Design and Implementation of the Pedestrian Information Analysis System

To cite this article: Wenli Zhang et al 2018 IOP Conf. Ser.: Mater. Sci. Eng. 439 032091

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Design and Implementation of the Pedestrian Information Analysis System

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Abstract. In this paper, we proposed a pedestrian information analysis system. It is consisted of the pedestrian detection module and the pedestrian tracking module. Compared with various pedestrian detection methods, the Deformable Part Model (DPM) algorithm is used to detect the pedestrians in the picture. Meanwhile, this paper proposes a pedestrian tracking method. This method uses the pedestrian detection result to calculate the pedestrian's centroid and uses the video time domain information to track the centroid. It can help us to obtain the pedestrian information that includes the pedestrian moving distance and direction. We set the count line to count the pedestrian’s number and direction in this system. The experiment results show that the system we proposed can analyse pedestrians more accurately.

1. Introduction
Nowadays, more and more public places installed the camera to monitor in real time. Although the picture captured by the camera is real-time, the picture information cannot transform the number of pedestrians automatically and the pedestrian information cannot be obtained in real time. The pedestrian’s information is indispensable to management and decision making. The subway station and the railway station can guide the passenger flow according to the number of passengers. Malls can arrange the advertisement at the best position and adjust the rent of shops reasonably according to the number of customers. We can see that the analysis of pedestrian information in surveillance video is the focus and difficulty of recent research.

In recent years, domestic and foreign researchers have proposed a lot of pedestrian detection algorithms and pedestrian tracking algorithms, which will be explained separately.

1.1. Pedestrian detection algorithm
Pedestrian detection is to distinguish pedestrians in images and videos from the background. There are mainly Histograms of Oriented Gradient (HOG) algorithm, Local Binary Pattern (LBP) algorithm and Deformable Part Model (DPM) algorithm. Dalal[1] used HOG descriptors to extract pedestrian features for pedestrian detection. This algorithm is the most widely used pedestrian detection algorithm. Mu[2] proposed LBP-like features based on the pedestrian’s feature and the LBP algorithm that proposed by Ojala[3]. This algorithm has a fast calculation speed, but it cannot discriminate the pedestrian when the picture has low resolution. The DPM algorithm which proposed by Felzenszwalb et al.[4] has a good pedestrian detection effect, but the detection speed is relatively slow. Then in 2010, a star-cascade DPM [5] model was proposed to improve the pedestrian detection speed. Gadeski E[6] used GPU to accelerate the DPM algorithm. Wu[7] combined BING[8] and EdgeBoxes[9] with the
classic DPM model for pedestrian detection. This algorithm detected and marked the pedestrian position in the proposal area, which improves the detection efficiency of the DPM algorithm.

1.2. Pedestrian tracking algorithm

Pedestrian tracking is the process of finding pedestrians in a video sequence. There are mainly mean shift (Meanshift) algorithm and continuous adaptive mean shift (Camshift) algorithm. The meanshift algorithm [10] used the colour features and the mean shift strategy to find the optimal region that is similar to the target colour distribution. However, this algorithm is susceptible to background or other moving objects that contain similar colours. It will result in the tracking position drift. Chen [11] optimized it to improve target tracking stability. The Camshift algorithm [12] is simple in calculation. It can track the target more accurately and solve the problem that caused by the target is blocked. But the Camshift algorithm is similar to the Meanshift algorithm. The Camshift algorithm creates a target histogram based on colour information to track the target. When the background has a large area of similar colour, the algorithm does not track pedestrian targets truly. Xiu [13] chose the Gaussian weight function to obtain the interest region in the background. It can eliminate background interference with the object, but this algorithm needs some time to obtain the interest region in the background.

Through the introduction of the pedestrian detection algorithm, it is not difficult to find that the DPM algorithm can adapt to a variety of postures of pedestrians and the algorithm's detection accuracy is high. Meanwhile, we find that the pedestrian tracking algorithms which proposed by other researchers are mostly limited to the detection scene and it takes a certain amount of time to extract features or information in the detection picture. It will affect the efficiency and accuracy of the entire tracking process seriously. In order to ensure the efficiency and accuracy of the system that we proposed, this system uses the DPM algorithm to detect pedestrians and proposes a pedestrian tracking algorithm that used the pedestrian’s centroid to reduce the system's resource consumption.

The paper structure is as follow: The first chapter is introduction; the second chapter introduces our system; the third chapter discusses the experiment result; the fourth chapter is conclusion.

2. System design and implementation

2.1. Pedestrian detection module

DPM uses a traditional sliding window detection method to build a scale pyramid to search the pedestrian at each scale. When detecting the pedestrian in the picture, the response score of each detection target is calculated the position where each component filter is placed. The response score is calculated the inner product of the features of the pre-trained pedestrian model and the window area at this location.

The DPM algorithm steps are as follows:
(a) Input the original image and extract the image features to obtain a feature image.
(b) The feature image is matched with the model to obtain a filtered image.
(c) Response transformation: we set the anchor point as the reference position. According to the matching degree of component models and image features and the loss of part model’s ideal position, the optimal component model position and response score are obtained.

In each floor of pyramid, the response score of each position can be calculated based on the sum of the response values of the root filter of each layer of the pyramid and the resampled component response values. It is calculated as formula (1).

\[
    score(x_0, y_0, l_0) = R_{0,l_0}(x_0, y_0) + \sum_{i=1}^{n} D_{l_0-\Delta}(2(x_0, y_0) + v_i) + b
\]

\( (x_0, y_0) \) is the position of the top left corner of the root filter on the feature layer \( l_0 \) of the pyramid. \( v_i \) is the offset of the root filter relative to the component filter i on the feature layer \( l_0 \) of the pyramid. \( 2(x_0, y_0) + v_i \) is the absolute positions of component filter i at the centre position.

The response value is calculated at first, when matching with the pedestrian goal. After the calculation, it will be transformed as formula (2).
\[ D_{i,j}(x, y) = \max_{dx, dy}(R_{i,j}(x + dx, y + dy) - d_i \cdot \phi_d(dx, dy)) \] (2)

\( D_{i,j}(x, y) \) is the root position response score at the position \( (x, y) \) of the \( i \)th component filter in the \( L \)th layer pyramid.

2.2. Pedestrian tracking module based on the pedestrian centroid

After the pedestrian is detected in the picture, the pedestrian's position can be analysed. According to the video sequence, the pedestrian's movement direction and locus can be obtained. The steps of the pedestrian tracking algorithm are as follows:

(a) Calculate the pedestrian centroid according to the pedestrian detection result.
(b) Match the pedestrian centroid according to the centroid moving distance and get the pedestrian centroid matching pair.
(c) Calculate the pedestrian centroid’s moving direction according to the previous frame’s centroid matching pair.
(d) Use the pedestrian centroid’s moving direction to optimize and obtain this frame’s pedestrian centroid matching pair.
(e) Determine the relationship between the pedestrian centroid and the count line.

The specific flow of the pedestrian tracking algorithm based on the pedestrian centroid is shown in figure 1:

![Figure 1: The specific flow of the pedestrian tracking algorithm based on the pedestrian centroid](image)

2.2.1. Pedestrian centroid calculation. The centroid [14] as a mark of moving target has smaller position deviation and better stability. Therefore, it is very important to extract the pedestrian centroid for analysing the pedestrian’s position. The markers of the pedestrian's centroid are shown in figure 2.

![Figure 2: The markers of the pedestrian's centroid](image)

From the figure2, it can be seen that the centre position of the rectangle is basically at the waist position of the pedestrian. Compared with the arm and the leg, the waist does not oscillate substantially when the pedestrian moves in the video and the waist movement is the same as that of a pedestrian. Therefore, the centre position of the rectangle is set as the pedestrian's centroid.

\( P_2(x, y) \) is the pedestrian centroid position, \( P_L(x_L, y_L) \) is the top left corner position of the rectangle. \( P_R(x_R, y_R) \) is the bottom right corner position of the rectangle. The pedestrian centroid position is calculated as shown in formula 3 and formula 4.

\[ x = \frac{x_L + x_R}{2} \] (3)
\[ y = \frac{y_L + y_R}{2} \] (4)
2.2.2. **Pedestrian centroid matching.** In the near two frames of video, the centroid positions of the same pedestrian are usually close and the centroid direction is usually same. The pedestrian centroid matching process is as follows. Firstly, the pedestrian centroids are calculated by the formula(3) and formula(4). The pedestrian centroid is matched by the distance. Then, the pedestrian direction is calculated by the previous frame’s centroid matching pair. Finally, this frame’s pedestrian centroid matching pair can be obtained and optimized by the pedestrian’s direction. If the pedestrian centroid distance is less than the minimum distance, and the pedestrian moving direction is the same as the previous frame’s centroid matching pair, these pedestrians' centroids are matched. The pedestrian centroid matching process is shown in figure 3.

![Figure 3 The pedestrian centroid matching process](image)

2.2.3. **Pedestrian crossing detection.** This system uses centroid matching pair to determine the pedestrian passes the count line. Taking the vertical counting line as an example, the judgment process steps are as follows:

(a) Set the count line position.
(b) Input the centroid matching pair.
(c) Determine the relationship between the previous frame’s pedestrian centroid and the count line.
(d) Determine the relationship between this frame’s pedestrian centroid and the count line.
(e) If the relationship between step (c) and step (d) changes, it means that the pedestrian passes the count line. If the relationship between the centroid and the count line changes and this frame pedestrian centroid is located on the right side of the count line, the pedestrian movement direction is right. On the contrary, the pedestrian movement direction is left. The experiment results are shown in figure 4.

![Figure 4 The pedestrian crossing detection result](image)

### 3. Experimental results

3.1. **Experimental data acquisition**

In this paper, the video resolution is 640*480, 24 frames per second. We collected the experimental data in Beijing University of Technology that includes the entrance of the auditorium(figure5-a), the eastern side of the first teaching building(figure5-b), the western side of the student activity building(figure5-c), and the southern side of the 4th dormitory building(figure5-d). These scenes are shown in figure 5.

![Figure 5 The experimental data collection environment](image)
3.2. Evaluation and discussion
The system mainly has two modules: pedestrian detection module and pedestrian tracking module. Therefore, the results of these two modules are analysed separately. We used the precision (P) and the recall (R) to calculate the F1 score [15]. Then, we used the F1 score to evaluate these modules. The higher the F1 score, the better the module effect. The F1 score is calculated as shown in formula 5.

\[ F1 = \frac{2PR}{P+R} \]  

As far as we know, the accuracy of pedestrian detection results is determined by the number of pedestrians in the picture, whether the pedestrian is blocked, and whether the shooting environment is complex. Through a large number of experiments, it was found that when the shooting angle is changeless, there is a positive correlation between the number of pedestrians and the probability that the pedestrian is blocked. In this experiment, the number of pedestrians is divided into four categories that include 1 to 4 persons, 5 to 8 persons, 9 to 12 and 13 to 15 persons. Each type of image is sampled in 50 frames. We calculate the F1 scores of the two modules separately according to the number of pedestrians. The experimental results are shown in figure 6.

![Figure 6](image_url)

(a) The F1 score of the pedestrian detection module (b) The F1 score of the pedestrian tracking module

The experimental results

According the figure 6(a) and figure 6(b), it is obvious to know that the F1 score of the pedestrian tracking module is positively correlated with the F1 score of the pedestrian detection module. When the number of pedestrians is large, pedestrians are more likely to be blocked and decrease the F1 score of the pedestrian detection module. It will affect the accuracy of pedestrian centroid matching in video and decrease the F1 score of the pedestrian tracking module. The experiment results of this system are shown in figure 7, (a)(b) is the experiment results of the system when there are fewer pedestrians, and (c)(d) is the experiment results of the system when there are many pedestrians.

![Figure 7](image_url)

(a) (b) (c) (d)

The experiment results of the system

4. Conclusion
In this paper, we proposed a pedestrian information analysis system which consisted of the pedestrian detection module and the pedestrian tracking module. The system uses the DPM algorithm to detect pedestrians in the picture at first. Then, the system uses the pedestrian tracking algorithm that we proposed to track the pedestrians in the picture. It can help us to obtain pedestrian information that includes the pedestrian moving distance and direction. Finally, we use the F1 score to evaluate these two modules of the system. The experimental results show that when the number of pedestrians is
small, the F1 scores of both modules are high. It indicates that the system we proposed has good results when the number of pedestrians is small.

This system needs to solve some problems in the future. First of all, it is necessary to improve the human detection algorithm to solve the problem that the detection result is inaccurate when the pedestrians are blocked. Secondly, it is necessary to speed up the pedestrian detection algorithm. It will improve the real-time performance of this system.

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