Research and implementation of FOD detector for airport runway

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Abstract. A foreign object on an airport runway is also called a foreign object, that is, some foreign material, debris or object that may cause damage to the aircraft, such as scattered aircraft parts, luggage parts, wildlife, etc. On airport runway, there are mainly the activities of aircraft, less activities of human. As a result, most of the foreign objects on runway are parts that fall off the aircraft, mostly made of metal. Due to the strong suction of aircraft engines and high speed crushing of tires during take-off and landing, aircraft is relatively fragile compared with foreign bodies, and the presence of foreign bodies on the runway can cause serious damage to the structure of aircraft. A tiny object sucked into the engine could cause damage to the blades, and debris could accumulate in the machinery, affecting the plane's normal operation. In view of the above problems, the research and realization of the FOD detector of airport runway are carried out in depth.

1. Introduction

1.1. Foreign matter on airport runway and its hazards
A seemingly small piece of garbage may damage the engine, tire and other parts of the aircraft, causing losses of hundreds of thousands or even millions of dollars, resulting in safety accidents and disastrous consequences. There is a serious threat to aircraft's taxiing and landing on the runway, resulting in flight delay, interruption of take-off, and even endangering the lives of passengers. Many aviation accidents caused by foreign objects on the runway occur every year, causing huge direct or indirect losses [1, 2].

Foreign bodies on airport runways can not only damage aircraft and endanger precious lives, but also cause serious operational problems and huge economic losses to airlines and airports. In 1996, the American air transport association counted FOD events among 23 member airlines in three years. The results showed that the average annual loss caused by FOD was $7.4 million for each airline, and the average annual loss of all member airlines was $170 million. If combined with the indirect losses caused by flight delay, interruption of take-off and closure of runway, these losses will be astronomical [3].

From May 2007 to May 2008, FOD caused as many as 4,500 accidents in China. About 13% of the tires of most airlines are damaged by FOD, and premature scrapping and repairing of tires is a big expense [4]. In 2008, the civil aviation administration organized relevant units to carry out special research on foreign matter prevention, and carried out a series of special activities on foreign matter prevention and management in the industry.
1.2. The significance of FOD detector for airport runway is studied

It is an effective way to ensure flight safety to avoid damage to aircraft caused by foreign body on airport runway and bring hidden dangers to flight safety. With the development of modern science and technology, especially the rapid development of computer technology, communication technology and image processing technology, the research and development and production of FOD detection system have been greatly promoted.

At present, a number of foreign companies have developed FOD detection systems based on different operating principles, and a number of countries have put these FOD detection systems into the actual application of airports. For China, the introduction of foreign FOD detection system is expensive, the purchase cost is as high as millions of dollars, the maintenance cost is huge, and the foreign countries block related technologies. Considering the above situation, the FOD testing system produced by foreign companies has not been widely purchased and used in China.

Due to the late start, the self-developed FOD detection system in China is still in the preliminary stage, and the mature and practical FOD detection system has not been developed successfully. At present, the detection of foreign body on the runway of Chinese airports is mainly completed by naked eyes, as shown in figure 1. However, the visual FOD detection has many defects, such as inattention, especially when people feel tired, and the radio communication are easy to cause distraction.

On the one hand, individual physiological differences will lead to inconsistency in object recognition. On the other hand, different visual field areas have different recognition accuracy, and object location differences will also lead to inconsistency in object recognition. The influence of environment on judgment can not only be affected by the difference of weather conditions, but also cannot be accurately judged by naked eyes under certain circumstances, such as rubber fragments on track tread marks and grey metal in puddles.

Figure 1. Regularly organize the inspection of foreign objects.

The degree of damage to aircraft by foreign body on airport runway is different, and the treatment method for foreign body on airport runway is also different. The level of damage to aircraft by foreign body on airport runway can be obtained in time, which is helpful for the staff to carry out proper treatment on the detected foreign body. At present, the recognition of runway foreign body also depends on the human eye close distance recognition, and the same treatment method is adopted for all runway foreign body. On the one hand, the workload of the staff is increased; on the other hand, the use efficiency of the runway is also affected. Therefore, based on the detection of runway foreign body, the recognition of runway foreign body and the classification of risk level also have strong practical significance.
2. Implementation plan

2.1. The overall layout
Design and development of FOD detector for airport runway, including integrated system of laser transmitter, induction device, transfer device, receiving device and vehicle, and automatic navigation control system. The laser transmission, induction, transmission and receiving equipment includes the laser transmitter circuit system and the laser receiver circuit system. The former includes laser beam unit, 4G signal transmitting system and transmitting end information processing system. The latter includes 4G signal receiving system and receiving end information processing system.

Laser correlation device assembled on the end of a long rod in the level state of laser beam scanning can be close to the ground, when the laser beam is stopped by FOD, then the signal is blocked and pass to the information processing system, information processing system through information identifying alarm and the result was sent to carrying on the alarm signal at the receiver (both take a wireless connection). The signal alarm receiver senses that the signal begins to sound an alarm through the loudspeaker.

2.2. Automatic navigation control system
The automatic navigation control system is developed and loaded into the FOD detector of airport runway. Automatic navigation control system is a kind of feedback control system for autonomous vehicle traveling along the planned path.

The main technology of automatic navigation control system is divided into three parts. One is the hardware part. The second part is the path part, that is, planning out an appropriate detection path, which is the path of FOD navigation aiming, and the quality of the planning directly affects the navigation effect; The third part is the algorithm part, that is, calculating the detector's front wheel angle according to the bias, so as to correct the bias.

3. Feasibility study
A lot of related theoretical and experimental studies have been carried out in the early stage, and related patent application work has been done, which has accumulated valuable theoretical basis and practical experience for the overall architecture design of FOD detector.

For the feasibility of automatic navigation control system, team also make the necessary theoretical research, the technology is relatively mature, the United States, Germany, Japan and other countries in view of the automatic navigation control system, carry out the research and achieved certain results, some developed countries, led by the United States, has the automatic navigation system is widely applied in agriculture [5]. The automatic navigation position sensor and navigation control algorithm of automatic navigation control system are introduced as follows:

3.1. Automatic navigation position sensor
There are many methods for accurate positioning in automatic navigation, among which machine vision, GPS navigation and inertial navigation are widely used.

Machine vision is now widely used in various fields, such as the automatic obstacle avoidance lawn mower produced by Baoshide Company. It can recognize various obstacles in front through image processing, so as to avoid these obstacles ahead of time. The core of machine vision is image sensor and image processing algorithm. The image sensor is mainly to obtain the image data in the field of vision, while the image processing algorithm is to classify the image data, so as to judge the shape, size and distance of various objects in the field of vision.

Machine vision is mainly used to capture field crops in agricultural production. For example, in the field, there are crops, weeds, mud, stones, etc., so how to distinguish the crops from other objects quickly and lock their positions is the problem that machine vision has to solve. For example, the automatic spraying of pesticides on the target has achieved good results. It can quickly capture the
position of crops and feed back to the control console. Based on this position, the control console controls the spraying of pesticides on crops, which greatly avoids the waste of pesticides and reduces the pollution to the environment. The main advantage of machine vision is low development cost, while the disadvantage is easy to be affected by objective environment such as light and land flatness.

GPS is the global positioning system, which is a satellite navigation system with omni-directional, all-weather, full-time and high-precision. Several bands have been opened for civilian use. But due to the satellite ephemeris, the satellite clock error, the troposphere, the influence of the ionosphere to the signal, the noise of the receiver's own error and objective environment in the process of application, such as greenhouses, canopy, blocking the signal partly, makes the positioning precision of civilian only tens of meters in order of magnitude. It is not meet the needs of agricultural machinery positioning.

With the in-depth research on GPS positioning, differential positioning technology (such as DGPS and DGNSS) has emerged in recent years, and its positioning accuracy can reach up to cm. Differential GPS system contains one or more installed on the known coordinates of GPS receiver station as a benchmark, through the base station of the GPS satellite signal of the measuring and calculation on a business trip, and then put the difference correction quantity spread to the difference service within the scope of the user receiver (also called rover), in order to improve the positioning accuracy of user receiver. Real-time dynamic difference (RTK) is often used in the automatic navigation of agricultural machinery because it is a technology that provides precise positioning in real time for dynamic users.

3.2. Navigation control algorithm

Control algorithm is the core of automatic navigation. But it first needs to obtain the data measured by various sensors, such as the position coordinates, heading Angle, roll Angle, speed and pitch Angle of the rice transplanter. This information is sent to the control system along with the pre-defined path information to determine the next turn of the rice transplanter. Finally, the command is sent to the steering wheel to rotate at a certain Angle to get the transplanter back to the pre-defined path.

At present, common path tracking control algorithms include linear model, PID control, optimal control, fuzzy logic, neural network and pure tracking model. The linear model algorithm is relatively simple. It first judges the relationship between the front wheel Angle and the lateral deviation and the heading deviation according to experience, then sets a proportional relation with parameters, and finally determines the proportional parameters through simulation or experiment.

Obviously, this algorithm is not very precise and can not eliminate the steady-state error. PID control algorithm is widely used in industry, because the mathematical model is easy to build, the transfer function is easy to be derived, and the steady-state error can be smaller quickly.

However, it is difficult to determine the three control parameters, so a combination algorithm, such as fuzzy PID control algorithm and optimal PID control algorithm, comes into being. In the final analysis, these algorithms are all for obtaining better control parameters. The optimal control method can directly calculate the optimal control parameters, but the mathematical model of the controlled object needs to be determined.

The algorithm has poor adaptability to curve tracking, and more importantly, the accurate mathematical model of rice transplanter driving in paddy field is difficult to establish. Fuzzy algorithm is an empirical control method. It does not need to establish a precise mathematical model of the controlled object. Therefore, its robustness is relatively strong and is not easily affected by external changes, but its tracking error is generally large. The neural network has a good control effect on the controlled object of complex motion characteristics, but a batch of high quality training samples are needed first. The pure tracking model derives the control equation by establishing a geometric model, so as to obtain the functional relationship between input parameters and output parameters. In general, higher control accuracy can be obtained, but the forward distance is not easy to adjust [6].
4. Conclusion
This project aims to develop an airport runway FOD detector. In the work, it can not only effectively detect the small FOD in the airport runway, but also has the advantages of high detection efficiency, reliable detection results and easy maintenance.

Because there are human errors and other major safety hidden trouble by human detection, at the same time, in order to bring the operators from heavy, repetitive production process, develop a special automatic navigation control system, and in the airport runway FOD detection, it not only improve the accuracy of FOD detection operation effectively, but also reduce the waste of human resources in the detection process.

Finally, the FOD detector prototype has been put in airport runway test for many times, to verify the performance and related parameters. Focus on the detection precision and the automatic detection, except doing the necessary theoretical research, at the same time to do the related patent application (has been authorized by the end of 2018), after the completion of the project, it can be applied to automatic detection for airport runway FOD regularly, it has a high practical value.

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