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Application Progress of Agricultural Internet of Things in Major Countries

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Abstract. Agriculture is the important application field of the agricultural Internet of Things. With the development of information technology and computer network technology, IoT (Internet of Things) has entered various fields such as agricultural production, management, management, service and so on. On the basis of systematic discussion of the application of Internet of Things in the developed countries such as USA, Japan and Holland, the paper looks forwards to the key application fields in the future such as agricultural resources and environment monitoring, precision operation in the field, intelligent monitoring of facility gardening, fine management of livestock and poultry, prevention and control of diseases and pests, intelligent irrigation, agricultural product quality trace ability, etc.

1. Introduction

The concept of IoT was put forward by the Massachusetts Institute of Technology in 1999. At the end of 2008, after IBM put forward the strategy of "Wisdom of the Earth" to the US government, the Internet of Things quickly got a lot of attention of many countries. In 2009, EU proposed the "Internet of Things — An action plan ", the Japanese government launched the "i-Japan Strategy 2015" and South Korea promulgated the "Basic Plan of IoT Infrastructure Construction ". In 2013, China issued "Guidance Opinion on Promoting the Orderly and Healthy Development of Internet of Things ", and put forward the national strategy of " Internet + " [1] regarding the cloud computing, Internet of Things and large data as the core in the "Government Work Report "in 2015. The application time of IoT in the agriculture is earlier in foreign countries and the technology is relatively mature; Europe, the United States, Japan, South Korea and other developed countries walk in the forefront of the world in the aspect of application of agricultural IoT. Therefore, it is of great significance to study the development mode of modem agricultural Internet of Things in developed countries and grasp its latest application development progress and put forward the national strategy of " Internet + " [1] regarding the cloud computing, Internet of Things and large data as the core in the "Government Work Report "in 2015. The application time of IoT in the agriculture is earlier in foreign countries and the technology is relatively mature; Europe, the United States, Japan, South Korea and other developed countries walk in the forefront of the world in the aspect of application of agricultural IoT. Therefore, it is of great significance to study the development mode of modem agricultural Internet of Things in developed countries and grasp its latest application development progress.

2. Application in major countries

2.1. The United States

As the largest country in electronic information industry in the world, The United States is in a leadership position in the use of IoT technology for promoting the intelligent and precision agriculture. In recent years, the United States develops agricultural IoT technology vigorously and actively integrates these technological achievements into the agricultural system so that IoT technology has been widely used in agriculture in the United States. In February 2011, the US Department of Agriculture released a report showing that more than 70 percent of US farms with annual sales of more than $ 250,000 used IoT in the farm business and 41 percent of smaller farms used IoT. The application of Internet of Things in agriculture has covered the detection of soil nutrient components, prevention and control of diseases of crops and aquatic animals, water conservation irrigation, quality and safety trace ability management of agricultural and sideline products [2]. Through the development and promotion of the IoT facilities and information systems in various agricultural systems, the ordinary agricultural production facilities have the ability of perception, learning and interaction with the environment. For example, the communication of "Machine to machine" for commanding unmanned aerial vehicles for spraying of pesticides through the induction of diseases and pests; apply IoT to the intelligent irrigation, collect soil moisture content and air humidity and other elements through the sensor so as to control the frequency and water of irrigation to avoid waste of water resources; grasping the real-time diseases of livestock and poultry, diseases and pests of crops and other information by means o f the IoT technology and taking real- time emergency measures can save a lot of time and money and reduce the use of pesticides so as to gradually realize the precision of agriculture. Through the establishment of the US agricultural system simulation and forecasting system, the US agriculture has made great achievements in dealing with pests and diseases, natural disasters, diseases of livestock and poultry; its effect of savings in agricultural costs and increase of agricultural output is very obvious. Therefore, the coverage of application of Internet of Things in the US agriculture is wider, which has effectively promoted the process of US agricultural modernization. Of course, because the equipment installation, maintenance and other costs of agricultural IoT are relatively high, the current coverage rate in small and medium-sized farms in the United States is not high.

2.2. Japan

Japan has regarded the development of efficient agriculture as the important objective of the development of its agricultural information technology. Japan actively responds to the rise of IoT technology, and actively applies it to agriculture, which effectively solves the problems of farming, control, quality and safety of foods, reduction of costs and others in agricultural field operations in Japan, and it will gradually develop Japanese agriculture into ecological, safe, efficient agricultural industry. In 2004, for the first time Japan wrote the development of agricultural IoT into the government plan, at the same time, the Japanese Ministry of Internal Affairs and Communications proposed the U-Japan plan. One of the core aims of this project is to realize the interconnection between human beings and objects, consequently to form a system in which people and things can be interconnected and exist in various production links in agriculture [3]. At present, Hitachi and other large technology companies mainly take the lead in research and development of agricultural IoT technology in Japan, vigorously develop the agricultural IoT equipments, and with the help of forces of association and government, promote and apply it to the agricultural production process in Japan. For example, the promotion and application of intelligent greenhouse integrated IoT technology, farmers can establish wireless networks in the scattered plastic greenhouses, connect them with various monitoring probes of different users, and with sensors of soil, solar, air temperatures and carbon dioxide emission, and other equipments, and ultimately with the control terminal or data terminal. The system terminal also provides the function of sensing the abnormality of numerical value and automatically giving a warning. These systems can realize intelligent fertilization, watering, adjustment of temperature and other operations; farmers can know the real-time farm operations only through the computer or mobile terminal, and achieve the reviewing, control, confirmation and management for the temperature, humidity and growth. According to the information, more than half of Japanese farmers choose and use IoT technology, which not only greatly improves the efficiency of agricultural production and circulation, but also helps solve the problems of labor shortage, aging and others in Japanese agriculture.

2.3. The Netherlands

The Netherlands has built the efficient agricultural greenhouse production system; light, water demand, oxygen demand, etc. in the greenhouse are automatically controlled by the computer, and are supplied quantitatively at regular intervals. Each farmer has the computer-controlled spraying, dropper irrigation and artificial climate system, which achieves the automation and mechanization of the entire process of agricultural production and business. Greenhouse potted flower cultivation intelligent equipment system is developed rapidly, which uses the automatic production control system to control the operation by means of the remote computer and control the transportation by regarding the seedbed as the unit. According to the growth of potted flowers, the potted flower cultivation and management expert system carries out the automatic management operations for their greenhouse lighting, temperature, nutrient solution ratio, tidal irrigation and other cultivation management. When seedlings are put into the pots, the substrate filling machine is associated with the seedling transplanting machine; the substrate filling machine sends the flower pots filled with substrate directly to the operation position of the seedling transplanting machine; no conveyor belt is needed for the transportation of flower pots; During the transportation of potted flowers, the equidistantly arranged potted flowers transported by the equidistant arrangement conveyor belt are placed into the seedbed by the pot pickup fork of potted flower seedbed placing machine; after the seedbeds are filled with potted flowers, they are automatically transported to the specified position in the greenhouse through the seedbed transfer tracks or the seedbed conveyors. The seedbed transport tracks can be used for horizontal or vertical transport for the seedbeds. When the potted flowers are operated by grading, the potted flowers to be graded are transported into the visual grading system by the conveyor belt; the potted flowers rotate and go forward in front of the digital camera under the action of the pot rotating machine consisting of tow conveyor belts with opposite movement, and then the images of potted flowers in several directions are obtained, therefore integrated scoring grading can be carried out. The graded potted flowers enter the sub-regional management of different regions through the automatic divided passage of the conveyor belt or carry out packaging after grading, which effectively improve the production efficiency and reduce labor costs [4].

2.4. Israel

Through the construction of agricultural IoT science and technology innovation service system, Israel greatly promotes the research and development, popularization and application of agricultural IoT technology. The farm management remote consultation system, farm advisory system and the agriculture-related technology center website of three-level network of "Country-province-farm (farmer)" established by Rural Promotion Administration of South Korea have become the important carriers for farmers for obtaining information service [5]. Israel's water-saving irrigation IoT has been developed rapidly, according to the soil data from the sensor, irrigation of a large number of farmlands can be controlled by a few farmers through intelligent equipments, valuable water resources and labor costs are saved. On the basis of drip irrigation technology, Israel has developed the buried irrigation technology, it means is to bury the pipeline at 50cm underground; this irrigation method can keep the surface dry, even in the irrigation, it does not affect field operations. In this buried drip system, Israel uses a material called Tarplan, which can prevent the root growth near the irrigation emitter so that the drip system can avoid the penetration by small roots. When the water valve is turned off and the irrigation is stopped, the air valve of the drip system is opened so that the pipeline is filled with air for preventing foreign dust from being sucked into the irrigation emitter.

3. Key application direction in the future

3.1. Agricultural resources and environmental monitoring

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There are mainly two types of monitoring methods, one is to complete the monitoring of agro-ecological environment and agricultural conditions through low-altitude sensors and wireless sensor network in the near place. The other method is the real-time monitoring of crop growth, area, estimated yield and quality through remote sensing, Internet and wireless sensor network by means of 3S technology, and to make the research on inversion model algorithm and mechanism of important biological and agricultural parameters by means of the hyperspectral remote sensing data [6-7]. The automatic continuous monitoring system and macro ecological monitoring system have been established in the United States, Japan, Europe and other developed countries and regions; they are widely used in the agricultural environment monitoring, irrigation and fertilization control, monitoring network of fine breeding of livestock and poultry and fisheries. For example, through the real-time monitoring in the California region, the forest resources and environmental monitoring network established by the University of California, Los Angeles, provides real-time information for the corresponding departments so as to provide support for the overall management of forestry; Researchers from the University of California, Berkeley carried out the periodic environmental monitoring of the habit of petrels at Great Duck Island for 9 months; they used the regional static MICA sensor node deployment and achieved the monitoring of sensitive wild animals and their habitats without invasion and destruction. By mainly using the establishment of a national coverage of the agricultural information platform comprehensively, the United States, France, Japan and others achieve the automatic monitoring of agricultural ecological environment and ensure the sustainable development of agricultural ecological environment [8]. Europe achieves the real-time monitoring of the land use information mainly by means of the resource satellite, in which, France uses the communication satellite technology to forecast disaster weather and observe and predict diseases and pests.

3.2. Precision operations in the field

The fine management, automatic monitoring and control for crop cultivation and management, prevention and control of crop pests in key aspects of field planting and production process by means of the information technology can effectively enhance the level of agricultural production management and improve resource utilization and output efficiency. Large farms in the United States are leaders in aspect of application of agricultural IoT technology, on the basis of the developed agricultural network system, the entire network-wide precision agriculture model is basically formed; variable fertilization and spraying pesticides, automatic identification technology for weeds and precision control technology for large-scale irrigation machine have begun the large-scale industrial application [9]. In recent years, the United States has began to use GPS system, CORS (continuously operating reference stations), RTK (real-time kinematic) and other high-tech for the agricultural equipments such as grain combine harvester, sprayer, planter and so on so that large-scale intelligent agricultural machinery can achieve automatic driving, precision sowing, navigation for spraying pesticides, especially for four corners of farmland that circular sprinkler irrigation can not cover; through the installation of RTK receiver at the irrigation machine, precisely set the withdrawing and opening time for the outermost section of pipeline of the spray irrigation machine so that it can spread to the corners that can not be reached originally, which improves the efficiency of land use. The application of these high and new technologies have greatly promoted the development of IoT of agricultural machinery; at present 15% of farmers in the United States have used the agricultural machinery and equipments with global satellite positioning system (GPS). Japan is characterized by the light-type smart farm machinery. It vigorously develops the precision agriculture of modest scale farms; now it mainly concentrates in two aspects, one is the basic research of precision agriculture, which can provide crop growth model database for agricultural production and application; the second one is the research of precision agricultural machinery, which can provide intelligent operation terminal of agricultural IoT, so as to achieve the prevention and control of pests and diseases in the field, fertilizer management and harvest prediction.

3.3. Intelligent monitoring of facility horticulture

The development of IoT technology achieves intelligent monitoring of planting production; it is widely used especially in the facility horticulture production. Carry out the real-time monitoring of environmental factor data, such as "Temperature, humidity, light and soil moisture" in the greenhouse by means of various sensors; achieve intelligent decision-making under the support of the expert decision-making system; implement real-time adjustment and control of wet curtain fan, spray drip irrigation, internal and external shading, heating and supplementing light and other equipments through the computer, mobile phones, touch screen and other terminals; regulate the growth environment in the greenhouse to the appropriate state, which makes up for insufficient agricultural parameter acquisition monitoring of traditional facilities and achieves scientific monitoring and cultivation and improves comprehensive agricultural benefits, for example, real-time monitoring device for growth of strawberry used by the strawberry producer, in Oxnard, California, the United States, "Norcal Harvesting" company was developed by the US "Climate Minder" company. In the strawberry field of "Norcal Harvesting" company, the sensor is responsible for the measurement of salinity and water, etc. in soil; IoT uses electronic tags identified by the radio frequency to transmit the data to the network server of the "Climate Keeper". Farmers can visit the website through the specific account and carry out the real-time observation of data of strawberry greenhouse. The system can also automatically trigger related activities according to the conditions of the air and soil, such as watering or temperature adjustment. IoT devices of "Libelium" (A Spanish company founded in 2006) were introduced in the vineyards in Rías-Baixas region of Galicia, Spain; the wireless sensor network was set up in the vineyard for collecting data of ambient temperature, humidity and foliar humidity; it is combined with precise location and time information provided by GPS device and transmits them to the cloud through 3G Network. Gardeners can monitor and adjust environment data in the vineyard only through the connection to the Internet.

3.4. Fine management of livestock and poultry

The application of agricultural IoT technology in the industry of aquaculture, pigs, cows and others is more mature. By means of the animal growth model, nutrition optimization model, sensors, intelligent equipments, automatic control and other modern information technologies, according to the information such as growth cycle, individual quality, feeding cycle, capacity for eating and feeding situation of livestock and poultry, carry out scientific optimization and control for the feeding time and capacity for eating so as to achieve automatic feeding [10-11]. Through the real-time acquisition and analysis of animal body temperature information, achieve fine management of individual physiological information of livestock and poultry and implement early warning of major epidemic situation effectively. Through the establishment of livestock and poultry information health records, monitor the whole process from production to circulation for livestock and poultry products by means of the individual positioning and traceability management system and achieve safety management of diseases and products of livestock and poultry. The EU attaches great importance to precise livestock husbandry and has sponsored a number of projects in recent years. For example, PCM project put into operation in 2011, its aim is to record and monitor the cough of pigs. Compared to observation by people, the project can find respiratory diseases of pigs earlier so that veterinarians can quickly intervene and treat early. Through the installation of sensors in cattle, French Academy of Agricultural Sciences makes the statistics of the real-time position, weight, capacity for eating and methane emissions of the cattle and strengthens the research and analysis of livestock behavior. "Farr Menon", Founded in 2011, is a Croatian start-up company focusing on livestock husbandry; the company helps farmers collect information from farms so that they can get real-time information on every cow by using Tablet PC; the data include milk production, weight, medical care, health problems, reproduction, and so on. The data are expressed in clear and crisp charts, which allow the farmer to grasp the growth cycle, feed ratio and feeding of livestock.

3.5. Prevention and control of diseases and pests

In the aspect of prevention and control of diseases and pests, the real-time monitoring of density of pests is carried out and intelligent control is implemented by means of sensors, infrared cameras and other detection equipments; when the pest density exceeds the warning value, it will give a warning, and pheromones are sprayed by another device installed in farmland; the pheromones can interfere with insect mating so as to achieve the effect of control of pests. Japan has developed the farm crop mapping system, detection system for the number of rice seedling, crop leaf color detection system and other agricultural intelligence systems, which are widely used. Based on the position information provided by GPS when tractors travel in the field, the Japanese field mapping system can take pictures of crop growth in the whole farmland continuously; the computer terminal can know the details of the crops in the farmland. The detection system for the number of rice seedling can take pictures movably and process images by tractors equipped with digital cameras and GPS; it can automatically detect situation of seedlings. The detection range of the camera is covered with a light shield, which is not affected by external light; the camera can capture high-quality images. The crop leaf color detection system can determine the situation of rice blast. It regards the sun light as the light source and determines the color of plant leaves according to the reflectivity of two wavelengths. The detection value is closely related to the blast disease of rice leaves and rice ears; it can be used to infer the rice blast so as to prevent and control effectively.

3.6. Intelligent irrigation

In the aspect of intelligent irrigation, sensors are used to explore terrain, soil structure and water content, and transmit the real-time data to the server through wireless devices. Based on the different absorption speed and demand for water by different crop roots, design the irrigation implementation plan for specific land and help farmers implement precision irrigation, which saves a lot of water resources [12]. For example, the United States Silicon Valley "CropX" company, its main product is the hardware exploring soil parameters and it uses software to show the data for farmers; its aim is to establish "Soil IoT." The company's hardware products include three important sensors responsible for collecting terrain information, soil structure and water content respectively so as to determine the soil demand for water. "CropX" company uses the mobile application client to send cloud computing results to farmers such as irrigation maps and soil moisture status. Farmers can also calculate the amount of irrigation needed by soil in different regions by changing the corresponding parameter so that every drop of water returns to the field [13]. Headquartered in Zurich, Switzerland, ABB company promoted and applied the "Neptune" smart irrigation system in the key agricultural regions of 210 square kilometers in the south of Madrid, Spain so that 12% and 20% of electricity and water were saved respectively. The “Neptune" irrigation system consists of remote terminal devices, data acquisition and monitoring system and communication. The “Neptune" data acquisition and monitoring system can not only display the status, alarm, event, report and historical data of remote terminal device but also communicate through SMS and e-mail; it allows users to remotely access via the Internet.

3.7. Quality tracing of agricultural products

The agricultural product traceability system uses bar code technology and RFID technology to track, identify and monitor the production, transportation, consumption process of agricultural products so as to ensure their quality safety. For example, since 2001, Canadian beef cattle have used one-dimensional bar code ear tag, followed by electronic ear tag; Japan established the beef cattle traceability system in 2001, developed the "Beef identity card" system in 2002 and established individual cattle information system; consumers can check beef origin, variety, birth time, breeders, feed ingredients, slaughtering date and circulation process and other details through the Internet or mobile phones at the sales terminal. And then gradually it is extended to other types of agricultural products, so far, Japan has realized traceable management for all agricultural products. Australia established the National livestock Identification Scheme (NLIS) in 2001, namely the livestock product quality safety traceability system. It uses rumen marker ball or ear tags identified by NLIS to identify identity for cattle and sheep. The national central database carried out a unified management for information recorded; the whole process of animal individual can be tracked from birth to slaughter. South Korea attaches great importance to food safety. Since 2004, the traceability system has been implemented in the production associations tentatively, and at the same time it has been developed in the aspect of livestock, fruits, vegetables, raw materials, food, special crops and others. In 2005, the South Korean government introduced a full range of agricultural product traceability procedures into the Agricultural Product Quality Control Act, and began to implement it in the country in 2006.

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