

ORIGINAL RESEARCH ARTICLE

Development trend of agricultural drone technology based on patent analysis

Hari Prasad^{1,2,3}, Young-Woong Suh^{1,2*}, Veeralakshmi Vaddeboina¹, Anand Narani¹, David Raju Burri¹, Seetha Rama Rao Kamaraju¹*

¹ China Technology Exchange

² Department of Chemical Engineering, Hanyang University, Seoul 133-791, Republic of Korea. E-mail: ywsuh@hanyang.ac.kr

³ Research Institute of Industrial Science, Hanyang University, Seoul 133-791, Republic of Korea. E-mail: hari83@hanyang.ac.kr

ABSTRACT

In recent years, global agricultural drone technology patent applications have continued to grow rapidly every year. In the global applicant rankings, the top 10 applicants are all Chinese applicants, with Chinese companies and universities far ahead. The patent applied for is mainly about operation management, which is closely related to the application scenarios of agricultural drones. In order to study the development trend of agricultural drone technology, the patent applications in the field of agricultural drone technology after 2009 were analyzed. The characteristics of agricultural drone technology patent activities are revealed from the perspectives of overall trends, geographical distribution, major competitors, and technical composition, and the development trend of agricultural drone technology is revealed from the perspective of patents. The results show that the agricultural drone technology is in the stage of technological development and has a bright future. In the next few years, the number of patent applications and applicants related to agricultural drone technology will continue to maintain a high growth trend. Overseas layout, improving the awareness of patent protection has become the focus. The research results can provide reference for the development of agricultural drone industry.

Keywords: agricultural drones; patented technology; patent analysis

1. Introduction

The demand for agricultural aviation in modern agriculture is increasing day by day, especially the micro and small agricultural drone industry for agricultural plant protection is developing rapidly in my country. Agricultural drones can provide convenient,

intelligent and reliable agricultural plant protection solutions, with good operation quality, low cost and strong adaptability, and the operation efficiency can be increased by 60 to 90 times compared with manual operations. Therefore, in the industrial drone market. It occupies an extremely important industrial position and commercial value ^[1].

ARTICLE INFO

Received: July 7, 2021 | Accepted: July 7, 2021 | Available online: August 7, 2021

CITATION

Prasad H, Suh YW, Vaddeboina V. Nano CoO-Cu-MgO catalyst for vapor phase simultaneous synthesis of ortho-chloroaniline and γ -butyrolactone from ortho-chloronitrobenzene and 1,4-butanediol. Frontiers in Cancer Research 2021; 1(1): xxx.

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From the perspective of use, agricultural drones can be mainly divided into three types.

One is plant protection drones, which are used for plant protection. The protection method is mainly to achieve pesticide spraying through ground remote-controlled aircraft [1–3]. The main advantages are that the spraying operation efficiency is high; the long-distance remote control operation avoids the danger of pesticide poisoning; the low-altitude operation makes the droplets sprayed from the sprayer to be accelerated by the downward airflow of the rotor to form an aerosol flow, which increases the penetration of the liquid droplets on the crops. Therefore, the control effect is better than traditional spraying, and it can also reduce the pollution caused by the penetration of pesticides into the soil [4–5].

The second is the farmland monitoring drone, which is used to obtain farmland information and usually carries a variety of task loads. Non-contact monitoring equipment such as imaging spectrometers can obtain remote sensing digital information about farmland and crops, and then obtain information such as crop growth and farmland environment through data processing and analysis [6].

Farmland monitoring UAV can accurately and real-time monitor crop growth parameters, such as vegetation cover, leaf area index, plant height and the correlation between these parameters and yield. It is helpful for the decision of crop growth, such as the diagnosis of crop nutrition status and soil moisture information in the field. It also has high accuracy in the monitoring of pests and diseases. It can also quickly obtain spatial location information of farmland, crops and soil information at different stages, divide land use types, locate farmland boundaries and infrastructure, and measure planting area [7–8]. Compared with traditional field positioning monitoring, agricultural UAV monitoring has the characteristics of fast information collection and high spatial coverage [9–10].

The third is the seeding and fertilization UAV, which is used for seeding, fertilization and application of medicine. During operation, the air flow from

the propeller of the UAV is used to blow the plants open, and the fertilizer liquid squirted from the spraying device is evenly sprayed onto the crop leaves under the action of the air flow, which has the characteristics of accurate fertilization, high operating efficiency and conducive to large-scale production [11–12].

In the global rapid development of high and new technology, patent applications, under the situation of sustained and rapid growth, in view of the field of agricultural technology, this paper retrieves 2009–2019, an application for a patent for all agricultural unmanned aerial vehicle (uav), the agricultural technology in the global patent application, patent application situation in our country, the main applicant and technology constitute the content such as macro statistics and quantitative analysis, it is concluded that the The overall situation and development in the field of technology.

2. Data sources and data description

The patent literature data used are mainly from IncoPat Science and Technology Innovation Information platform, China Patent Literature Database of the State Intellectual Property Office (CNPAT) and the Patent Literature Database of the European Patent Office (EPODOC). The search deadline for China Patent Database and global patent database is September 2019. Focusing on the application of UAV technology in the agricultural industry, the research boundary determined is the agricultural UAV technology closely related to the agricultural operation scene, without involving the general technology in the field of UAV technology.

3. Patent situation analysis

3.1 Patent Application Trends

As of the search date, there were 4 483 agricultural UAV patent applications worldwide, and the trend of global/Chinese agricultural UAV patent applications is shown in Figure 1. As can be seen from

Figure 1, the overall number of agricultural UAV applications in the past 10 years showed an upward trend. Before 2012, the annual number of patent applications was less than 100, mainly overseas patent applications. The number of applications began to exceed 100 in 2013, and showed a rapid growth trend in 2016. Since 2013, China's patent applications in this field have been growing rapidly, and in 2016, they began to show explosive growth, with China coming from behind to lead the rapid growth of global filings.

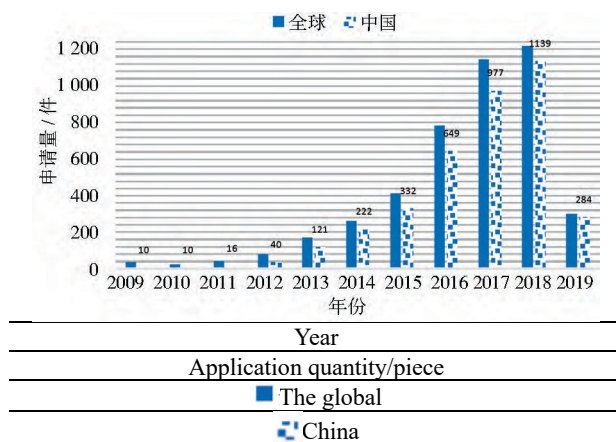
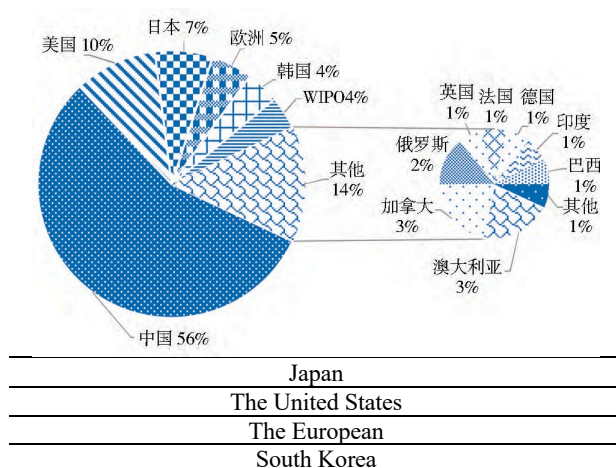


Figure 1. Global/Chinese Agricultural UAV Patent Application Trend

3.2 Geographical distribution of patent applications

The global distribution of agricultural UAV patent countries/organizations is shown in Figure 2. It can be seen that the sales volume of China's agricultural UAV industry has occupied a large market share in the global agricultural UAV market in recent years [13–14].



Britain
The French
Germany
India
Russia
Other
Brazil
Canada
Australia
China

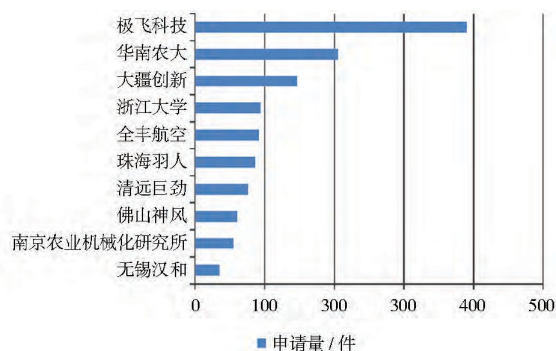
Figure 2. Distribution of Patent Countries/Organizations for Agricultural UAV

In terms of the number of patent applications, from the perspective of global patent distribution, in the field of agricultural UAV technology, China's patent applications account for 56% of the total number of global patent applications by country, becoming the main applicant country in this field. Second, the United States accounted for 10 percent of global patent filings, while Japan accounted for 7 percent of global patent filings. In terms of regional applications, European patents accounted for 5% of the total number of EP patents filed in the EPO, excluding the number of individual applications filed in European countries. From the perspective of global application scope, China, the United States, Japan and Europe are all key countries or regions in the field of agricultural UAV. Since 2013, the number of applications in China has been continuously rising, far surpassing those in the United States and Japan. This indicates that the domestic applicant has actively arranged agricultural uavs in China, invested relatively high research and development efforts in this field, and has certain competitiveness and innovation ability.

3.3 Main patent applicants

The top 10 applicants for agricultural UAV technology patent applications are all Chinese applicants, led by enterprises and universities. The ranking of global patent applicants is shown in Figure 3. Yamaha Engine Corp. And Aero Vironment, Inc. Of the United States, which are established agricultural UAV companies in Japan, have about 30 applications. In addition, international traditional agricultural machinery manufacturers such as Kubota, Iseki Agricultural Machinery and Deere have a small number of patents in the field of agricultural drones. From

the composition of applicants, the main force engaged in the research and development and innovation of agricultural uavs are traditional industrial or consumer uavs manufacturers, and traditional agricultural machinery manufacturers do not participate much. Of the top 10 applicants, three are universities and research institutes, with South China Agricultural University in second place, Zhejiang University in fifth place and Nanjing Institute of Agricultural Mechanization in 10th place. Jifei Technology (390 applications), South China Agricultural University (205 applications) and DJI Innovation (147 applications) were the top three applicants.



A fly technology
South China agricultural university
Big xinjiang innovation
Zhejiang university,
All abundant air
Zhuhai thefeathermen
Qingyuan huge effort
Foshan kamikaze
Nanjing Institute of Agricultural Mechanization
Wuxi han and
Application quantity/piece

Figure 3. Ranking of global patent applicants

Jifi Technology Co., LTD. (Guangzhou jifi Technology Co., LTD.) Was established in 2007, focusing on the R&D and manufacturing of civil agricultural uavs and flight control systems, and is a leading agricultural uavs R&D enterprise in China [15]. Jifi Technology released the first-generation P20 UAV system for plant protection and agriculture in 2015, and P20 2017 UAV system for plant protection and agriculture in 2016. In 2017, three new plant protection agricultural UAV systems (P10 2018, P20 2018, P30 2018) and Jifei Geographic intelligent Surveying and mapping agricultural UAV C2000 were released. In 2018, the P series 2019 plant protection agricultural UAV system and xmission multi-

functional agricultural UAV system were released. In terms of market share, according to statistics, as of November 30, 2018, the number of plant protection agricultural uavs operated by JIFI Technology worldwide was 21 731. As of September 21, 2019, the global cumulative operating area of plant protection UAV of Jifei Technology has exceeded 2 000 hm², saving 4.29 million tons of water for agricultural spraying and reducing the abuse of 18.6 million tons of pesticides and fertilizers.

South China agricultural university, south China agricultural university) has a "national aviation technology applying pesticide precision agriculture international joint research center", the research center, is the Ministry of Science and Technology of national research center for domestic pesticide applying typical food crops, cash crops in aviation plant protection, the United States department of agriculture agricultural research service agency aviation technology center (USDA - ARS - AATRU), the University of Queensland, Australia Queensland) Pesticide Application and Safety Center and other foreign advanced agricultural aviation application technology research institutions, around precision agricultural aviation, jointly carry out agricultural aviation remote sensing, aviation precision variable spray and other related technology and equipment innovation research key technologies and common problems, promote precision agricultural aviation technology. South China agricultural university depends on research center, in precision agriculture airline, air spray technology and aviation research and development application of remote sensing technology, agricultural drones air distribution of spray droplets deposition, agricultural nongqing of low altitude remote sensing information acquisition and parsing, agricultural drones intelligent control system, agricultural precision applying pesticide, key components, control technology and control equipment and agricultural unmanned aerial vehicle (uav) Many patents have been produced in key technologies such as performance testing platform.

Dji Innovation (Shenzhen DJI Innovation Technology Co., LTD.) Was founded in 2006, is the

world's leading unmanned aerial vehicle control system and agricultural UAV solution development and manufacturer. In December 2015, DJI launched an intelligent agricultural UAV for agricultural spraying prevention—DJI MG-1 Agricultural plant protection machine, which marked DJI innovation's official entry into the field of agricultural UAV^[16].

In general, in the field of agricultural UAV technology, universities and research institutes are important forces that can not be ignored in the development of agricultural UAV technology. The effective cooperation between industry, university and research institute will accelerate China's technological development in the field of agricultural uavs, and effectively enhance and promote China's agricultural uavs market share in the world.

3.4 Composition of patented technology

Agricultural UAV technology can be divided into UAV application technology in various scenes of modern agriculture and UAV performance improvement technology to adapt to agricultural application scenarios. Therefore, agricultural UAV technology is divided into technology components as shown in Figure 4.

According to the trend of applications over the years in Figure 4, the branch of operation management (2 212 cases) has the largest number of patent documents, accounting for about 50% of the total number of agricultural UAV patent documents. Due to the fact that many technical schemes protected by agricultural UAV patents are not the improvement of agricultural UAV system itself, but the technological innovation of agricultural UAV operation behaviors focused on agricultural application scenarios, such as spraying pesticide, powder and seed on farmland^[2-4]. Therefore, the patent of application type such as operation management accounts for a large proportion, which is also corresponding to the application of agricultural UAV mainly in plant protection operation, farmland monitoring, sowing and fertilization^[17-19].

Secondly, 1 658 patents in the direction of

the body accounted for a large proportion, accounting for 37% of the total application volume of agricultural UAV, among which the main contribution came from Chinese applicants for Chinese patents. Patent system in our country started in 1985, our country the applicant for a patent for the writing level of the patent is still in its primary stage, involves the structure of the patent writing classes, usually from the protection products through the writing of the overall structure, making the patent application in agricultural unmanned aerial vehicle (uav), the agricultural unmanned aerial vehicle (uav) connection between the body and the body parts structure of patent application The amount is more.

Flight control technology and power/drive technology had fewer patent applications, accounting for 10% and 3% respectively. Both technologies are basic supporting technologies of UAV technology, and relatively few patents focus on agricultural scenarios for technological improvement in patent applications^[20]. The patent application of flight control technology mainly focuses on the direction of trajectory control and control system control method^[6]. Trajectory control mainly includes path/route planning technology and UAV obstacle avoidance technology^[21-22]. The patent layout in these two directions has increased significantly since 2016, and it is expected that there will still be a large space for development in the future. (Since it takes at least 18 months for a patent to be filed to be published, the data coverage of patent applications in 2018 and 2019 is not complete.) For the control system control method of flight control, there are many patents that apply artificial intelligence technology to UAV, which is used to accurately identify the data information of the operation scene, and then provide route planning and decision for the flight of UAV based on the rules of expert system. Artificial intelligence, machine learning, deep learning and other technologies are integrated with UAV technology in agricultural scenarios, which further improves the automation and intelligence level of agricultural UAV flight control. Power/drive technology, the power system to change or improve the performance of affected by

application scenario change is not big, so for unmanned aerial vehicle (uav) in agricultural scenarios of power/drive system improvement is unusual, according to unmanned aerial vehicle (uav) power source, power/drive technology mainly includes the

fuel/gas drive, electric drive, such as solar power and hybrid drive. Among them, electric and fuel driven, and domestic applications tend to battery-driven air weight lightweight design.

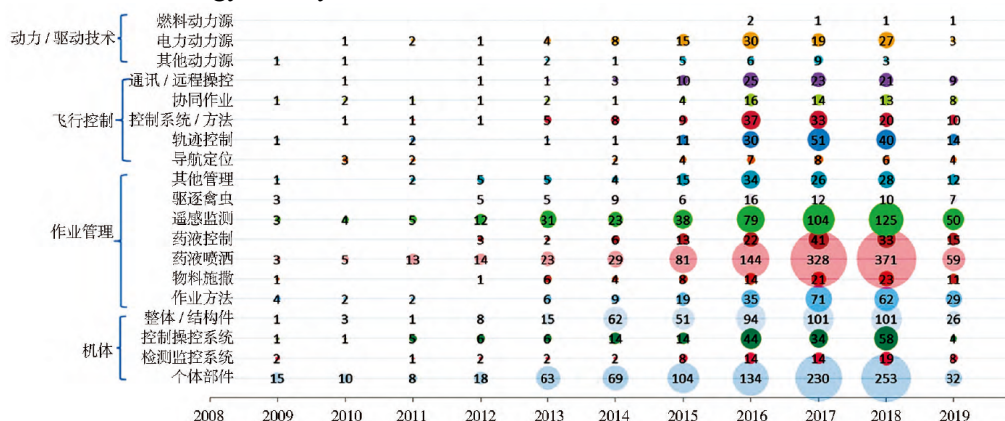


Figure 4. Application trend of agricultural UAV technologies

3.5 Analysis of representative patents of technological development

The innovative technologies of agricultural uavs in application scenarios such as plant protection operation, farmland monitoring operation and sowing and pollination operation were analyzed by combining representative patents in each technology branch. Based on the comprehensive consideration of application date, citation frequency, family status and technical content, the representative patent diagram shown in Figure 5 is determined to reflect the research hotspots and trends in this technical field.

From the perspective of the application years of representative patents, more technical achievements were made from 2015 to 2017, focusing on the field of job management technology and body improvement technology. In the field of operation management technology, the most important patents are in the field of remote sensing monitoring and subdivision technology, followed by the patent of plant protection operation method related to spraying and application. Among them, in the field monitoring operation direction, Low profile multi-band hyperspectral imaging for Machine Vision proposed by DJI in 2017 (CN110476118A), provides a hyperspectral imaging system that can be used in machine

vision system. This imaging system has higher spatial resolution because it can use all sensor pixels of the camera when filtering images in different spectral bands, and at the same time provides better spectral resolution than traditional RGB camera system [23]. In 2017, DJI Innovation also proposed the output image generation method, equipment and UAV (CN109076173A), which focuses on protecting how to improve the accuracy and accuracy of UAV images [24]. In addition, the highest temperature point tracking method, device and UAV (CN109154815A) patent, the infrared camera on the UAV can sense the thermodynamic temperature of each object in the picture captured by the UAV, realizing the tracking and shooting of the highest temperature point, so that the highest temperature point is located in the target position of the image [25].

The above three patents were all filed in 2017, and the technical solutions protected by these patents correspond well to the P4 Multispectral UAV released by DJI in September 2019. This UAV is the first by DJI to integrate the multi-spectral imaging system into the UAV platform to accurately collect multi-spectral data. Compared with visible light imaging, multispectral imaging can provide more accurate directional information and help farmers and agricultural technicians to understand the growth status and health of plants.

Harris Aerial is a commercial UAV manufacturer in the United States. In 2018, it launched Carrier H4 HY-BRID, a hybrid hybrid UAV. The main features of the UAV are as follows: first, it is equipped with battery, gasoline generator and cylinder to achieve long range of hybrid UAV; Second, the propeller can be folded, and the volume can be reduced by 50% after folding, which is convenient to carry, collect and store, and save transportation costs [8,26]. Among them, the folding heavy Aerial UAV (US10266245) applied by Harris Aerial in 2016 is a collapsible structure to protect the propeller [27]. In addition, the Harris Aerial's 2017 application for a modular sprayer system for heavy Aerial vehicles (US10478841), listed in Figure 5, provides a liquid storage tank, its structural and connection relationship with the mounting unit and pump assembly, and includes a level sensor for determining the liquid level in the liquid storage tank [28]. US10478841 also protects the content of UAV communication, which is related to the communication standard (ETSI_ TS 23 502, ETSI_ TS 23 288) and becomes a standard essential patent. Standard essential patents are included in the international standards, national standards and industry standards, and in the implementation of standards must use a patent, that is to say, when the organization for standardization in setting certain standards, some or all of the draft standard because there is no other technical or commercial alternatives, inevitably involves patent or patent application, that is generally considered to be the standard essential patents have higher Value. The number of standard necessary patents in the field of agricultural drones is extremely rare.

From the perspective of representative patent applicants, the patent layout of traditional agricultural machinery manufacturers in the field of agricultural UAV still focuses on the field application research of UAV. For example, the aerial spreading device applied by Yanma in 2015 has patent layout in China, and the patent cited by DJI Innovation, Inseki Agricultural Machinery and other companies. The patent provides an aerial spreading device capable of matching the amount of spreading with crop growth and yield deviations for efficient spreading.

Deere also filed a patent in 2015 for the use of drone technology for yield estimation. Its agricultural drone technology is not available in China, but farm machinery giants kesneholland and Agco have also cited the patent.

申请年	2009—2011	2012—2014	2015—2016	2017—2019
飞行控制	2009 大疆创新 CN201429796Y 无人直升机自动 飞行控制系统电路 2010 L-3 UNMANNED SYSTEMS US8380425 无人机自动防撞 系统	2012 清华大学 CN102628690A 两架无人机任务 协同可视 导航方法	2015 道通航空 CN105346706A 飞行装置、 飞行控制系统 及方法	2017星克 跃尔株式会社 KR1020170101776A 无人飞行器航线 构建方法及系统
机体	2011 大疆创新 US20190253596A1 稳定云台	2013 雅马哈 JP5698802B2 遥控装置 2014 极飞科技 CN204223176U 旋翼飞行器机 臂与机身的 连接结构	2015 大疆创新 CN107614121A 具有液体流量 和转速的反馈 的喷洒系统 2016 雅马哈 JP6340384B2 无人飞行器	2017 大疆创新 CN109071021A 播撒装置及其 控制方法、以 及植保无人机
动力/驱动		2013 EP2799336A1 波音公司用于 无人驾驶飞行器 的装置和方法 2013 JP5801851B2 雅马哈 无人直升机	2015 高通公司 US9704409 搭载无人驾驶 飞行器	2017 US20170203850A1 大疆创新 UAV混合电力系统 和方法
作业管理	2010 中国专利奖优秀奖 农业部南京农业 机械化研究所 CN101963806A 基于GPS导航的无 人机施药作业自动 控制系统及方法	2012 天宝有限公司 CN103930919A 农业和土壤管理 2014 BEE ROBOTICS US9382003 用于农作物 喷药、种植、 施肥等野外 作业的空中农场 机器人系统	2015 洋马 JP6431395B2 空中散布装置 2015 迪尔 US10188037 产量估算 2016 极飞科技 CN105537027B 一种飞行器 喷洒控制装 置、方法 及喷洒系统	2017 HARRIS AERIAL US10478841 重型无人机的 模块化喷器系统 2017 大疆创新 CN110476118A 用于机器视觉的 低轮廓多波段 高光谱成像

Figure 5. Representative patents of different technology components

From the perspective of the patent layout, plant operation and farmland monitoring operation is a hot spot in current research and development, to participate in the main body of research and development type is given priority to with unmanned aircraft manufacturers and agricultural machinery manufacturers, and domestic manufacturers to fly and big xinjiang innovation science and technology, the two have more international patent layout, layout is mainly focused on Europe and the United States, Japan and South Korea. The risk of repeated research and development is high, and the difficulty of technological innovation is relatively large. The types of subjects involved in the R&D of flight control technology and power drive technology are relatively unconcentrated, including traditional aircraft manufacturers,

communication manufacturers, and some exploratory aviation companies, such as Google, which successively applied for two articles (US9957037, US9518873) in 2013 and 2014) patents related to UAV technology integrated with solar cells and have technical layout in China ^[29-30]. The R&D personnel can comprehensively consider the terrain, environment and other factors in agricultural scenarios to strengthen the patent layout in the direction of power system and flight control ^[31].

4. Conclusion

In general, agricultural UAV technology is in the period of technological development, promising prospects. In the next few years, the number of patent applications and applicants related to agricultural UAV technology will continue to maintain a high growth trend. Through the above patent information, the development of agricultural UAV technology is revealed, which provides information basis for technical development of scientific and technical personnel. Based on the above analysis, three suggestions are put forward for the patent layout of agricultural UAV technology.

(1) Strengthen the layout of overseas patents in the field of agricultural UAV, and improve the bidding ability of products in overseas markets. According to blueweave Consulting, the global agricultural UAV market size is expected to grow from USD 1.1 billion in 2019 to USD 4.7 billion by the end of 2026, growing at a rapid CAGR(Compound Annual Growth) of 31.3 percent over the forecast period from 2019 to 2026 The compound annual growth Rate (compound annual growth Rate) Technological innovation, patent protection of innovative technology and market competitiveness of innovative technology products are closely related. In the environment of the booming agricultural UAV market, our agricultural UAV enterprises should strengthen the application of domestic invention patent, in order to pursue a long-term technical protection period; At the same time, the application and layout of international patents should be strengthened to lay a solid

foundation of intellectual property rights for agricultural uavs to go abroad and improve the bidding ability of agricultural uavs in overseas markets.

(2) Improve patent writing skills and strengthen the awareness of the layout of patent claims. Extremely eppo uav technology and big innovation of xinjiang is China's two leading enterprises, for agricultural unmanned aerial vehicle (uav) patent quantity, such as fly technology minnayan: based on patent analysis of agricultural technology development trend of the number of more than 13 big innovation of xinjiang, the main reason is that a fly science and technology in agricultural unmanned aerial vehicle (uav) as its main business, and is big innovation of xinjiang in 2015 began to farm uavs layout, Many of its patents focus on consumer drones. The skillful operation of the two patents in writing is worth learning (refer to patents such as CN110382356A, CN209626259U and CN209080184U) ^[32-34]. In the aspect of claim protection, the general technical components of UAV will be used for protection. However, in the subject of protection, the application of UAV in agriculture is usually protected by an independent claim. At the same time, the application scenario in agriculture is described in the embodiment of the specification, which not only ensures the scope of patent protection, but also realizes the visualization of technology in the application scenario. This way of writing and layout of claims is very helpful for the explanation of claims in the invalid stage of patent and the comparison and alignment of patents and infringing products in patent infringement litigation.

(3) While strengthening the awareness of patent protection, improve the ability of market-oriented application of patents. The acquisition of the patent right makes the right holder have the exclusivity and exclusivity of his patented technology, so naturally he has the ability to take the initiative to claim his rights. Since 2015, there has been a wave of patent wars in the field of consumer drones. According to incomplete statistics, DJI Innovation has sued Shenzhen Daotong Foshan Dark Horse Guangzhou

Huakeer Yuneec Haoxiang and Beijing Zero for patent infringement. Feifei Technology also has a number of patents involved in patent infringement litigation. At present, there is no large-scale competition for intellectual property rights in the field of agricultural drones. However, with the development of the agricultural drone market and the strengthening of market competition, the patent war in the field of agricultural drones will be triggered.

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