Design of airport road surface inspection system based on machine vision and deep learning

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Abstract. The specific objective of this study was to solve the problem of high risk and low efficiency of manual inspection of airport road surface. This paper describes the design of an Airport Road Surface Intelligent Inspection System Based on machine vision and deep learning. The system completes the airport pavement inspection through autonomous navigation. MobileNet-SSD and Mask R-CNN algorithms are used for target detection and semantic segmentation of airport pavement apparent disease and foreign object debris in this paper. At the same time, topological feature extraction and pixel size measurement were carried out. Finally, the information is uploaded to the storage server and the target information is displayed on the Android mobile terminal. The inspection system can complete the work of airport pavement inspection and provide a new way for airport pavement health monitoring.

1. Introduction

Aviation is an important part of transportation, a key aspect of the safety of the flight landing is Airport Pavement Health. Airport pavement apparent disease [1] and Foreign Object Debris (FOD) [2] are important factors threatening the health of the airport pavement. As the most common apparent diseases of airport pavement, cracks and pits not only affect the take-off and landing of aircraft, but also easily develop into more serious diseases [3] such as plate fracture and pavement shedding. Foreign Object Debris as the foreign material are left in the runway area, there are easily causing the plane slip of partial or engine ceasefire [4]. So for periodic monitoring of airport pavement is of great significance.

At present, there are companies aiming at the development and application of the airport pavement monitoring system in different aspects. Typical examples are the FodFinder system developed by Trex Enterprises, the Tarsier Radar system developed by Qinetiq, and the FoDetect system developed by xSight. Trex Enterprises' FodFinder system uses an on-board, mobile platform that can detect foreign objects on the runway and aircraft park. But it does not change the model of human involvement in surface monitoring. The FoxDetect system developed by xSight is a small product that is installed on the runway edge light and consists of 120 sub-detection systems. This method can avoid interference from the runway edge light on the detection system. But it is vulnerable to strong winds, oil stains and other erosion due to its work location being too close to the aircraft. The Tarsier Radar system of Qinetiq Company is widely used and relatively mature which has been applied to airports in many countries. The Tarsier Radar system is equipped with optical cameras and can continuously monitor the airport pavement. However, it is only convenient for the staff to identify The Apparent Disease and FOD which has not been separated from the manual monitoring mode.
This paper develops an airport pavement inspection system by using computer vision and navigation positioning technology [5]. The system completes the inspection work by autonomous navigation. It also identifies and segments airport pavement apparent disease and FOD based on MobileNet-SSD and Mask R-CNN algorithm. The pixel size and location information of airport pavement apparent disease and FOD can be detected, and finally displayed at the display terminal, so as to guide the staff to further work.

2. Architecture of pavement inspection system
The system architecture is shown in Figure 1. The whole system is divided into four parts: automatic inspection module, Image Processing Module, Information Storage and Terminal Display Module. The Automatic inspection module is responsible for automatic navigation of vehicles. Image Processing Module is used to recognize and segment the pavement image. Information Storage Module is responsible for Target Image storage and communication Transmission. The Terminal Display Module is responsible for displaying target information. The work of the system is divided into preparation stage and patrol stage. In the preparation stage, the inspection vehicle is manually controlled to move in the inspection area and build a regional map. In the working stage, the MobileNet-SSD algorithm is used to identify airport pavement apparent disease and FOD. Then the Mask R-CNN algorithm is used to segment the target image and extract the pixel size. Finally, the target results are uploaded to the information storage module and returned to the display terminal.

3. System implementation

3.1 Automatic Inspection Module
Automatic Inspection Module includes Vehicle Chassis Based on McNam Wheel [6], laser radar, IMU inertial measurement unit and STM32F103RC controller. It can not only realize the autonomous positioning and navigation of inspection vehicles, but also upload the sensor data collected by the lower computer to Information Storage and Terminal Display Module. Automatic Inspection Module uses Jetson TX2 as the core controller, ubuntu18.04 based on ROS [7] as operating system, and STM32 as the driving board of the lower machine to control the detection of vehicle movement. The overall framework of the automatic inspection module is shown in Figure 2.
3.2 The Image Processing Module

Aiming at the problems of low recognition accuracy of SSD algorithm, less target information and slow processing speed of Mask R-CNN algorithm in airport pavement apparent disease and FOD detection, the author adopts MobileNet-SSD and Mask R-CNN dual algorithms. Firstly, the SSD algorithm is used to locate and recognize the target for the first time. On the basis of getting the identified image, reprocessing the recognition image based on Mask R-CNN algorithm. Finally, the topological characteristics of the target are extracted to obtain the pixel size of the target.

The image processing module consists of three parts: Jetson TX2, Beidou BDS+GPS positioning device and CGImageTech industrial camera. The camera captures the video images in the cruise process, Jetson TX2 decodes the real-time track video shot by the camera into frames for image recognition and segmentation, and the Beidou BDS+GPS positioning device is used to obtain the GPS coordinates of the target image for subsequent positioning. Figure 3 shows the workflow of the Image Processing Module.
3.3 Information Storage Module

After a cycle of image processing is completed, the target image and related information are uploaded to the information storage module for analysis, management and storage. Information Storage Module is based on Linux operating system. It mainly consists of an FTP file server, a MySQL database and a NginxWeb server. The FTP server communicates with Image Processing Module and receives the apparent disease after recognition and segmentation during inspection. As an information storage database, MySQL can save the target image and related information for a long time. The Nginx Web server is used to generate the target information storage file chain for the display terminal to access the server and obtain the inspection result information.

3.4 Terminal Display Module

In order to facilitate the staff to observe the road inspection, the system uses Terminal Display Module which uses Android development technology and JAVA language. Terminal Display Module mainly includes four sub-modules: data download module, data upload module, information display module and navigation module. The data download module is composed of Retrofit, OkHTTP and Rejava frameworks. The network upload module adopts FTP transmission protocol. Information module is composed of data list display window and image details window. The development of navigation engine and navigation interface in navigation module is completed by Baidu map SDK [9].

Figure 4 (a) is the main interface window of the terminal display module, which mainly provides the functions of airport pavement apparent disease and FOD information display and image updating.
When the staff presses the button of the pavement disease information database, the interface jumps to the data display window which displays the type, length, width and area of each disease data (Figure 4 (b)). The disease detailed information window (Figure 4 (c)) displays the type, contour and pixel size of the disease. In order to facilitate the user to determine the location information of the disease and guide the repair and maintenance work, the user pressed the navigation button and the interface jumped to the navigation window (Figure 4 (d)).

4. Conclusion
This paper introduces an intelligent inspection system for airport pavement. This system adopts the technology of the autopilot control inspection vehicle pavement inspection work, uses the MobileNet-SSD and Mask R-CNN algorithm for target recognition and semantic segmentation, and designed the terminal display module based on the android operating system, can real time positioning the target position in the process of inspection. It can offer help workers to carry out airport pavement health restoration work.