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Research on Snow Removal Effect Evaluation on Airport Runway Based on Wireless Data Transmission and Image Recognition

[1, 2] Bin Chen, [3] Bing-Liang Nie, [1,2] Tao Jin, [1, 2] Xu-Dong Shi, [1, 2] Li-Wen Wang

[1] Tianjin Key Laboratory for Civil Aircraft Airworthiness and Maintenance of Civil Aviation University of China, Tianjin, 300300, China

[2] Ground Support Equipments Research Base of Civil University of China, Tianjin, 300300, China

[3] Flight Training Center of Shenzhen Airlines Co., Ltd, Shenzhen, 518128, China

[1] E-mail: binchenedu@126.com

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Abstract: The effect of snow removal on airport runaway is relied on the human naked eyes. A new method that is based on image recognition and transmission technology to evaluate the effect of snow removal was presented and the architecture of snow sweeper's monitoring system was established in this paper. JPEG compaction algorithm was used for compression and transmission of image data in based on Digital Signal Processor platform, then the wireless data transmission and image acquisition method was used in the monitoring system. Meanwhile, this paper proposes digital analysis for real-time image acquired by image recognition technology and explores the image processing algorithms for accumulated snow on runaway to realize automatic monitoring of snow removal operation on runaway. The experiments results reveal this method is feasible. Hopefully, it could be a technical platform to optimize the scheduling and control system for airport deicing special vehicles. *Copyright © 2013 IFSA.*

Keywords: Data transmission, Image recognition, Snow removal, Airport runway, Monitoring system.

1. Introduction

With the development of the Civil Aviation, there is an increasing workload and work strength for snow removal vehicles serving for flights at the airport. Using traditional wireless intercom technology to monitor so many snow removal vehicles is difficult to meet the practical needs in both efficiency and security. In addition, the standard to evaluation the runway snow removal effect is relied on the human naked eyes. In this way, it brings low efficiency to remove the snow on the runway and is easy to bring some uncertain judgements, which could bring some latent danger for the aircraft flying.

The airport's snow removal operation is an extremely busy and complex work in the winter of the north. With the rapid development of the civil aviation, density of the flights taking off and landing at the airport is increasing day by day, which puts forward higher requirements for operating efficiency and safety performance of snow removal vehicles. So it is necessary to study the automatic monitoring technology for automated command and control system and effect of snow removal vehicles operation. This paper aims at the command and control system of airport snow removal vehicles. The data transmission method, real-time monitoring of acquiring the images and the automatic identification technology of image has been studied.

2. Design of Airport Snow Removal Vehicles Monitoring System

2.1. Overview of Airport Snow Removal Vehicles Monitoring System

Airport snow removal vehicles monitoring system is composed of the mobile terminal and the monitoring center. Mobile terminal is responsible for real-time acquisition of information, including the real-time image information, the vehicle GPS location and status information at this moment, such as temperature information, pressure information, traffic information, speed information, etc. [1]. The mobile terminal also shoulders early-warning task, in response to the warning signal from the monitoring center, such as the anti-collision warning. System schematic diagram is as shown in Fig. 1.

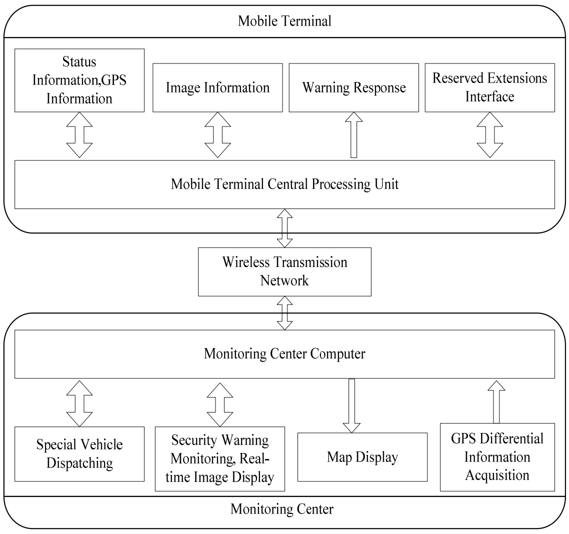

Fig. 1. Vehicle Command and Dispatching System Schematic.

2.2. Requirements of Data Transmission for Snow Removal Vehicles Monitoring System

Requirements of data transmission for snow removal vehicles monitoring system are mainly divided into the following sections. The first part is the transmission of the GPS location information. The second part is the status information, including the amount of the deicing fluid, flow, temperature, and vehicle running speed, etc. The third part is the mutual information of the mobile terminal and monitoring center, which is mainly the release and response of early-warning information. The fourth part is the image data. According to the current conditions of the wireless data transmission, it is necessary to compress the image data so as to achieve the wireless transmission of images.

2.3. Design of Data Transmission Method

GPRS service can, in theory, reach the rate of 171.2 kbps, which features highly efficient and low-cost thanks to its transmitting and receiving data in the packet switching mode. In the communication platform of this system, the wireless communication module based on GPRS--CM3160P GPRS DTU (Data Terminate Unit) is used to establish a mobile terminal as a wireless transmission channel. The 3 G network or the wired broadband network is used in the monitoring center. The schematic diagram of the communication platform system is shown in Fig. 2.

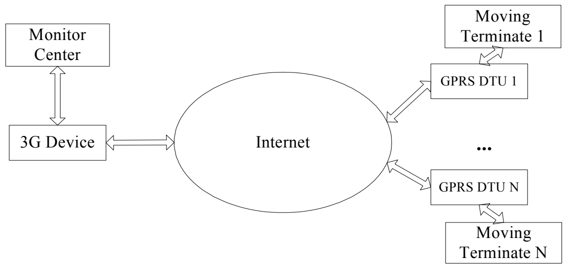

Fig. 2. Schematic diagram of Communications platform.

3. Design of Image Acquisition Unit

3.1. Design of Image Acquisition and Compression Method

The signal flow of the image acquisition unit is substantially as follows. After image acquisition instruction is detected by DSP, CPLD control logic starts the camera into the image acquisition program. The acquired original image data is stored into SDRAM under the control of DSP [2, 3]. When a frame acquisition is completed, the DSP initiates image compression program and stores the compressed data into SDRAM. After compression is completed, DSP sends the compression completion signal and initiates image transmission program. The overall structure and signal flow of image acquisition unit is shown in Fig. 3.

The JPEG lossy compression technology is used in this paper. The system software flow of image acquisition unit based on the JPEG compression algorithm is shown in Fig. 4.

The JPEG image compression algorithm used in the system for compressing still images has the following features: the relative easiness to achieve algorithm, having a standard function library, less visual distortion, more compression, etc. [4]. The algorithm flow is shown in Fig. 5.

The JPEG algorithm process includes four main steps: partitioning for the image data, the DCT transformation for the partitioned data, followed by quantization and Huffman coding [5, 6]. Original image must go through pretreatments such as color mode conversion, partitioning and interpolation firstly.

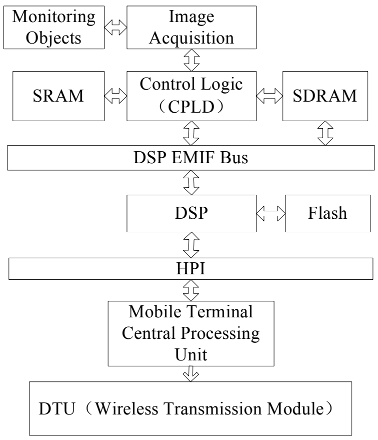

Fig. 3. Image Unit Hardware Diagram.

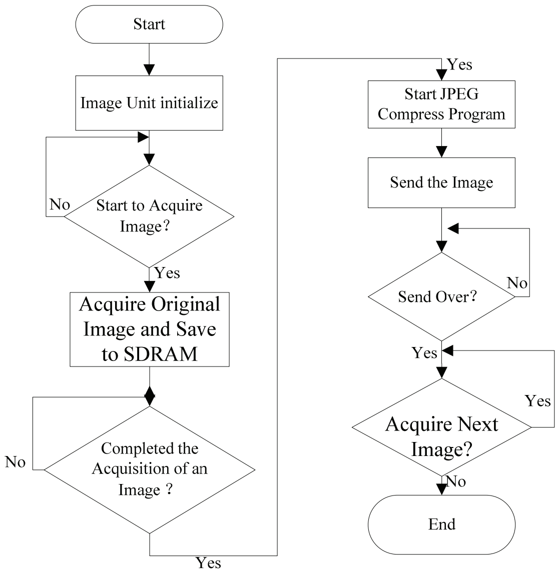

Fig. 4. The Software Flowchart of Image Acquisition Unit.

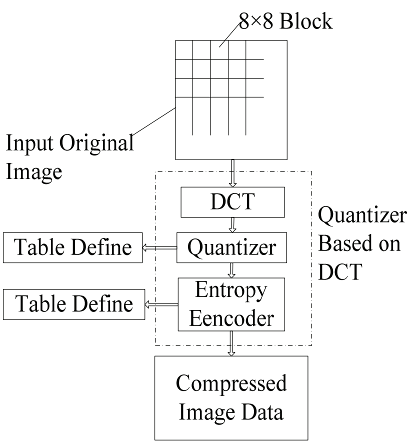

Fig. 5. The Software Flowchart of Image Acquisition Unit.

8×8 pixel block is calculated by DCT, and 64 DCT coefficients are scalar quantized. After quantizing DCT coefficients, the coefficients in the block are re-sorted according to the "Z" shaped scanning mode. Thus the obtained bit stream is an intermediate symbol sequence generated by line sequential coding. If these symbols are encoded by entropy encoder, the final JEPG encoding is completed [7, 8].

3.2. Design of Image Transmission and Monitoring Center

If the resolution of images collected by the acquisition unit is 320×240, the images will be 10 kB ~ 30 kB in size after JPEG compression, and the time to transmit a frame image will theoretically be 1 s~3 s. In the process of transmission, the operation of adding the head of the JPEG file will be carried out on the host computer. Thus, the transmission format of the data will only be the theme data portion of compressed images. The specifically used image data format is shown in Fig. 6.

Head of Frame($) —Size— Frame No.—Data Area······ Checking— End of Frame

Fig. 6. The Format of Compressed Image Data.

With the format of data transmission, larger image data can be transferred by sub-block, and the image data will be integrated by monitoring center. The workflow of image transmission test is as follows. Firstly a communication link is to be established. The lower machine should make a series of parameter configuration for the GPRS DTU, including the serial port baud rate, the domain name of network service, etc. After rewriting the compiled lower computer program into the core control devices of image unit within the mobile terminal, the monitoring software of host computer is to be opened. When the network linking is established successfully, the image acquisition command can be sent to the lower computer to start a real-time image acquisition. The image acquisition unit is shown in Fig. 7. The left side is image acquisition unit, and the right side is communication module.

Fig. 7. The Picture of Image Acquisition Unit and Lower Machine Communication Module.

The powerful visualized software development tool, Microsoft Visual C + + 6.0, is used in the image monitoring center of the system. The workflow of the image monitoring center is shown in Fig. 8.

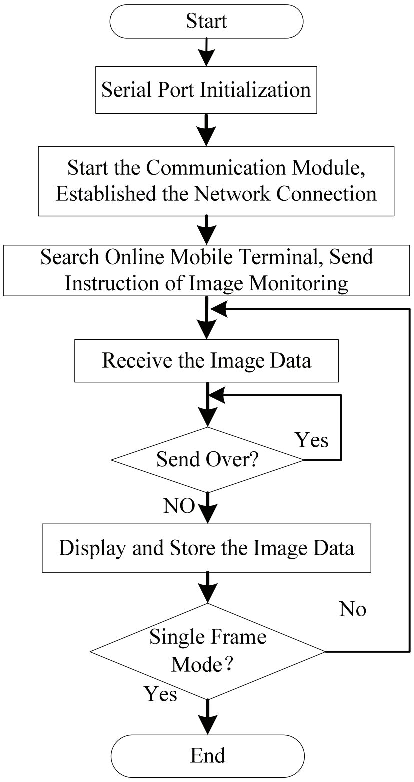

Fig. 8. The Monitoring Process of Image Monitoring center.

4. Design of Automatic Detection Methods for Airport Snow Removal Vehicles Operating Effect

4.1. Research of Pattern Recognition Technology

From the point of view of visual recognition, pattern recognition can be called image recognition. Image recognition is to identify the image information obtained by computer by using computer and optical system. While there is an extremely wide range for the amount of information contained in images, which, specifically, can be a variety of intuitive image pictures, patterns, text, drawings and non-intuitive image only with data or signal waveform, such as voice, electrocardiogram and seismic waves. Image recognition aims to take advantage of computers automatically to complete the image classification and identification automatically instead of people. Strictly speaking, the image recognition and the pattern recognition are the same in principle and only different in the recognition process. The image recognition process can be included in the pattern recognition. The image recognition process mainly includes image preprocessing, image segmentation, image feature extraction and image classification, etc. as shown in Fig. 9.

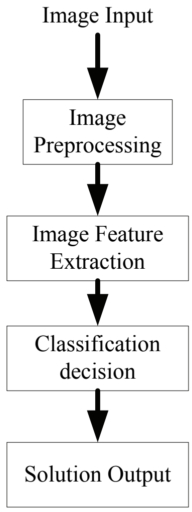

Fig. 9. The Basic Process of Image Recognition.

As for the image processing of effect of snow removal vehicles operating in this paper, the processing methods mainly include image graying, region segmentation and extraction of threshold, image smoothing and enhancement, Color transformation and segmentation, etc.

4.2. Research of Automatic Evaluation Methods of Operating Effect

Firstly, we should preprocess the acquired real-time image of snow removal job effects, and mainly process the image smoothing. The processing method selected in this paper is mean filter (also called moving average method). RGB value of a pixel in the color image is expressed as $f(r_{ij}, g_{ij}, b_{ij})$, whose neighborhood are shown differentially according to the subscript i and j, and the value range of each component R, G, and B is [0,255]. The mean-filtered pixel value is expressed as $g(r_{ij}, g_{ij}, b_{ij})$ which is decided by Formula (1).

$$
\begin{aligned}
g(r_{ij}, g_{ij}, b_{ij}) = [& f(r_{i-1j-1}, g_{i-1j-1}, b_{i-1j-1}) + f(r_{i-1j}, g_{i-1j}, b_{i-1j}) \\
& + f(r_{i-1j+1}, g_{i-1j+1}, b_{i-1j+1}) + f(r_{ij-1}, g_{ij-1}, b_{ij-1}) + f(r_{ij}, g_{ij}, b_{ij}) \\
& + f(r_{ij+1}, g_{ij+1}, b_{ij+1}) + f(r_{i+1j-1}, g_{i+1j-1}, b_{i+1j-1}) \\
& + f(r_{i+1j}, g_{i+1j}, b_{i+1j}) + f(r_{i+1j+1}, g_{i+1j+1}, b_{i+1j+1})]/9
\end{aligned} \quad (1)
$$

3×3 matrix is selected as denoising template of mean filter, and the 8 neighborhood average method is used, whose configuration is shown in Fig. 10.

f_{ij} is equivalent to the above-mentioned $f(r_{ij}, g_{ij}, b_{ij})$ and g_{ij} is equivalent to $g(r_{ij}, g_{ij}, b_{ij})$ in this place [9].

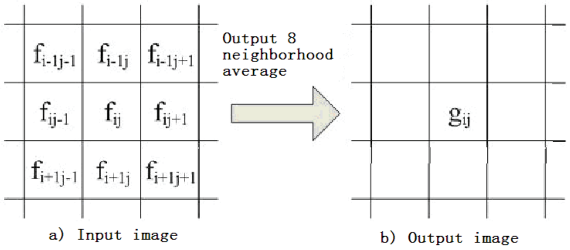

Fig. 10. 3×3 Point Denoising Processing Schematic Drawing Template.

Mean filter function Average Filter () is compiled according to the 8 neighborhood average method. And this function is added to VC++ for noise filtering processing of images. The effect is shown in Fig. 11.

Fig. 11. The Comparison Chart of Snow Removal Vehicles Operating Effect Diagram by Mean Filter.

The image threshold segmentation of operation effect is followed. Image threshold segmentation is an image processing technology based on the region, which apart the image regions with specific characteristics from other different regions by setting threshold value with different characteristics. The commonly used characteristics are image grayscale and RGB. Based on careful analysis of effect image of snow removal vehicles operating, it can be known that feature extraction is to extract the white snow's feature. The characteristic parameters acquisition is to acquire the amount of color information of each pixel of white snow. After testing, the grayscale threshold value of snow is set to (160 ～ 240) and the characteristic area threshold value is set to (670 ～ 680).

5. Experiment and Result Analysis

5.1. The Experiment Idea

The most simple and direct way to acquire the field road residual snow characteristics is to mark uniform region. The most obvious feature of snow is highlighted, whose pixel in distribution area are totally distinct from the nature color of the field road, while the marked uniform region is similar to the image binary region mark. The main difference between them is that the former does not require pretreatment before region marking, and areas within a certain threshold value range can be marked directly. Then we can obtain area characteristics S by making a statistic of the number of pixels in the marked uniform region.

For traditional pattern recognition, the acquired characteristics need to be compared with the existing sample library for training the sample library, and then we can make a corresponding identification. While in automatic monitoring system of snow removal vehicles operating effect, the size of the obtained region should be paid attention to instead of the shape. Therefore, we can assess the effect of snow removal, as long as the ratio of the characteristic and the total region, that is the ratio of the residual snow region and the detected surface, is acquired in the system [10].

5.2. The Result and Analysis

In order to get the effective region of snow removal vehicles, the edge of the field road must be found in the analysis of the residual snow region. The search for effective area of snow removal and the calculation of percentage of residual snow area can be processed by analyzing the data of the binary images in the system. The image binary effect of snow removal vehicles operating effect diagram is shown in Fig. 12. The CANNY Operator is used for image edge detection in this paper, and the edge detection effect of runway in snow removal effect pictures is shown in Fig. 13.

Fig. 12. The Image Binary of Removal Vehicles Operating Effect Diagram.

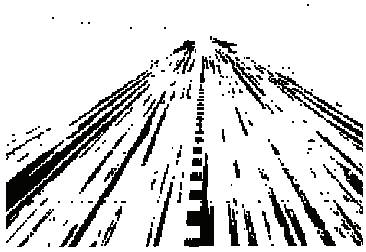

Fig. 13. The Runway Area after Edge Detection.

The percentage of the snow remaining area can be drawn by analyzing Fig. 13. The effective snow removal area is 46 % through the calculation of PC software. After getting the residual snow's relative proportion, the basis of deicing quality evaluation and scheduling system is established.

6. Conclusions

1) The way of wireless data transfer and image acquisition for the airport deicing vehicles was founded, as well as the image compress and transfer using JPEG algorithms based on DSP. The experiment results revealed that the response of the moving terminal was less than 100 ms. The monitoring center can decompress image data of JPG format, display the data, and automatically evaluate the snow removal effect by analyzing the images. The time from sending commands to completing the assessment is less than 5 s, which basically meets the requirements. The main reason for the long time spent on acquiring images is the bandwidth limit of GPRS network.

2) The airport runway snow removal result based on image recognition was researched, and the experiment verified that the way can get the area proportion between the residual snow and the runway by analyzing the runway snow removal image, which could help to evaluation the runway snow removal and the further schedule and optimization.

Acknowledgements

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