Design of Real-time Video Transmission System for Drone Reliability

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Abstract. The low-latency reliability video transmission system designed in this paper can complete the functions of real-time image acquisition, transmission and display. The system uses Raspberry Pi 3B+ controller as the core; the 500W pixel camera OV5647 module with CSI interface feature is used as the acquisition module to collect image data in real time and perform compression coding processing; adaptive control of image measurement and control data through 4G public mobile communication network transmission. The experimental results show that the reliability video transmission method designed in this paper can achieve low latency reliability transmission of 480P and 720P resolutions. It can ensure low-latency reception of HD images at the receiving end, and the receiving frame rate is stable above 11FPS, which satisfies the system design requirements.

Keywords: Image acquisition; image compression; data transmission; Raspberry Pi.

1. Introduction

UAVs have been widely used in civil three-dimensional city modelling, environmental monitoring, military drone inspection area. This application involves real-time reliable transmission of high-definition images and measurement and control data [1]. Since the real-time image information collection of the drone has poor anti-interference ability and large delay, the transmission of the reliability video cannot be guaranteed. In view of the huge image data, the transmission of HD images, network delay, the frame rate of transmission, visual and observability, and other indicators are extremely important, which is an important factor affecting the quality of UAV HD video transmission. In network image transmission, most of them are currently transmitted based on pixel access. The size of the transmission is the resolution of the image and the number of channels. The resolution of the image size captured by the ordinary camera is 640*480*3, based on pixel access. The image transmission needs to transmit 921,600 bytes. The consumption of network resources is large, and the real-time reliability of image data cannot be guaranteed, which easily causes the video to be stuck. Therefore, for the UAV measurement and control technology based on public mobile communication network, the real-time reliability transmission technology of broadband HD image and measurement and control data is broken, and a remote monitoring and control system for UAV based on 4G public mobile communication network is developed [2]. Low latency reliability video transmission. The reliability video transmission system designed in this paper can complete the acquisition, compression and measurement for real-time image data. According to the integration with image information, network parallel transmission, secondary cache display and other functions is completed. Through acquisition and compression, the real-time image data of the OV5647 module camera is collected, and the image data is pre-processed by a simple image compression algorithm to ensure the
normal transmission of high-definition images. The parallel transmission of the network and the secondary cache of the receiving end ensure the smoothness of the display, and the subsequent functions such as display and acquisition of the data stream are realized by developing the host computer software. It avoids the jam of the video and has certain application innovations.

2. The System Works
The system consists of an image acquisition controller and a host computer software. The specific working principle is as follows. First of all, the UAV on the image acquisition controller needs to be used to open the image acquisition command by means of the host computer software, and at the same time set the image transmission resolution and transmit the data through the 4G module. The host computer software realizes data decoding and real-time display of the transmitted image. The working principle of the system is shown in Fig 1.

3. Image Acquisition Controller Design
The image acquisition controller consists of Raspberry Pi 3B+ module [3-4], video image acquisition module, 4G network transmission module and so on. as shown in Fig 2:

3.1. Raspberry Pi 3B+ Module
The Raspberry Pi 3B+ module is used as the CPU module of the transmission system. The Raspberry Pi is an ARM-based micro-computer motherboard with an SD/MicroSD card as a memory hard drive and a Linux system. The Raspberry Pi hardware supports Python language development; it also has a direct external USB interface for direct external image input to the USB camera. The CSI interface can also be used for external cameras, making it easier to collect real-time images.

3.2. Video Image Acquisition Module
In order to obtain the real-time image of the drone, the 500W pixel camera OV5647 module with more convenient CSI interface characteristics is used as the image data acquisition. The camera supports multiple resolutions. Use IIC to communicate with the CPU to implement the setting of the OV5647 module.

3.3. 4G Network Module
The 4G module can realize the interaction between the image acquisition controller and the PC host computer software, and realizes the interaction of the network data and the image transmission through the PC host computer software. Python3 sets the 4G module through the AT command. Set the Raspberry Pi controller to the client and the PC to the server. The acquisition and transmission image command is enabled by the server, and after the client answers, the image of the two resolutions is set to be transmitted. The UAV remote measurement and control system based on 4G public mobile communication network can realize the low-delay reliability video transmission through image
compression, parallel transmission and L2 cache. The system working block diagram is shown in Fig4 below:

![System working block diagram](image)

**Figure 3. Video image acquisition module interface diagram**

**Fig 4. 4G module working block diagram**

Fig 5 shows the circuit connection diagram of the 4G communication module. The communication module uses the SIM7600CE chip. The chip has full Netcom 7 mode, LTE CAT4 (up to 150Mbps network speed), low power consumption, etc., and can directly interact with the module through the serial port. Rapid development with AT commands.

3.4. MicroSD Module

For the Micro SD module, it is an indispensable part of the system. The environment and code for the system are installed in the SD. The circuit connection diagram of the system storage module is shown in Fig6. It has four data line interfaces, respectively connected with pull-up resistors, and CMD is a command line to interact with the CPU.

![4G module interface diagram](image)

**Figure 5. 4G module interface diagram**

**Figure 6. SD module interface diagram.**

3.5. HDMI Module

HDMI is mainly responsible for the debugging output display of the Raspberry Pi system. Fig7 shows the connection diagram of the HDMI display module, 2 clock signals and 3 data signals, CEC is the control signal line, and a pair of IIC signals, mainly to obtain the basic information of the display. HPD is the hot plug signal, this signal is more important. When the HPD pin is greater than 2V, TMDS will output.

4. Software Design

4.1. Image Compression Algorithm Design
Image segmentation data is used for processing, and inter-frame data compression technology is used to compress video stream data [5-6]. The three-level discrete wavelet transform, DWT (Discrete Wavelet Transform), is used to transform the spatial domain image into the frequency domain for analysis. The base vector is independent of the image content and has a certain interference ability for the image noise. After the image is transformed by DWT, the frequency coefficients are mainly concentrated in a relatively small range and mainly distributed in the low frequency part. The portion of the sparse spectrum that has less energy retains the main frequency components in the transmission spectrum, thereby achieving the purpose of compressing the data. The wavelet transform can also observe the data information in both the time domain and the frequency domain. In the JPEG2000 codec system, the wavelet transform can generate a large number of wave-let transform coefficients of 0 or approximately 0, thereby obtaining a higher compression ratio [7]. Fig 8 shows the code decoding flowchart of this article:

4.2. Parallel Transmission Module Design
In order to ensure that the video stream data of the receiving end can produce a silky video effect, the receiving queue is used to receive the data in the data stream transmitted from the transmitting end, and the image data is stored in the image stream data buffer after pre-processing the received data area. When an image is required, it can be read through the image data stream buffer area to realize display and output of image data. At the same time, the image data stream is fragmented at the data transmission end, and transmitted in parallel through the transmission queue, thereby improving transmission efficiency and reducing transmission delay. Fig 9 below shows a schematic diagram of the secondary cache for data reception.

4.3. PC Software Design
The host computer software uses the Microsoft Visual Studio 2012 development tool developed by Microsoft to write the "low latency reliability video transmission" PC software based on UDP network transmission, open the Server service, control the client-side image acquisition mode and image data in real time display. Using Python3+PyQt5 for UI design, the UI file designed by QT Designer can be compiled into a Python file by using the pyuic5 command, which can be called directly using Python3 [8].

Fig 10 shows the running software of the PC host computer with the pixel of 640*480 when the onboard UAV is hovering and flying.
The PC computer software mainly sets the Server service by setting. After the Client connects, the resolution of the acquisition is set at the same time. After the image acquisition is started, the RGB three-component and grey-scale video stream display can be performed by the "Red, Green, Blue and Grey" in the host computer software. Mode switching, you can manually adjust the "exposure time, gain, contrast" and other imaging parameters to achieve a more comfortable display. At the same time, the resolution of the currently acquired image can be displayed in real time and the current frame rate FPS can be calculated.

The system can collect high-definition image data and calculate the acquisition frame rate in real time. The image quality is more comfortable by manually adjusting the "exposure time, gain, contrast" and the like. As shown in Fig11, the 640*480 and 1280*720 resolutions are in the upper computer operation diagram under different parameter configurations. It can be seen from the current frame rate that the frame rate of 640*480 is generally higher than 1280*720. When the HD video stream data is displayed, the receiving frame rate is slightly decreased, which is about 11FPS, which basically meets the project requirements.

5. Experimental Analysis and Discussion

Due to the limited running resources of the Raspberry Pi, there is a certain delay for the real-time transmission of video stream data, which basically does not affect the visual effect. The three indicators that are concerned about the transmission of UAV real-time video: delay, frame rate, resolution, where the transmission delay affects the display frame rate in real time, and the resolution affects the video pixels [9-11]. The OV5647 module is used to collect images of different resolutions in real time for network transmission. This paper mainly tests real-time video transmission indicators for resolution 640*480 and resolution 1280*720. For network delay and video frame rate mainly affect the visual effect of the receiving end, this paper uses one every 10 frames of image to perform data statistics, that is the average data per 10 frames, that is, the transmission network delay and display frequency are separated by 10 frames. As shown in Table 1, the test results are statistically calculated for each of the parameters of image acquisition and reception.

| Resolution | Collection (ms) | Coding (ms) | Decoding (ms) | Display (ms) | Total Time (ms) | Receive-Frame-Rate (FPS) |
|------------|----------------|-------------|---------------|--------------|-----------------|--------------------------|
| 480P       | 10.145161      | 25.750587   | 24.024348     | 2.098006     | 61              | 18.51                    |
| 720P       | 15.811349      | 50.498578   | 51.527059     | 3.801657     | 119             | 13.9                     |

It can be seen from Table 1 that when the resolution is 640*480, it can realize low-latency reliability video transmission, and the receiving frame rate can reach 18FPS, which basically does not produce a click feeling. For the resolution of 1280*720, the delay has reached 119ms, and the receiving display frame rate is 13FPS, resulting in a slight click feeling. From the video stream picture
received by the receiving end in real time, the corresponding fluency can be basically maintained [12-14].

6. Conclusion
The reliability video transmission system designed in this paper realizes the real-time transmission of low-latency reliability HD video through image compression and parallel transmission through 4G as a network communication method, and tests the real-time video transmission of 480P and 720P resolutions through experiments. Basically, the smoothness of the video can be guaranteed. It shows that the current system has certain feasibility, and it has certain research significance for the realization of remote measurement and control of drone.

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