Research and Design of Face Recognition System Based on Embedded Wi-Fi

Mi Wang, Kezhong Zhang, and Peizhi Liu

***Abstract*—The purpose of this study is building a face recognition system. Wireless technology and Adaboost algorithm is applied in this embedded system.The whole system includes two parts: server part and client part.The server part, which is based on ARM9 microprocessor, can detect faces, compress the image data and send it to the server part using Wi-Fi wireless transmission module. Then the client part receives the data, manages to recognize face automatically and identify faces by comparing image in the database. The client part deals with face detection and face region positioning via Adaboost fast face detection algorithm combined with digital image processing of grayscale balance, filtering, wavelet transform to acquire standard face image. Three-layer BP neural network is designed for automatic face recognition. The result achieve a recognition rate at 98.6 percent with a small number of 45 training samples.**

***Index Terms*—Linux, Wi-Fi, Adaboost, BPNN.**

I. Introduction

Currently, in the field of personal identity authentication,which mainly relying on traditional methods of identification such as ID cards and passwords, the apparent defect, lack of efficiency, gradually become obstruction of the rapid development of science and technology. Biometric technology makes great progress on identity authentication. In various biometric technology, the human face identification is the most direct one, as well as the best method in accordance with the human habits. With the rapid development of face recognition technology, many research institutions have interest in face recognition. At the same time, commercial applications of face recognition systems are also developed. In recent years, research on face recognition is still mainly carried out on the separate PC or embedded system.

With the progress in wireless image transmission technology, remote identity authentication technology is gradually introduced to the face recognition system which tightly combined with wireless image transmission technology. In the field of wireless image transmission technology,Wi-Fi (Wireless Fidelity) is widely used, which is a kind of short-range wireless communications protocol with the advantage of fast transmission rate, long transmission distance and low cost. The rate and transmission distance of Wi-Fi is competent in terms of face recognition system. It can be effective in reducing the time of image transmission in the front of the face recognition stage.

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II. Overall Design

The whole system includes two parts: the server part and the client part. The core of the server is ARM9 microprocessor, integrating with USB Wi-Fi module and CMOS camera module. In the server, face image is acquired, compressed and transferred to client through wireless LAN. After receiving the data, the client decodes and processes it, in order to successfully identify faces. Server/client mode used in this system can decrease the burden of server. Overall system design is shown in Fig. 1.

Fig. 1. Overall system design.

III. Server Design

A. Hardware Design

The server is a mini-computer system which performs several specific services. In general, the server is a complete hardware and mechanical devices which holds the control operation system [1].

This embedded terminal including core controlling module (embedded microprocessor S3C2440A), Image acquisition module (OV9650) and USB Wi-Fi module (RT73), which is shown in Fig. 2.

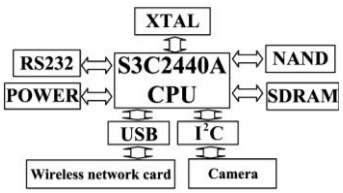

Fig. 2. Hardware design.

Server is based on the Samsung S3C2440A which is an ARM920T based high-performance 32-bit RISC microcontroller, 4KB RAM, with the advantages of low power consumption, small size and high performance [2].

OV9650 color CMOS camera chip is used to acquire image. OV9650 CMOS image sensor, Manufactured by Omnision, supports SXGA, VGA, QVGA and CIF. It communicates with host processor through the I^2C interface.

USB Wi-Fi driver on embedded systems will take up more resources and is too complex to design. Therefore, Wi-Fi module based on serial is generally a feasible choice.

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Applications in the terminal are designed to acquire, compress and transfer image data. USB Wi-Fi module can eliminate the bad impact of slow serial rate, so that the system can have a higher transfer rate and cost less. USB interface is designed to be a USB HOST. Ralink RT73 is used to build Wi-Fi module, which is USB2.0, 54Mbps, compatible with IEEE 802.11g and IEEE 802.11b protocol and supports WEP, WPA, IEEE 802.1X, TKIP encryption and security mechanism.

B. Program Design

Embedded terminal program can acquire, compress transfer image data.The program should deal with kernel transplantation, driver transplantation on Wi-Fi and camera and program design.

1) Kernel and file system

Firstly, a cross-compiler environment should be built in the progress of kernel transplantation. We select the Ubuntu as system environment and install arm-linux-gcc cross compiler to build a cross-compiler environment.

Then mkyaffs2image tool creates a mirroring of the root file system and transplants the kernel image and file system mirroring on ARM9 platforms. Now, system environment of terminal is successfully built.

2) Driver transplantation

Linux has a monolithic kernel. Device drivers and kernel extensions run in kernel space (ring 0 in many CPU architectures), with full access to the hardware. Although some exceptions run in user space, such as file systems based on FUSE. Unlike standard monolithic kernels, device drivers are easily configured as modules, and loaded or unloaded while system is running. Also unlike standard monolithic kernels, device drivers can be pre-empted under certain conditions. Therefore, kernel mirror can be built as small as possible. Especially, if external devices are hot plugging available, driver modules can be loaded after external equipments are inserted, and modules can be removed after external equipments are power off. Such mechanism consumes more system resources, which has significance to the memory and power sensitive embedded system.

Driver of RT73 USB Wi-Fi can be compiled independently, which should be loaded after Wi-Fi module is inserted into the system. A ko file which is the driver module of Wi-Fi can be generated by cross compiler. After the ko file is downloaded to the Linux file folder system by the insmod command, parameters on wireless Wi-Fi network should be configured. Thus Wi-Fi module on ARM platform can be operated. Configuration commands are as follows:

```
/sbin/ifconfig rausb0 up
/sbin/ifconfig rausb0 192.168.0.2
/bin/iwconfig rausb0 essid "Netcore"
/bin/iwconfig rausb0 ap auto
```

Encryption supporting secure in network processing for wireless sensor networks needs transplanting wpa\supplicant tool to authorize and authenticate wireless LAN. Now, wpa\supplicant can only support wireless network with configured ESSID, compatible with WPA and WPA2, CCMP and TKIP encrypted. According to the network environment, to modify wpa\supplicant.conf file is as follows:

```
ctrl_interface=/var/run/wpa_supplicant
ctrl_interface_group=root
ap_scan=1
network=
{
ssid=" Netcore "
key_mgmt=WPA-PSK
proto=WPA RSN
pairwise=TKIP CCMP
psk="12345678"
}
```

Configuration files, namely wpa_supplicant.conf and Wpa_supplicant should be downloaded on demoboard. Then the command wpa_supplicant-B-iRausb0-c/etc/wpa_supplicant.conf & operates on ARM platform. After running it successfully, the system can support WPA encryption and authentication.

Then we load the driver of camera, with the similar way to Wi-Fi. OV9650 camera supports the GRB (4:2:2) format. The driver source code is modified to support GRB format, which make it easier to compress image data.

3) Application programming

After receiving the request of image acquisition, application in terminal can capture and compress the image data, and then transfer it to client. Obviously, image transmission can be carried out only after the acquisition is completed. While the transfer request from client is a burst process, which means that when client commands server to transfer image data can not be estimated. Therefore, read error could be generated.

Image data is acquired by Video4Linux interface which is kernel driver in the Linux operating system and video equipment, specifically for video device application programming interface functions. Signal should be sent to drivers by ioctl in drivers of every equipment and system calls in Linux, so that every equipment can become steerable. In addition, the device file corresponding to Video4Linux is /dev/video. Video4Linux module must be added in the progress of kernel compiling.

The raw data is so large that it cannot be stored and transferred easily. Raw data is compressed into JPEG format by the system. The JPEG compression algorithm is at its best on photographs and paintings of realistic scenes with smooth variations of tone and color. For web usage, where the amount of data used for an image is important, JPEG is very popular. JPEG/Exif is also the most common format saved by digital cameras. The progress of image acquisition and compression is shown in Fig. 3.

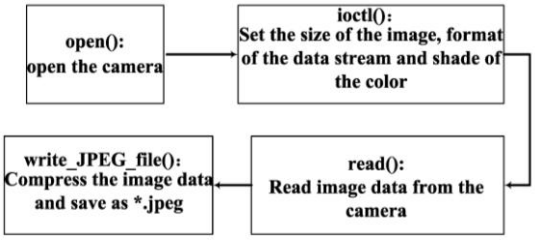

Fig. 3. Progress of Image acquisition and compression.

Image data is transferred via socket programming whichsupports TCP/IP protocol. So socket can be used as two-way communication endpoint for processes in different hosts. Sockets include stream sockets and datagram sockets. Stream socket provides a connection-oriented, orderly and nonrepetitive data streaming service, in order to ensure reliable delivery of data. Datagram Sockets is connectionless oriented and can not provide reliable data delivery. Since packet loss is not permitted in our system, stream sockets are selected to transfer image data.

IV. Client Algorithm

Client deals with face recognition, including image receiving, image decoding, face detection, image pre-processing of the human face, and face recognition, which is shown in Fig. 4.

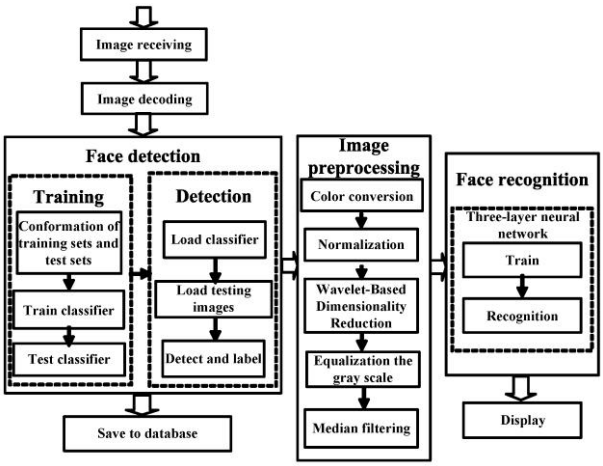

Fig. 4. The face recognition process.

A. Receiving and Decoding

Client communicates with server through stream socket. Application for receiving image data is built by CSocket class, provided in MFC. Image data is so big that it has to be received based on clustering in order to acquire the whole image data. *BmpBitmapEncoder* can transform JPEG files into BMP ones. In WPF, *BmpBitmapEncoder* defines encoder for BMP images. Moreover, namespace of *BmpBitmapEncoder is System::Windows::Media::Imaging*.

B. Face Detection Algorithm

Face detections is a hot point at present. The task of the face recognition algorithm is to classify a new test (or probe) face image as one of N possible training (or gallery) images. Adaboost-based detection algorithm is proved to be better in practical applications. Adaboost algorithm is a kind of fast face detection algorithm, whose basic idea is that strong classifiers can be constituted by a linear combination of weak classifiers [3]. Adaboost-based algorithm narrows the gap between machine learning and the ability of biophotonic detection, therefore, which makes it faster and more accurate to process image. Adaboost-based detection algorithm consists of training module and testing module. The progress of training module includes 4 steps: sample collection, generating training class & testing, training and testing classifier. Training module can load classifier, load pending image, detect and label image data [4]. The structure of Adaboost-based detection algorithm is shown in Fig. 5.

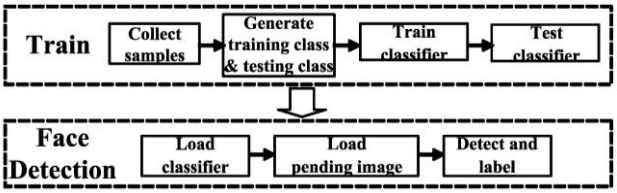

Fig. 4. The process of Adaboost-based detection algorithm.

Adaboost-based function is encapsulated in OpenCV library, which is an open source cross-platform computer vision library built by Intel. It is easier to identity faces through functions and classifier in OpenCV. Function to load classifier is *cvLoadHaarClassifierCascade*, which is loaded from cascade classifiers using Haarlike features or classifier database embedded in OpenCV.

haarcascade_frontalface_alt.xml is used to detect faces in our system. Function to detect target is *cvHaarDetectObjects*, which can find rectangular area containing face through training cascade classifier and return these sections as a series of rectangles. After these rectangles containing faces are acquired, pixels of these selected sections are intercepted. The size of image intercepted is related to the size of face image detected.

C. Preprocess Face Image

In order to reduce the impact of size, illumination, image noise, and so on, image normalization, grayscale equalization and median filter pretreatment must be achieved [5].After normalization, the scale of image becomes 92×12, so as to be consistent with ORL face database used in our system. Grayscale equalization is achieved by point operations to transfer the received image to the one with the same pixel dots in every grayscale, which can normalize image brightness and enhance contrast.

The wavelet transform can reduce the dimension of the face image, reduce the number of neural network input nodes and improve both the recognition speed and rate. After wavelet decomposition, the low-frequency smoothing image retains most of the information of the image. If only the low frequency smoothed image is retained, the face image pixel can be reduced to $1/4$ of the original image. So after n transformation, the image pixel can be reduced to $1/4n$ of the original image. With the growth of the transform levels, the number of dimension of the image can be smaller and the number of neural network input nodes could be fewer, however, distortion of the image become more serious. Obviously, it is a contradiction between the image contradicts, the number of dimension of the image and the number of neural network. Therefore, suitable levels need to be adopted according to the experimental results.

D. Design Neural Network Algorithm

Three layers back propagation, i.e. BP. manual neural network with the ability of self-learning and self-adaption is adopted in our system to recognize faces. Neural network algorithm is a kind of intelligent algorithm. The detail calculation, please refer to [6].It includes two steps, namely, training and recognition. In the training phase, network is trained according to the given input and the desired output. Weights are adjusted by gradient descent algorithm to

achieve optimal convergence value of weights. Neural network classifier achieved in this way will get the maximum likelihood output, corresponding to the input similar to the former one. In recognition phase, neural network classifier adopted in the training phase will identify the image and recognize faces.

1) The basic idea of BP is that the learning process is composed of two processes including, positive diffusion of signal and inverted diffusion of error. Generally, BP neural network[7] consists of three layers: input layer, hidden layer and output layer. The detail calculation, please refer to [8].Input in the input layer depends on the pixel dots of the images received, and output in output layer nodes depends on how many types of faces, that is, there is one to one correspondence between the number of users and the number of output layer nodes. Hidden layer is determined by the equality $n=\sqrt{N_i+N_o}+\alpha$ or $n=\log_2 N_i+\alpha$. Here N_i is the number of nodes in input layer, No is the number of nodes in output layer and is integer between 1 to 10. Training progress of BP network shown as follow.

Firstly, initialize the number of nodes in input layer, hidden layer and output layer.

Secondly, load the input data which is gray level image with the pixels of 46×56.

Thirdly, load the output data, which is a set of vectors equal to the number of users stored in the database [9].Output data can be written as I_m=[E_1, E_2, E_3, …, E_n]^T, where i=1, 2, 3, …, n, $i\neq k$, and $E_k=1$,The detail calculation, please refer to [10].

Fourthly, set the learning rate, momentum and the number of iterations. There have already enough researches for these three parameters and some improved algorithms have been developed. Generally, algorithms will be convergent if learning rate is adopted to be a constant. The dynamic adjustment of the learning rate, however, can achieve fast convergence. Traditional BP algorithm is easy to get lost in local minima. Momentum can reduce error of the network for local surface details of the sensitivity, to effectively curb the network into local minima.

After trained, the neural network classifier can identify faces. Generally, the stable neural network classifier comes out after trained many times to have iteration error no more than 0:005.

2) In the identification phase, measured images are compared with ones stored in database. Image data is judged by normalized Euclidian distance which can be written as follow:

$$d=\sqrt{\sum_{i=1}^{n}\left(Y_i+T_{i,m}\right)^2} \tag{1}$$

where Y=[Y_1, Y_2, Y_3, …, Y_n]^T is output data and T_m=[$T_{1,m}$, $T_{2,m}$, $T_{3,m}$, …, $T_{n,m}$]^T is original data. We use MAP (Maximum Posterior Estimation) to identify faces. If the distance between Y and T_m is less than the threshold, Y is judged to be face image of user m. Otherwise, the face image will be judged to be stranger's. In addition, threshold is a mean approximation after a large amount of statistics.

V. Result

In this experiment, the entire system is divided into the embedded system and the PC connected wireless card. Hardware development board connects external USB wireless card and USB camera through the USB Hub. USB camera captures images and USB wireless card sends images. The other side is the PC which is responsible for receiving images under the Ubuntu operating system [5].

The driver of camera and USB Wi-Fi is loaded automatically. IP address of client and server (Pentium(R)4, CPU 2.50GHz, memory 2G) should be in the same network segment. In our system, IP address of embedded terminal is 192:168:0:2, and that of network card in PC is 192:168:0:3. Fig . 6 to Fig . 9 are captured in the Visual C++ 6.0, MFC procedures which can create efficient toolbars.

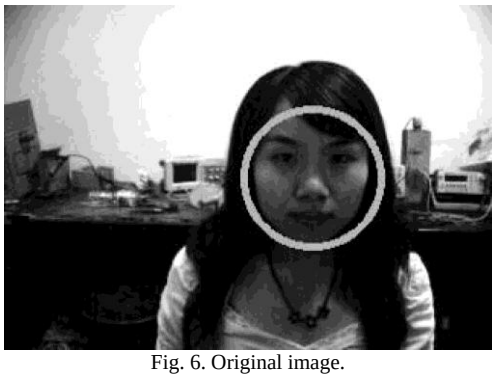

Fig. 6. Original image.

Fig. 6 is Original image received by client with complex background. The circle in 6 means that the system considers there is a face within it. Obviously, the system has successfully found out a face, in spite of complex background.

Fig. 7. Normal face image.

Fig. 7 is normal face image after located and intercepted with 92×112 picture element.

Fig. 8. Face gray scale image

Fig. 7 is face gray scale image, after wavelet transformed, with 45×56 picture element. Fig. 8 will be sent to neutral network to be trained.

ORL database is used as a reference. ORL database is created by the AT&T Labs, University of Cambridge, containing images of 40 persons. We randomly select 5 images of each person in ORL database and add another 50 images of 5 volunteers. Therefore, there are 45 persons and

450 images in all.

After trained many times, average iteration error of neutral network decreases to 0.003.The Euclidean distance between the actual output and the desired output is 0.0268, which means that this neutral network is well-trained. The result of face recognition is shown in Fig. 9. The result achieves a recognition rate at 98.6 percent with a number of 45 training samples.

```
--------------------------------------------------
Time:297.000000ms
Error:0.090912.
Face recognition finished
Face image capture finished, please click "detect".
Face detection finished. This face exists in database.
Identification time:274.000000ms
Error:0.052402
Face recognition finished.
```

Fig. 9. The result.

VI. Conclusion

Embedded Wi-Fi technology applied to the face recognition system is one of the main trends of the application of computer technology. This system innovatively combines face recognition technology with Wi-Fi technology to achieve remote authentication, which expands the scope of the Wi-Fi technology. Embedded ARM9 terminal is designed to capture and send images to the server. This system has a high recognition rate and short identification time.

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Prof Liu, his two products won the Scientific progress award by Ministry of Information Industry.