Real-time Human Detecting System Design for Intelligent Air-conditioning Control

Nan Wang, Harutoshi Ogai, Haitao Xiao and Duan Zhou

***Abstract*—In this paper, we select K60 as the core of the system and OV7620 as the camera sensor, designing a real-time character detecting node for the intelligent control of air conditioning. Also, we use NRF24L01 as the radio frequency module, finally composing these nodes of the whole system by WSN(wireless sense network). Meanwhile, considering the storage and computing speed of embedded system, we apply OTSU dynamic binarization algorithm and SOBEL operators to make image processing of the acquired images by OV7620, and propose a human detecting algorithm based on frame difference method. The final experiment shows that the system can detect if someone comes or leaves in the detecting area with the range 2 meters, and sends the result to control center. Finally, we also show the experimental results of different detecting distance and make a short conclusion.**

***Index Terms*—embedded system, image acquisition, human detecting, frame difference method.**

I. Introduction

In the process of energy saving and ZEB(Zero Energy Building) of buildings, we found that the energy consumption of air condition takes a great part, especially in the office, which could reach to 53% of the whole cost. conventional method and our proposed method. Finally the conclusion will be summarized in Section 6.The main reasons of the great cost can be concluded as following:

1) Work for a too long time so as to be in a overload state.

2) Frequent adjusting the state of air condition artificially, not depends on the environment.

The applications of air conditioners on the market is quite popular, involving the most basic control technologies and functions are quite mature. However, there is a serious lack of use in human design, such as: 1. The air conditioner is still in the working state, though there are nobody in the rooms; 2. The flow directions of air conditioner cannot change with the position of human, etc, which results in a large number of energy waste. The most common intelligent air conditioner system is usually controlled by infrared sensors, which will sense the current environmental temperature so as to control the state of air conditioner. However, the obvious shortcoming is that the infrared sensor cannot detect and locate human.

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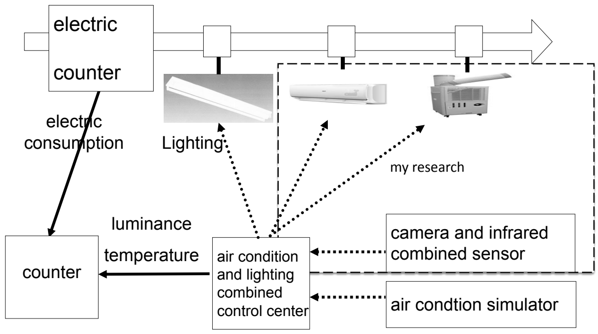

Fig. 1. Intelligent air-conditioning control system.

As Fig.1 shows, our purpose is designing a camera and infrared combined system to collect the environmental information(human detection and temperature) so as to control the state of all the air conditioners in the building, which will indirectly improve the efficiency of air-conditioning and enhance the overall air-conditioning performance. The main content of this paper is mainly proposing a real-time human detecting system.

This paper can be divided into two parts:1. Hardware design; 2. Method of human detecting. There are two kinds of ways to detect objects: frame difference and background difference method. Compared with background difference method, frame difference method has the advantages: the whole algorithm is easy to implement and the programming complexity is low; it is not sensitive to the changes of light and other scenes, also can adapt to various dynamic environments with better stability. Considering about the storage and calculating speed of our hardware, in the second part, we propose an effective method to detect the human based on the frame difference method [1].

II. Hardware design

The whole process can be described as: Camera collects the images of detecting area, and send the images to the FIFO memory to store by IIC protocol, then the stored images are sent to the MCU, and runs the proposed image processing algorithms to detect the human, finally sends the result to the control center(PC) by RF part.

Fig.2 shows the hardware design of one sensor, to make the designed hardware part, we choose OV7620 as the camera, which is a single-chip CMOS VGA color digital camera, K60(MK60DN512ZVLQ10) as the MCU, which is from Freescale based on ARM structure, and NRF24L01 as the Radio Frequency module [2]–[4].

As Fig.3 shows, we connect K60, OV7620 and NRF24L01 to form a node shown in Fig.5 of the whole WSN with the image acquiring and information sending functions.

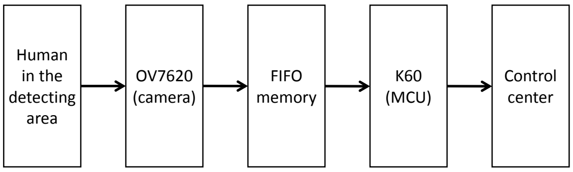

Fig. 2. Hardware design of one node.

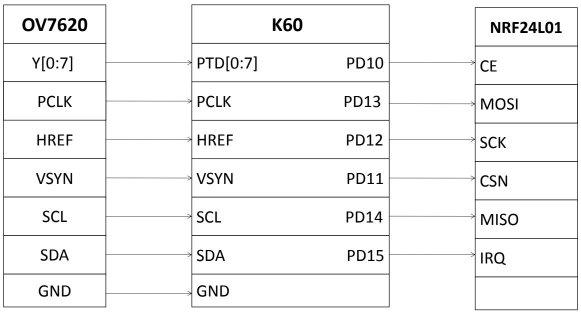

Fig. 3. Connection between camera,MCU and RF.

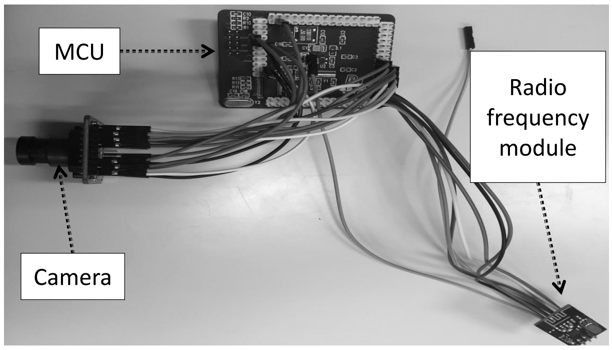

Fig. 4. One node of the whole system.

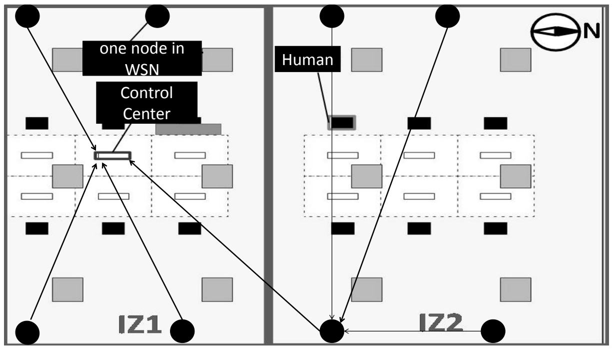

Fig. 5. The whole human detecting system.

Fig.5 is the whole detecting system, blue point stands one node shown in Fig.4. These nodes consists of a WSN by using the ant colony optimization based routing algorithm. In room IZ1, the nodes send the processed results to control center respectively. In room IZ2, one node collects all the results from the other nodes firstly, and then this node sends these results to control center. After collecting the current information, control center will make an analyze to control the air-conditioning intelligently [5].

III. Method of Human Detecting

Frame difference method is a common way to detect the objects by analyzing the difference between two frames. When detecting the object by frame difference method, in the different images, the unchanged part is eliminated while the changed part remains. However, limited by the storage and calculating speed of embedded system, first we add the edge extracting process into the whole process, which aims to reduce the useless information of an image as much as possible, then we promise an effective way to calculate the difference between two images based on frame difference method. Figure.6 shows the whole image process [6]–[8]:

A. Dynamic binarization

After step1, we can get the gray image, and the next step is to make binarization of images, which divides an image into two parts: one with the value 255, another one with the value 0.

$$binabuff[i][j] = \begin{cases} 0, if \quad imagebuff[i][j] <= threshold \\ 255, if \quad imagebuff[i][j] > threshold \end{cases} \tag{1}$$

Where $binabuff[i][j]$ is the binarization image matrix, and $imagebuff[i][j]$ is the gray image matrix.

Considering about our goal is to detect the human, OTSU is an effective way to divide the object from the background by calculating a dynamic threshold [9].

As figure.7 shows, the object is circled by the blue rectangle with the parameter ω_0 and μ_0, the left part is the background with the parameter ω_1 and μ_1.

$$\omega_0 = \frac{N_0}{M * N} \tag{2}$$

Where ω_0 is the ratio of pixel number between object and whole image, $M * N$ is the size of whole image, and N_0 stands for number of the pixels whose value is smaller than the threshold we want to calculate.

$$\omega_1 = \frac{N_1}{M * N} \tag{3}$$

Where ω_1 is the ratio of pixel number between background and whole image, $M*N$ is the size of whole image, and N_1 stands for number of the pixels whose value is bigger than the threshold we want to calculate.

$$N_0 + N_1 = M * N \tag{4}$$

$$\omega_0 + \omega_1 = 1 \tag{5}$$

$$\mu = \omega_0 * \mu_0 + \omega_1 * \mu_1 \tag{6}$$

Where μ is average value of the whole image.

$$g = \omega_0 * (\mu_0 - \mu)^2 + \omega_1 * (\mu_1 - \mu)^2 \tag{7}$$

Where g is the between-class variance, which is calculated by Eq.7.

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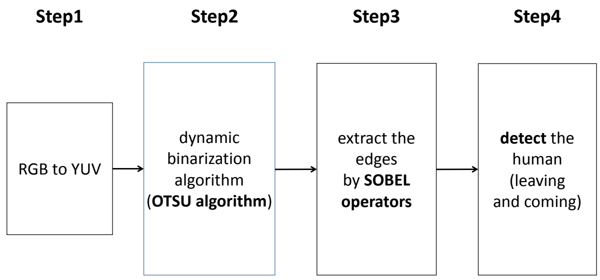

Fig. 6. The whole human detecting system.

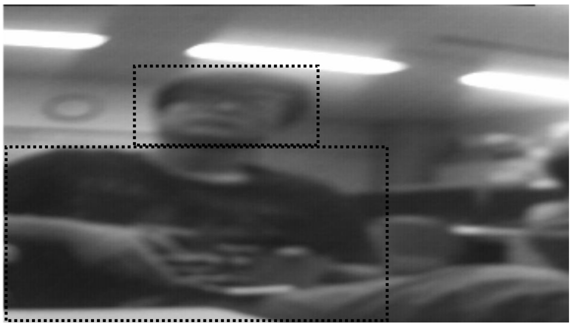

Fig. 7. One gray image acquired by OV7620.

Putting (6) to (7) ,

$$g = \omega_0 * \omega_1 * (\mu_0 - \mu_1)^2 \tag{8}$$

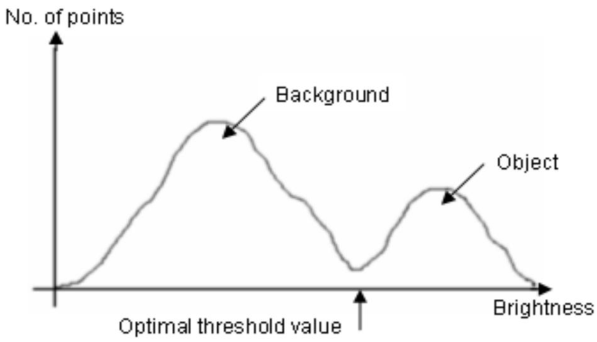

Fig. 8. OTSU algorithm.

As Fig.8 explains, scanning the whole image, when the value g becomes the biggest, then we get $T(T = g)$, T is the dynamic optimal threshold [8].

B. Edge extraction

Limited by the calculating speed and storage of embedded system, we make an edge extraction of images to decrease the useless information of images and remain the key parts. SOBEL operators is an effective way to get the edges, which consists of a pair of 33 convolution kernels as shown in Eq.8. One kernel is simply the other rotated by 90 [10], [11].

$$\begin{bmatrix} -1 & 0 & +1 \\ -2 & 0 & +2 \\ -1 & 0 & +1 \end{bmatrix} \begin{bmatrix} +1 & +2 & +1 \\ 0 & 0 & 0 \\ -1 & -2 & -1 \end{bmatrix} \tag{9}$$

where the left matrix is SOBEL convolution factor of X direction, and the right matrix is SOBEL convolution factor of X direction.

Then we use SOBEL operators to do matrix calculation with the image matrix, and extract the edges. As following Fig.9shows:

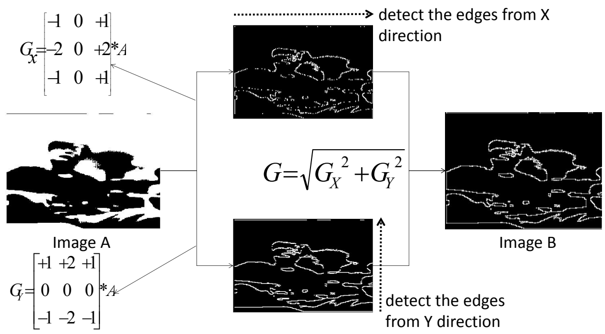

Fig. 9. edge detection by SOBEL operators.

Image A is the binarization image transformed by OTSU algorithm, doing the matrix calculation with the SOBEL kernels from horizontal and vertical directions respectively. Image B is the edge extracted result, from which we can see that the image B only remains a little information compared with image A. Also, the result indicates that the edge is circled by the white pixels, which are assigned to the value 0 in the process of binarizaiton.

C. Edge extraction

After the edge extraction by SOBEL operator, the human detecting is the final step. In this section, we come up with an effective way with less calculation based on frame difference method [12], [13].

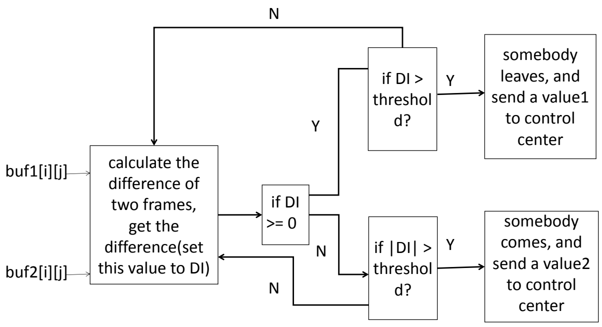

Fig. 10. OTSU algorithm.

As Fig.10 describes, because the angle and position of camera are fixed and the range of detecting area is set up in advance, we set $buf1[i][j]$ as the edge detected background image, which means that there is nobody in the detecting area, and $buf2[i][j]$ is the edge detected real-time image acquired by camera. In our algorithm, we define the difference between $buf1[i][j]$ and $buf2[i][j]$ as the number of the white pixels with value 0, and set the difference to DI. Meanwhile, Considering that in the binarization process, we use a dynamic algorithm, which leads to the result of binarization will be affected by the change of light intensity, so after

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the edge extraction, in the comparison of background and real-time acquired image, we need a threshold to compare with DI, ensuring the accuracy. Through a large number of experiments, the value of DI is mainly affected by the distance between the position of camera and monitoring area. When the distance is fixed, we found that the size of human and entire image exists a certain proportion. The size of the acquired image is 200 * 300, which means there are a total of 60,000 pixels. After binarization and marginalization, the number of white pixels in one image is from 20000 to 25000, and one object has a range of white pixels from 600 to 1000. Therefore, we set the threshold to 600.

As Fig.10 indicates, we set the white pixels number of $buf1[i][j]$ and $buf2[i][j]$ are sum1 and sum2 respectively.

$$DI = sum_2 - sum_1 \tag{10}$$

If DI is bigger than 0 and the threshold, then we can judge there someone comes; If DI is less than 0 but the absolute value of DI is bigger than the threshold, then we can judge there someone leaves.

IV. Experiment Result

Fig. 11. Experiment environment.

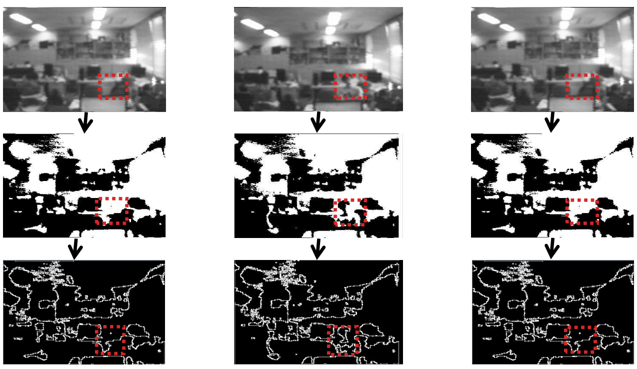

Fig. 12. Experiment result.

The experimental environment is shown in Fig.11, the distance between camera and detecting area is about 2 meters. In Fig.12, we show the results of each step in the whole system. First, we transform the image from RGB to GRAY. Then we use OTSU to binarize the gray image. Finally, we use SOBEL operators to extract the image edges. Each acquired image will be processed through these three steps, getting the final edge extracted image, finally making

TABLE I
Live Watch of Experiments

Expression	Value	Location	Type
sum1	21042	0x1FFF04A4	unsigned int
sum2	21849	0x1FFF04A8	unsigned int
Bina_data	array	0x1FFFEF10	u8[200][300]
ImageBuf	array	0x1FFF04B0	u8[200][300]
tmp	807	0x1FFF04AC	int

TABLE II
Live Watch of Experiments

Expression	Value	Location	Type
sum1	21895	0x1FFF04A4	unsigned int
sum2	20613	0x1FFF04A8	unsigned int
Bina_data	array	0x1FFFEF10	u8[200][300]
ImageBuf	array	0x1FFF04B0	u8[200][300]
tmp	-1282	0x1FFF04AC	int

TABLE III
Accuracy of Different Detecting Distance

Distance between detecting area and camera	Number of successful detection	Total number of detections	Accuracy
1 meter	43	50	86%
2 meters	41	50	82%
3 meters	23	50	46%

the human detection. As Fig.12 describes, someone comes to the detecting area firstly, and then leaves from the detecting area.

In TABLE I, sum1 is the white pixel number of previous frame with the value 21042, and sum2 is the white pixel number of the current frame with the value 21849. Threshold is the value of OTSU algorithm, and tmp is the difference of sum1 and sum2. Then, we can see that tmp is bigger than 0 and the set $threshold_1$ with the value 600 at the same time, it means somebody comes, and sends a value1 to control center.

In TABLE II, we can see that the tmp is smaller than 0, and the absolute value of tmp is bigger than the set $threshold_1$ with the value 600, which means somebody leaves, and sends a value2 to control center.

As TABLE III indicates, we also do experiments with different distance. The experimental accuracy is influenced by the distance between detecting area and camera, from TABLE III we find that the longer distance, the lower accuracy.

V. Conclusion

In this paper, we make K60 as the core of the system, CMOS OV7620 as the camera sensor, designing a human detection system. First the OV7620 gets the image information and sends to K60, then K60 completes the image processing. Comparing with the general algorithm flow, we joined the edge detection process, aiming to simplify the image and calculation. Finally, through our proposed human detecting algorithm to monitor the detecting area and judge if someone comes or leaves, meanwhile, returning the results to the control center.

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The experimental results show that the accuracy of the test results is 86% with 1 meter, 82% with 2 meters and 46% with 3 meters. Therefore, the system still has some shortcomings, how to improve the detecting distance and count the number of people in the detecting area will be the main future work. Also, in order to make a better control of air conditioner, we will combine the infrared with camera sensor in the future work.

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