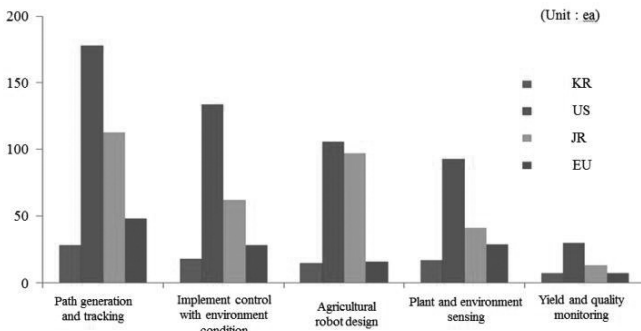
Fig. 5 The number of patent registration for major countries and technologies.

3.2 Core patent selection

For the core patent selection, the priority was decided after applying the weight to the patent indexes of the impact index, patent family size, etc., targeting the searched unmanned and automated technology for 1,080 paddyopen field area case patents. As a result of deciding the priority about all of the patents, the top 10% (100 cases) were 45 cases in the U.S., 30 cases in Japan, 23 cases in the European Union, and 2 cases in Korea. Particularly, all of the top 1% (10 cases) patents were possessed by the U.S. as shown in Table 2 so that it was shown that the domestic core patents should be urgently obtained.
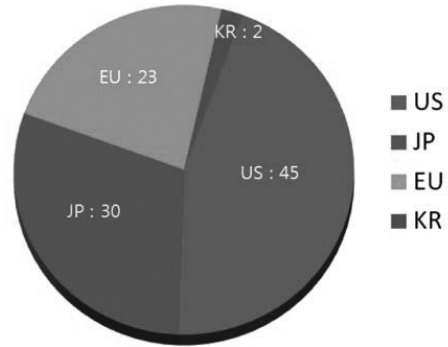
Fig. 6 Proportion of major countries of the major 100 patent registrations for the major technologies.

4 Summary and Conclusions

In this study, for the application of the unmanned and automated agricultural production for a paddyopen field, the core technologies were selected by investigating and analyzing the major patent trend targeting the world's major countries, and the main results are as follows:

1) As a result of searching the unmanned and automated technology patent for a paddyopen field in Korea, the U.S., Japan, and the European Union, 1,080 cases of the valid patents were searched, the U.S. showed the highest registration cases of 541 cases in classification by country. It was investigated that the next countries were Japan with 326 cases, the European Union with 128 cases, and Korea with 85 cases; it shows that the unmanned and automated technology for a paddyopen field in Korea is behind compared to the other advanced agricultural countries such as the US, Japan, and the European Union.

2) As a result of selecting the core technologies by grouping the similar technologies of the patents searched, the order of the share was as follows: 353 cases of the path generation and tracking technology (33%), 236 cases of the operation machine control technology through the environmental recognition (22%), 228 cases of the robotic agricultural operation system design technology (21%), 206 cases of the crop and environment sensing technology (19%), and 57 cases of yield and quality monitoring technology (5%); relatively, it is shown that the research about the path generation and tracking of the unmanned and automated system has been conducted a lot.

3) As a result of selecting the core patents using the patent indexes of the Cites Per Patent, Patent Impact Index, and Patent Family Size, it was revealed that the top 10% (100 cases) were the U.S. with 45 cases, Japan with 30 cases, the European Union with 23 cases, and Korea with 2 cases; particularly, all of the top 1% (10 cases) patents were possessed by the U.S.; therefore, we could assume that it is necessary to obtain the core patent of Korea.

Through this patent investigation and analysis, the patent information was provided as an objective data in entering the agriculture automation area and selecting

Table 2 Major 10 patents of the unmanned and automated agricultural production for a open field operation

Rank	Nation	Patent	CPP	PII	PFS	Normalized sum
1	US	Satellite-based vehicle guidance control in straight and contour modes.	184	33.27	1.974	2.096774
2	US	Apparatus and method for determining a distance to an object in a field for the controlled release of chemicals on plants, weeds, trees or soil and/or guidance of farm vehicles	58	10.49	20.395	1.520687
3	US	Closed loop control system, sensing apparatus and fluid application system for a precision irrigation device	131	23.69	1.974	1.4446
4	US	Sensor-fusion navigator for automated guidance of off-road vehicles	135	24.41	0.658	1.22756
5	US	Field navigation system	124	22.42	1.974	1.499649
6	US	Control of vehicular systems in response to the anticipated conditions predicted using pre-determined geo-referenced maps	107	19.35	1.316	1.630435
7	US	Trajectory path planner for a vision guidance system	106	19.17	0.658	1.140954
8	US	Closed loop control system, sensing apparatus and fluid application system for a precision irrigation device	102	18.44	0.658	1.085203
9	US	Methods and apparatus for precision agriculture operations utilizing real time kinematic global positioning system systems	85	15.37	3.289	1.032258
10	US	System and method for planning the operations of an agricultural machine in a field	92	16.64	0.658	1.184432

the technology development direction of Korea; it can be thought that it is possible to select the corepromising technology of the agricultural production by applying extensively to the various areas such as the horticulture field future facility area, etc. and suggest the direction for the future domestic agricultural production area through this.

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