Tracking and people counting using Particle Filter Method

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Abstract. In recent years, technology has developed quite rapidly, especially in the field of object tracking. Moreover, if the object under study is a person and the number of people a lot. The purpose of this research is to apply Particle Filter method for tracking and counting people in certain area. Tracking people will be rather difficult if there are some obstacles, one of which is occlusion. The stages of tracking and people counting scheme in this study include pre-processing, segmentation using Gaussian Mixture Model (GMM), tracking using particle filter, and counting based on centroid. The Particle Filter method uses the estimated motion included in the model used. The test results show that the tracking and people counting can be done well with an average accuracy of 89.33\% and 77.33\% respectively from six videos test data. In the process of tracking people, the results are good if there is partial occlusion and no occlusion

1. Introduction

The development of technology has increased rapidly in recent years. One is the use of surveillance cameras to oversee the activities of people in certain areas, such as highways, parking lots and offices. The surveillance camera is usually always equipped with an object tracking module to know the movement of the object. Visual object tracking has attracted considerable attention because there are so many events that require object tracking, whether it is object detection, analyzing people's activities and interactions between people and computers. For example, supervision within the school environment, traffic, office and others [1].

Tracking objects is one way to simplify people's work. Usually tracking and counting objects, especially people used by monitoring activities that exist in those environments [2]. Based on the object under study, object tracking can be grouped into one object tracking and tracking multiple objects [3].

Tracking one object or multiple objects is relatively simple from tracking multiple objects with poor background conditions [4]. There has been a lot of research related to tracking, whether it's an object or a lot of objects. The study aims to obtain effective tracking, ie through the detection of objects, techniques, or different algorithms such as Kalman filter, mean shift and particle filter [5]. In person tracking, Jin et al. [6] divides body parts into 3 representations of histogram, color and HOG, and are tracked separately. But the method only tracks objects singly and cannot overcome occlusion. Habibi et al [7] used adaptive particle filter for tracking of small object. Although the formulated particle filter kernel shows better results than a typical particle filter, it cannot track many objects and cannot overcome occlusion. Cabido et al. [8] formulates a tracking algorithm that combines a particle filter with a memetic algorithm. Although it can track many objects, but not yet able to handle occlusion.
In this study, tracking and people counting using Particle Filter Method has been performed. Experimental results show that the model used successfully tracking many objects and the occlusion condition.

2. Methods
2.1. Particle filter for tracking and people counting
Figure 1 shows the block diagram of the process of tracking and people counting using particle filter method applied in this study. The process of tracking object consists of four process: pre-processing, segmentation, tracking object, and counting.

![Figure 1. Scheme of the tracking and counting system](image)

The input video is a color video of scene. At the stage of pre-processing the input video is processed by video processing operations that is scanning video, set ROI, and Histogram Equalization. Results of pre-processing is input to the segmentation stage with Gaussian Mixture Model (GMM) and BLOB analysis. The stage of tracking consist of motion estimation and particle filter. Counting of people based on based on the amount of the centroid on ROI.
2.2. Gaussian mixture model

Gaussian mixture model (GMM) is a popular method that has been employed to segmentation background and non-background. That problem is called background subtraction. The GMM method is based on a parametric model in which the probability density function of the gray levels in the image.

GMM is an appropriate method for various conditions contained in the image, such as the image background is always static, multimodal, or that contain noise (disturbance or unwanted objects contained in the image). In the GMM process, the clustering algorithm is required to classify any pixels that include foreground or background. GMM models are formed from time-based pixel color data. The result of the model will be 2 parts, a model that reflects the background and non-background model. The number of GMM models used affects the number of background models. The more GMM models are used, the more the background model is owned by a pixel.

Step by step of GMM method:
1. Select the ROI area of the frame
2. Build GMM models. GMM models are formed from time-based pixel color data. The result of the model will be 2 parts, a model that reflects the background and non-background model.
3. Match each frame with pre-established GMM model frame.
4. Check whether the model is appropriate or not, if not then have to create a new model and return to step three, if it is appropriate it will proceed to the next step.
5. Update the GMM parameters then normalize the weights.
6. Sort the mode based on the weight, then select the GMM that will be the background and foreground.

2.3. Particle filter

Particle filter is a state space method for applying Bayesian filters. The main idea is to approximate the posterior probability distribution by the particles. Each particle represents a state of the object hypothesis, with a discrete sampling corresponding to probability (weight). The particles are usually done resampling to relieve particle degeneration. The efficiency and accuracy of particle filters for tracking depends on the distribution and effective model of observation for particle weighting [9].

Define an object state vector as $X = (x, y)$ with $(x, y)$ being the center of the object. The state space model of the object being tracked is:

$$X_{t+1} = f(X_t, \mu_t)$$  \hspace{1cm} (1)

$$Z_t = g(X_t, \xi_t)$$  \hspace{1cm} (2)

where $f$ is a dynamic model, $g$ is a observation model, $\mu_t$ and $\xi_t$ are the process and observation noise, respectively.

The dynamic models and observation models used in this study are similar to those used in [9]. The tracking process is done on the second frame because the object initialization has been done on the first frame. Then to get the motion vector added to the motion model, motion estimation is performed on two consecutive frames (N-1 and N frames). Furthermore the particle filter method is applied until the last frame.

2.4. Block matching algorithm

Block matching is one of the motion estimation algorithms. The purpose of the motion estimation technique is to obtain a motion vector (displacement or velocity) for each pixel in the image. This algorithm estimates movement on block to block. The area of movement is assumed to be constant with a square block area and represented by a single motion vector on each block [10]. Each block in the frame is now matched to the block in the previous frame based on a specific cost function. Some of the most popular and inexpensive computational cost functions are Mean Absolute Difference (MAD) as in Equation 3.
\[ MAD = \frac{1}{N^2} \sum_{i=0}^{N-1} \sum_{j=0}^{N-1} |C_{ij} - R_{ij}| \]  

(3)

where \( N \) being the macro size of the block, \( C_{ij} \) is the pixel on the current block macro and \( R_{ij} \) is the pixel on the block macro being referenced. Figure 1 shows the steps in the block matching algorithm.

![Figure 1](image1.png)

**Figure 2. Algorithm of the block matching [10]**

3. Experimental result

In the experiments, we used recorded videos of an outdoor scene. There are 6 videos used as test materials, Video has different number of frame. Table 1 shows the detailed information about the six videos.

| No | Name       | Number of Frame | Description                                      |
|----|------------|-----------------|-------------------------------------------------|
| 1  | Video1.avi | 78              | Two people with occlusion, walk                  |
| 2  | Video2.avi | 58              | Two people without occlusion, walk               |
| 3  | Video3.avi | 97              | Seven people with partial occlusion, walk        |
| 4  | Video4.avi | 26              | One people, run                                 |
| 5  | Video5.avi | 84              | One person with full occlusion, walk             |
| 6  | Video6.avi | 100             | Two people walk concurrently                     |

Figures 3, 4, 5, 6 show some examples of the results of tracking experiments and people counting.
Figure 3. Result of video1.avi

Figure 4. Result of video2.avi

Figure 5. Result of video3.avi

Figure 6. Result of video5.avi
Testing on video1.avi and video2.avi gives result of tracking and people's counting are good accurate with few errors. In the test on video3.avi the results obtained are not good because of partial occlusion so that people cannot be counted. Experiments on video4.avi obtained the result that the particle filter method can perform the object tracking very well. Tests on video6.avi obtained results that the system can do tracking but when two people walk together then the person is considered an object. Result of tracking and people counting for each of the videos are presented in Table 2 and Table 3.

Table 2. The results of tracking

| Video      | Number of Frame | Number of frames traced | Number of frames not traced | Percentage |
|------------|----------------|-------------------------|-----------------------------|------------|
| Video1.avi | 78             | 71                      | 7                           | 91 %       |
| Video2.avi | 58             | 58                      | 0                           | 100 %      |
| Video3.avi | 97             | 67                      | 30                          | 69 %       |
| Video4.avi | 26             | 25                      | 1                           | 96 %       |
| Video5.avi | 84             | 74                      | 10                          | 88 %       |
| Video6.avi | 100            | 92                      | 8                           | 92 %       |

Table 3. The results of people counting

| Video      | Number of Frame | Number of frame counting | Number of frame counting False | Percentage |
|------------|----------------|--------------------------|--------------------------------|------------|
| Video1.avi | 78             | 71                       | 7                              | 91 %       |
| Video2.avi | 58             | 58                       | 0                              | 100 %      |
| Video3.avi | 97             | 67                       | 30                             | 69 %       |
| Video4.avi | 26             | 21                       | 5                              | 81 %       |
| Video5.avi | 84             | 74                       | 10                             | 88 %       |
| Video6.avi | 100            | 35                       | 65                             | 35 %       |

4. Conclusion

In this study, particle filter method has been successfully applied to tracking and people counting. The tracking and counting done by several stages: video reading, pre-processing, segmentation using Gaussian Mixture Model (GMM), tracking using particle filter, and counting based on centroid.

The results show that the system can tracking and people counting with an accuracy rate of 89.33% and 77.33% respectively from six videos test data. This research has successfully tracked and counted people in the ROI area with good performance when there is no occlusion, it shows the results of experiment video1.avi, video2.avi, and video 4.avi. The Particle Filter has not been able to track properly if the observed people are running side by side based on the video5.avi test. In the process of tracking people, the results are good if there is partial occlusion and no occlusion.
References
[1] Naushad Ali M.M, Abdullah-Al-Wadud M and Lee, S.L et al. 2014 Multiple Object Tracking With Partial Occlusion Handling Using Salient Feature Points Information Sciences 278 448–465.
[2] Lefloch D, et al. 2008 Real-time people counting system using a single video camera Proc. SPIE 6811, Real-Time Image Processing 681109
[3] Amer E, Dubois E and Mitiche A. 2003 Real-time system for high-level video representations: application to video surveillance SPIE International Symposium on Electronic Imaging 5022 530-541
[4] Hou Y.Land Pang G.K.H. 2011 People counting and human detection in a challenging situation, IEEE. Trans.sys.man and cybernetics 41(1) 24-33
[5] Yang H, Shao L, Zheng F, Wang L and Song Z. 2011 Recent advances and trends in visual tracking: a review Neurocomputing 74 3823–3831
[6] Jin L., Cheng J. and Huang H 2010 Human tracking in the complicated background by particle filter using color-histogram and HoG IEEE International Symposium on Intelligent Signal Processing and Communication 2010 1-4
[7] Habibi Y,Sulistyaningrum D.R and Setiyono B 2017 A new algorithm for small object tracking based on super-resolution technique AIP Conference Proceedings 1867(020024)
[8] Cabido R., Montemayor A.S. and PantrigoJ.J. 2012 High performance memetic algorithm particle filter for multiple object tracking on modern GPUs Soft. Comput. 16(2) 217–230.
[9] Huang y and Llach J. 2008 Tracking the Small Object through Clutter with Adaptive Particle Filter Proc. Int'I. Conf. Audio Language Image Process 2008 357-362
[10] Wang Y., Ostermann J., and Zhang Y-Q. 2002. Video Processing and Communication (Upper Saddle River, N.J: Prentice Hall)