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# *Research on Personnel Information Collaborative Sensing Method of Intelligent Building Based on CPS*

**Wang Baoyi[a,*], Dou Zongjie[b], Zhang Shaomin[c]**

*School of Control and Computer Engineering, North China Electric Power University, Baoding, 071003, China*

*[a]email: wangbaoyiqj@126.com, [b]email: dzjwtt@vip.163.com, [c]email: zhangshaomin@126.com*

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***Abstract:*** Distribution of Personnel information within each area of the building is very important for energy efficiency and emission reduction of building energy systems. Staff perception is also the basis for satisfying the office and living environment with the least amount of energy consumption. This paper discusses the methods of staff perception and estimation for building energy systems, and discusses the use of multiple information-aware technologies and multi-source information fusion methods. A method of data acquisition based on pyroelectric sensor and recognition based on convolution neural network is proposed in this paper. At the end of the paper, the experimental results are obtained and compared with the other three methods, which proves the validity of the proposed method.

## 1. Introduction

An important source of information in CPS is personnel information, including the location, number, behavior, and psychology of personnel[1]. This information plays a key role in building energy-saving comfort and safe evacuation. The energy consumption of office buildings, commercial buildings, and residential buildings is closely related to the people in each building area. Through a variety of positioning and technical means to obtain the real-time distribution of personnel in the building, the HVAC can adjust the end output and improve the overall efficiency of the building energy system[2]. Part of the human behavior reflects the need for comfort. By using video infrared and human-computer interaction to understand the real-time comfort needs of each person, it is possible to improve the building's energy consumption while improving the comfort of the staff. The distribution of personnel in buildings, especially super-tall buildings and buildings with complex internal structures, is of great value in emergency evacuation, according to which the pressure of the evacuation paths can be equalized.

At present, the related research on the distribution of personnel information in buildings is divided into three categories: passive sensor personnel information perception, active sensor personnel information perception and fusion sensor personnel information perception[3].

In the context of CPS, this paper combines passive sensor personnel perception counting and fusion sensor personnel perception technology, using advanced sensor network technology, using pyroelectric technology to realize the detection of human infrared waves, and thus realize the distribution perception of personnel. At the same time, the Faster R-CNN is used to count and identify the sampled video features to meet the requirements of the human body for the comfort of the office environment, and to optimize the working state of the building refrigeration equipment, thereby saving the overall energy consumption of the building[4].

## 2. Application of CPS in Buildings

The physical structure of CPS mainly includes sensors with perception function and actuators with control function, or physical nodes with perception and control ability at the same time. Information system also includes network communication system and computational control system. In the process of CPS running, the sensor of physical layer collects data information through environment perception, and adjusts the internal association and model automatically to respond to the changes of external environment or user needs. At the same time, the sensor transmits information to other connected nodes and computer control centers through communication network, which has a higher priority control center. To control the response state of the actuator according to the global situation.

The combination of CPS and building system can realize intelligent transformation of building calculation, communication, control and other functions, and further improve the level of intelligence and automation of energy Internet[5]. This paper presents a building information physical system structure as shown in Figure 1.

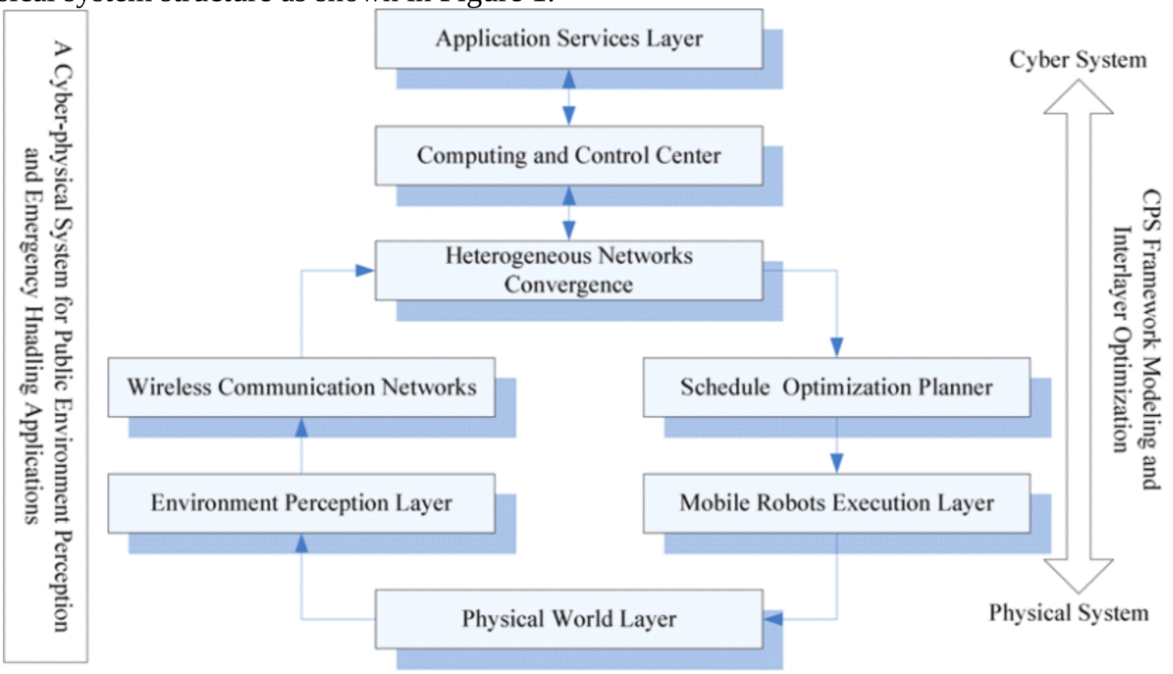


Figure 1: CPS perception framework

## 3. PIR Video Acquisition

This system is realized by creating an image processing thread and using the DSP core. On the premise of strictly following DaVinci software architecture, data exchange between two processor cores is realized by using shared memory[6]. The video analysis process is shown in the figure 2.

Image acquisition threads are responsible for obtaining frame-based images from analog cameras, and using the hardware filtering function of video coprocessor to eliminate the staggering phenomenon of analog video images, so that the image edges remain smooth. The image processing thread uses the DSP core to transfer the parameters and the image to be processed to the DSP core by sharing memory, and waits for the DSP core to complete moving target detection, target segmentation and target recognition[7].

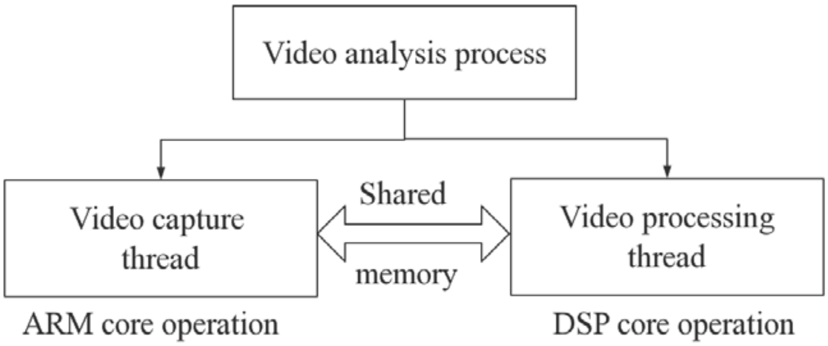


Figure 2: Video analysis process

Under the framework of DaVinci, the peripheral is controlled by the ARM subsystem, and the embedded Linux operating system runs on the ARM, so the operation of the peripheral needs to be carried out through the Linux API. Next, all peripherals are abstracted into a file, and the camera is no exception. In this system, the file/dev/fb/1 corresponds to the external analog camera. Supported by the camera driver, the image is received by calling functions of Linux API system such as ioctl. The image acquisition process is shown in the figure 3.

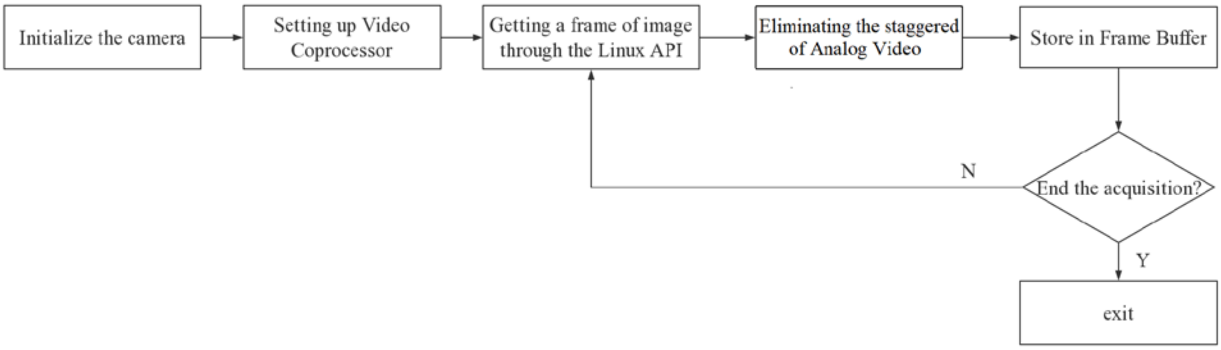


Figure 3: Flow chart of image acquisition

## 4. Infrared Person Detection Algorithm Based on Faster R-CNN

### 4.1. Faster R-CNN Structure

The overall network framework structure of the algorithm in this paper is shown in Figure 4. The RPN generates 300 candidate region inputs to the target recognition network Fast R-CNN. Since the front part of the RPN and the Fast R-CNN have several convolutional layers to calculate the feature map, the framework combines the two networks into one network. The convolutional layer parameters are shared, and the convolutional layer is simultaneously output to the RPN and the Fast R-CNN to form an end-to-end network structure[8].

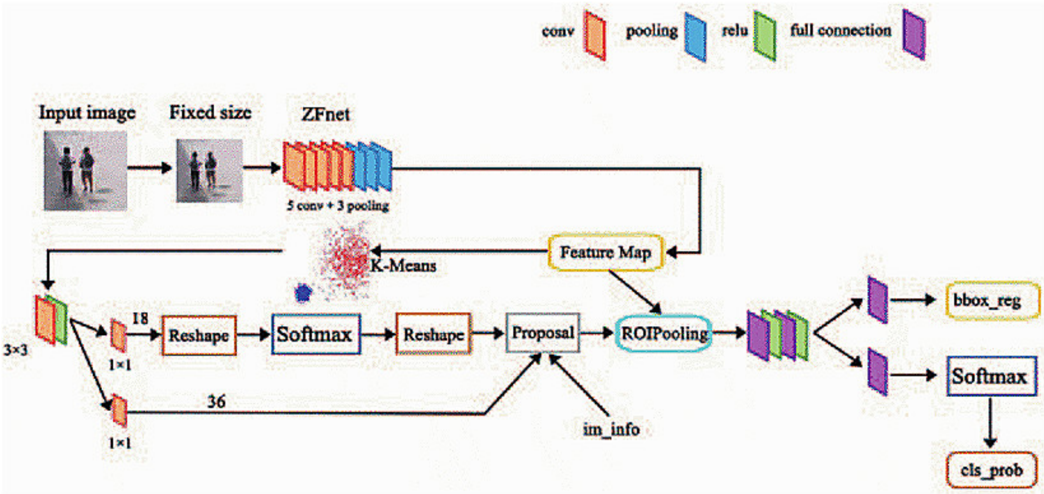


Figure 4: The network framework structure of Faster R-CNN

### 4.2. Algorithm Description

Step1: Collect database samples and set up training set and test set. The database samples are collected by pyroelectric cameras in the laboratory and set categories and codes of each category in classifier to construct training set.

Step2: Process the image, and image edge detection is mainly used to enhance the contour edge, details and gray jump part of the image to form a complete object boundary, so as to separate the object from the image or detect the area representing the same object surface. Fig. 5 is the binary processing of the target, and Fig. 6 is the feature extraction of the target.

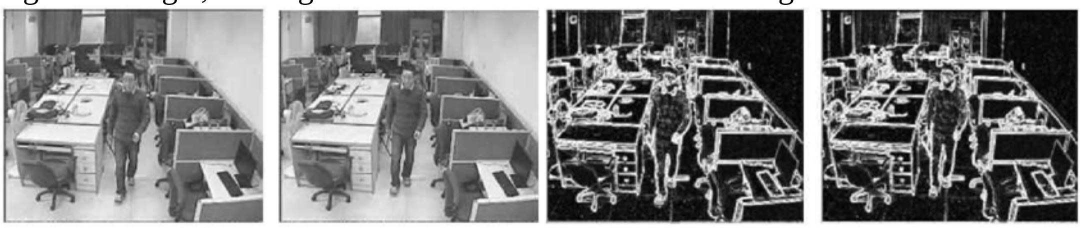

Figure 5: Binary image processing

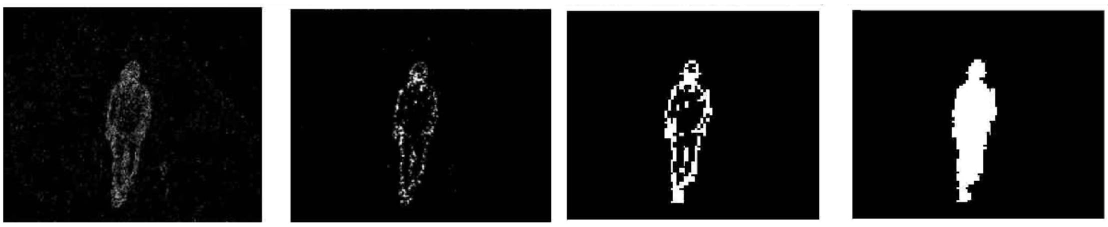

Figure 6: Example of object segmentation

Step3: Build the convolution neural network architecture, and set up the depth and width structure of the convolution neural network by overlapping several convolution layers and pooling layers.

Step4: In the convolution layer, deformable convolution core is used to sample. An additional convolution layer is added to learn offset, and input feature map is shared. Then input feature map and offset obtained by training are used as input layer of deformable convolution layer. At this time, the sampling points of deformable convolution layer migrate and convolute.

Step5: In the pooling layer, deformable interest regions are used for pooling operations, where

ROI is divided into n*n bins, which are input into an additional full-connection layer to learn offset, and then each bin is offset by a pooling layer of deformable interest regions.

Step6: Softmax classifier is added to the last layer of convolution neural network and the objective function is set.

Step7: The training set is used to train the convolutional neural network model once, and the training set is used to identify the test set data, and then the overall recognition rate is counted, and the training set is used to train the convolutional neural network model again.

Step8: Until the target function converges completely and the recognition rate is no longer improved, then the network parameters are trained and the deformable convolution neural network template. the infrared image object recognition system is obtained, the recognition result is shown in the figure 7.

Figure 7: Test recognition result

### 4.3. Result and Comparison with Different Algorithm

The traditional BP neural network algorithm and the Fast R-CNN algorithm were used to test on the same video, and the results of the three algorithms were compared, as shown in Table 1. It can be seen from the comparison results in Table 1 that the traditional machine learning method is lower than the method of deep learning at the detection speed (4.10 s/frame) and the correct rate (0. 652). This is because traditional methods require a lot of calculations when calculating various pedestrian features and windows traversing images. Although the Fast R-CNN algorithm has a larger improvement than the traditional method, it uses the selective search method to generate the candidate region alone. The calculation amount is relatively large and the speed is relatively slow (2.50 s/frame), the pedestrian detection that caused the video is not real-time. By using the convolutional network in the Faster R-CNN framework to generate candidate regions, it is an end-to-end processing method, and the speed is greatly improved (0.10 s/frame), which ensures the real-time detection of personnel. The framework used combines candidate region generation, region classification detection, and position refinement to enhance the correlation between them, so that the correct detection rate of the target is from 0. 719 of Fast R-CNN raised to 0. 898.

Table1: Comparison of three algorithms in building

| Method | Time/( s/frame) | Mean average precision |
|---|---|---|
| BP | 4.10 | 0.652 |
| Fast R-CNN | 2.50 | 0.719 |
| Faster R-CNN | 0.10 | 0.898 |

## 5. Conclusions

In this paper, the BP neural network algorithm, Fast R-CNN algorithm and the proposed algorithm are compared to prove the superiority of the method. The algorithm proposed in this paper is of great significance for sensing the distribution information of people in various areas of the building, energy saving and emission reduction of building energy systems, improving the energy efficiency of daily operations, and the rapid response efficiency of response systems in emergencies.

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