A scheme of transmission system in micro robotics based on combined information data

Ziyao Wang[1, a], Ye Xue[2, b], Zhijie Dong[2,c], Ziyuan Li[2,d], Congyue Zhang[2,e], Yingzi Tan[1f]

[1]School of Automation, Southeast University, Nanjing, China

[2]Chien-Shiung Wu College, Southeast University, Nanjing, China

[a]zy_wang@seu.edu.cn, [b]yexue@seu.edu.cn, [c]seudzj@163.com, [d]liziyuan@2008.sina.com
[e]zhangcongyue1993@sina.com,[f]tanyz@seu.edu.cn

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Abstract. Traditional inspection robots which equipped with analog camera normally have two channels to transmit image information and control signal. However, this double-channel method causes difficulties in miniaturization of robots. In this paper, we proposed a new scheme in which WIFI technology is utilized to intergrate images information and control signal to diminish the size of the module into 4*3cm^2. In order to realize the miniaturization, a RT5350 router is selected as the main controller. Through the establishment of a wireless local area network (WLAN), the mixed data (including frame image and the maximum 4KB control information) eventually reach the transmission rate of 15-30 fps. The scheme proposed in this paper can be implemented in a variety of situations, such as indoor mobile monitoring, micro land investigation, micro air vehicle, etc. Up to now, this scheme has been implemented and validated in miniature detecting robot. Experiments show that the transmission of image information is smooth and stable and the control signal is accurate and reliable.

Introduction

As is widely acknowledged, there are two key characteristics of miniature inspection robots: one is the small size, the other is transmitting images or other information. Currently, the transmission of image information and control signal are divided into two channels. This kind of design occupies a large space, which is a certain obstacle to reduce the volume of robots. In order to solve this problem, using a single module is proposed to replace the two-channel transmission.

In addition, miniature inspection robot is not only required to collect image information, but also, in some circumstance, to collect the information like temperature, smoke and poisonous components in the air, etc. In order to facilitate future upgrades, a number of interfaces are set aside for subsequent use.

Thus, many practitioners and researchers have designed the transmission system with combination of image information and control signal for a robotics system. Longshen Liu, Mingxia Shen et al. [1]have used FPGA as well as 3G wireless network to achieve the image acquisition and control signal transmission, but the transmission of frame image to be about 5.42s, which does not meet the real-time requirements. Wenwen Chen, Guozheng Yan et al. [2] have studied wireless two-way communication method for micro robot in intestinal clinic and designed a two-way half-duplex wireless communication system, including human computer interface, communication box and wireless data transmission module and video image transmission module. The experimental results show that the two-way communication of RF can completely send control single and receive diagnostic data within 0.6s. In the meanwhile, robot motion is continuously stable and video image is clear. Ren Chen, Zhenbo Li et al. [3] have extended USB module in the ARM chip external bus and the host computer through the USB interface to receive data and display images. The whole system has a small size, in low power consumption and high transmission rate, which can be used for micro robot vision and control system. However, the shortcoming is that wired transmission is not suit for remote control. Aiming at solving the deficiency of the micro unmanned aerial vehicle (MUAV) image simulation transmission and the requirement of real-time and reliable image transmission, Zhen Gao, Jiahao Deng et al. [4] have proposed an improved set partitioned embedded block (speck) image compression algorithm based on a 5/3 wavelet lifting scheme and a digital image wireless transmission system scheme based on Turbo channel coding and spread spectrum technology.

The main work of in this paper is to combine the two signal (video information and control signal) when transmission. In consideration of scalability, it is necessary to modular equipment, also make good to diminish the size of the module, and set aside communication interfaces.

System Architecture

Client-server architectural style is used in this system. The robot functions as the client together with a controller which works as the server to capture the control signal as well as processes and displays the image. This architecture takes advantages of the devices in both sides, therefore, has a low complexity in communication of the system. In addition, this architecture also shows a huge potential in extendibility.

Main control unit in server. In proposed system, server is in charge of various crucial tasks such as setting up the WLAN, image capture, image compression, reconfiguration of the image information and the instruction, transmission the control singnal, ect. Thus, a processor with the ability to solve big data, sufficient peripheral interfaces and other corresponding functions is required in server. Furthermore, the size of the control unit should be minimized according to the size of the robot.

Taking all the propoerties mentioned above into consideration, RT5350(produced by Ralink) is chosen as the controller in server. The RT5350 SoC combines Ralink’s 802.11n draft compliant 1T1R MAC/BBP/PA/RF, a high performance 360 MHz MIPS24KEc CUP core, 5-ports integrated 10/100 Ethernet Switch/PHY and an USB Host/Device. With the RT5350, there are very few external components required for 2.4GHz 11n wireless products. The RT5350 employs Ralink 2nd generation 11n technologies for longer range and better throughput. The embedded high performance CPU can process WIFI data processing without overloading the host processor. Also, the RT5350 has rich hardware interfaces with a small size package (12mm×12mm TFBGA-196). In addition, HLK-RM04, a low-cost embedded UART-ETH-WIFI module, is introduced in the server due to its mini size.

Video capture. In terms of a better performance, the OV9726 image sensor is seclected as the camera in this system. The OV9726 is a 1/6.5-inch native 720p/30 HD COMS image sensor, designed specifically for ultra-compact, high-performance HD cameras for portable electronics. The OV9726 can achieve superior low-light sensitivity(1300mv/lux-sec),reduced crosstalk and excellent quantum efficiency to ensure high color fidelity and image clarity. The sensor's short stack height of only 3.5mm enables the smallest available camera modules in its class.

Communication scheme. Table 1 lists four wireless communication methods which are in most extensive use. In terms of the transmission rate, distance and cost required in this system, WIFI is chosen due to its more rational trade-off.

Table 1. Comparison within wireless communication methods

Methods	Cost	power consumption	transmission rat e	transmission distance
3G/4G	High	High	High	Long
WIFI	Low	High	High	Short
Bluetooth	Low	Medium	Medium	Short
Zigbee	Low	Low	Low	Short

Software scheme

Software platform. Since HLK-RM04 module has a complete hardware structure and the size of it is also consistent with expectations, the design of the software which involved in proposed system is based on the HLK-RM04 module hardware platform.

HLK-RM04 module supports the LINUX systems with RT5350 as its CPU which contains 8M SPI FLASH and 32M SDRAM. Before changing the original system into LINUX system in this module, U-Boot is needed as a root of the system. Under this circumstance, Linux 2.6.4 operating system designed by the company Ralink is selected, and the DHCP is started through the WEB interface configuration, then follows by filtering MAC address, building bridge mode, ensuring SSID and passwords, choosing signal frequencies. Finally, Wireless Local Area Network can be established.

When developing Ralink AP SDK4.3.0.0 in PC Ubuntu system, NFS is used for files sharing and speeding up this process

Design of Client-Side. The Client adds the control signal which follows the rules of RT instruction into the Imaging and Control Information Transport Protocol, and then after processed by the Transport Protocol, all the information will be transmitted to the Server through Wireless Local Area Network. In the same way, image information sent by the Server, is also processed by the Transport Protocol and transmitted through Wireless Local Area Network. However, in order to reveal the Image on the screen, the Server decompresses the images and uses the technology of Libjpeg and API function. The structure of Client-Side is shown in Fig.1.

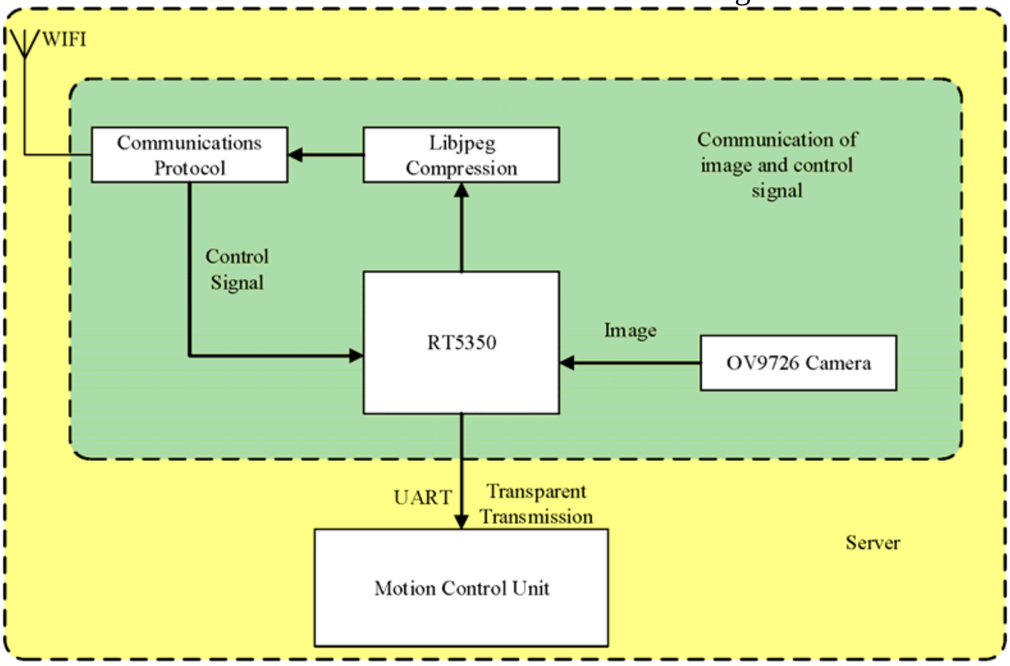

Fig.1. Architecture of server

Design of Server-Side. In Server-Side, RT5350 module employs camera OV9726 to acquire the information of images, and then compresses this information with the aid of the technology of Libjpeg. Finally, after adding with control messages, all information will be transmitted to the Client through Wireless Local Area Network. Meanwhile, the information transmitted by the Client is received by the Server. All information will be read by the Transport Protocol in order to get the control messages, which will be sent to RT5350 and transmitted transparently through UART to external control units. The structure of Client-Side is shown in Fig.2.

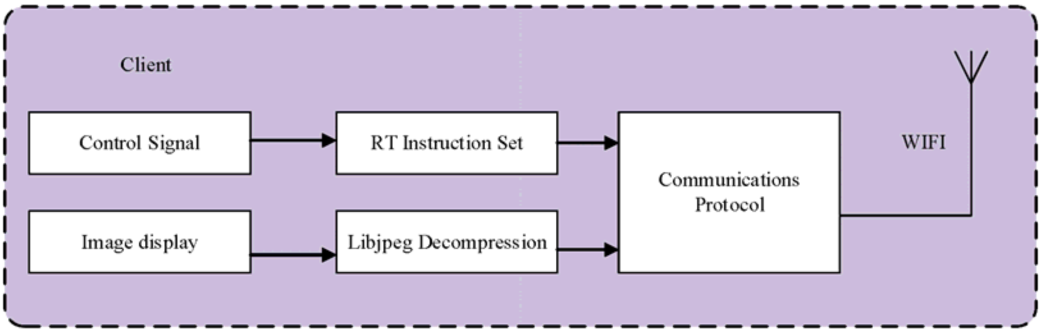

Fig.2. Architecture of client

Capture video. In the system of Linux, using video capture devices should comply with Video4Linux standard. Video4Linux (V4L) is a Linux kernel driver for video equipment, providing a set of interface functions to application programs for video devices, which including video capture cards and TV cards, USB cameras, etc.

The general process of capturing video is:

1) Open video devices;
2) Read the device information;
3) Capture video data;
4) Process and display this data;
5) Turn off video devices.

Two main methods of capturing video:

6) Directly read from devices;
7) Memory mapping.

The system uses the second method, of which, the advantages are obvious. When using memory mapping, directly using *mmap ()* function can make system share memory between processes through mapping the same file. Common files which are mapped into the process's address space, can be accessed by the process easily just like memory. There is no requirement of calling *read (), write (),* and other functions. And an obvious benefit of sharing memory is the high efficiency, because the process can read or write memory directly without the copies of the data.

Using Libjpeg for image compression. Libjpeg is a library written entirely in *C*, and contains the widely used JPEG decoder, JPEG encoder and other JPEG functions. This library is maintained by an independent JPEG Group. 6B, the latest version, released in 1998, can transform JPEG files between other popular graphics files, insert and extract textual information from JPEG file, transform between different JPEG formats without loss massages, eliminate the insert data from non-standard application by using some graphics programs, and do transformation in files, which including all "non-destructive" operation, such as changing grayscale gradients, rotating, flipping and cutting. The processes of using Libjpeg for Image Compression are shown in Fig.3.

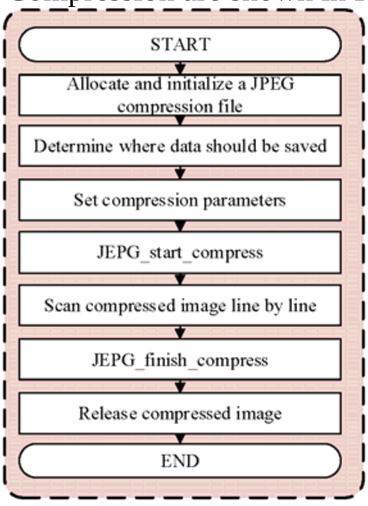

Fig.3. Processes of using Libjpeg for image compression

Using Libjpeg for image decompression. Decompression and compression are inverse processes which work in the same way but aim of different processes.

RT instruction formation. Transparent transmission is used in this module. In order to make it easier for the lower control unit to receive massages, PC should also follow RT instruction.

RT instruction is in the same style of AT instruction, but designed in an independent format, whose basic format is:

$$RT + command + one\ check\ bit + \backslash r + \backslash n$$

This check bit is the sum of all check bits received before.

When control unit receives *RT* characters, it will select the instructions from the middle section, and then perform appropriate actions.

The structure of RT instruction is simple and it is easy to transfer simple commands, but the structure of this instruction should avoid conflicting with the original formatting instructions when design it.

Picture and Transmission Control Protocol

In order to control the transmission of image and information effectively, a novel application layer protocol is proposed, which is modified by the HTTP protocol, and also, TCP protocol is used for reliable transmission in the network protocol stack. Further explanation of the transmission process is as follows:

1) When the server is in the listening state, the client begins to request the connection;
2) The client sends the authentication message with the server receives the authentication and returns the confirmation;
3) Image and control information are ready to be transmitted;
4) The server sends compressed image data length in ‘Lth: XXXX’ format, where "XXXX" is the data length; and the client is waiting for reception;
5) The client receives data in step 4,and data length together with returning a success state signal, if successful, it will wait to receive the server information, otherwise, exit the frame and turn back to step 4; Meanwhile, the server is in waiting state;
6) The server makes judge to the return state in step 5, if successful, transmitting compressed image, then wait for the client to receive the messages, if failed, the server exits the frame transmission and returns to step 4, if the received return state timeout, the servers returns to step1; The client waits for receiving or returns to step4;
7) The client receives the compressed image data, fills it into the compressed image data buffer, obtains the information that needs to be transmitted at present, and sends it to server, and then waits for the server to return information; The server waits for receiving;
8) The server receives data that needs transparent transmission, transmits all the information through UART, if receiving the return state timeout, returns to step 1, obtains the current received data that need to pass through to the client's information, sends to the client and waiting for a client to return information; the client waits to receive.
9) The client receives the information, fills in the transmission information buffer, and sends the confirmation information to the server, the client ends the frame transmission, then returns to step 4; the client waits to receive.
10) The server receives the confirmation message from the client side, returns the step 4, and returns the step 1 if the received return state is timed out;

All the work steps are shown in Fig.4

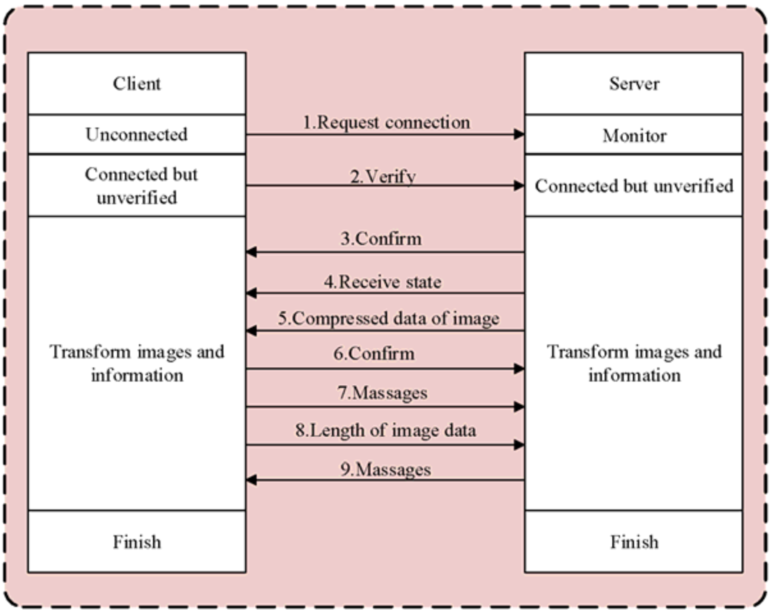

Fig.4. Process of Imaging and Control Information Transport Protocol

System implementation

Test results for the experiment of the proposed scheme is shown in Fig.5, with the experiments are made both on the ground and in the air. The video of client shown in the figure is clear and continuous, and the control of the robot in real-time is realized.

Fig.5. Air and ground experiments

The experimental data of each version is shown in Table 2, which illustrates the advantages of the current versions compared with the previous versions:

1) Image turns into a digital image from an analog image, image definition is guaranteed.
2) Image resolution ratio is improved, so as to benefit for showing details.
3) The number and size of modules are greatly reduced. (The number of antennas is reduced to 1, which provides more possibility for the miniaturization of the robot)
4) The frame rate is significantly improved, which provides smooth screen.
5) The volume of the robot is greatly reduced.

Table 2. Experimental data for three versions

test item \ version		First version	Second version	Current version
Image type		analog image	digital image	digital image
Image resolution		\	120x80	640x480
Module size [cm]		\	10x15	3x4
Antenna number		2	1	1
Transmission distance [m]		30	10	30
Frame number (5m)[fps]		\	0.4	24.4
Frame number (10m)[fps]		\	0.3	22.7
Frame number (20m)[fps]		\	0	18.9
Frame number (30m)[fps]		\	0	13.0
Robot size [cm]	length	20	35	7
	width	10	25	7
	height	10	8	2

Conclusions

Micro inspection robot is still under development due to the immature relevant technologies. Therefore, this paper makes analysis and summary the existing micro robots, and makes simple discussions and analysis about the key problems. The paper focuses on micro inspection robot in transmission problem.

Two possible solutions are proposed as follow:

1) Improving transmission efficiency by higher compression.
2) Reducing the channel interference through combining two channels.

The proposed scheme can be applied in a smaller and lighter robot, meanwhile provide the capability to transmit image information and control signal at the same time as well as to access the Internet. This scheme is suitable for indoor mobile monitoring, micro land surface investigation, and micro air vehicle. For the future research, A wide range of wireless remote control and detection is planned to be achieve by taking the advantages of WIFI an d other wireless networking

References

[1] Longshen Liu, Mingxia Shen, Yuwen Sun, Mingzhou Lu, Yingjun Xiong: Transactions of the Chinese Society for Agricultural Machinery (2011),42(12) p.187~190.

[2] Wenwen Chen, Guozheng Yan, Peng Gao: Chinese High Technology Letters (2012),22(10) p.1050~1055

[3]Ren Chen, Zhenbo Li, Jiapin Chen: MICROPROCESSORS(2009),30(5) p.122~127.

[4]Zhen Gao, Jiahao Deng, Ji Sun: TRANSACTIONS OF BEIJING INSTITUTE OF TECHNOLOGY (2008),28(12) p.1078~1082.

[5]Wanhui Liao, Lin Li: CONTROL & AUTOMATION (2009),25(8) p.242~244.

[6] Jing Fang, Yong Shi, Lelin Wang: CONTROL & AUTOMATION (2010),26(29) p.163~165.

