# Particle Filter with Gaussian Weighting for Human Tracking

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### Abstrak

*Penapis partikel untuk pelacakan obyek dapat mencapai akurasi pelacakan yang tinggi. Untuk melacak obyek, metode ini menghasilkan sejumlah partikel yang merupakan representasi dari obyek target kandidat. Lokasi obyek target ditentukan oleh partikel dan berat masing-masing. Kerugian dari filter partikel konvensional adalah waktu komputasi terutama pada perhitungan berat partikel. Partikel filter dengan pembobotan Gaussian diusulkan untuk menyelesaikan masalah komputasi. Ada dua tahap utama dalam metode ini, yaitu prediksi dan update. Perbedaan antara partikel filter konvensional dan filter partikel dengan pembobotan Gaussian adalah pada tahap update. Dalam metode partikel filter konvensional, berat dihitung setiap partikel, sedangkan pada metode yang diusulkan, berat partikel tertentu saja yang dihitung, dan berat partikel selebihnya dihitung menggunakan bobot Gaussian. Percobaan dilakukan menggunakan data set buatan. Keakuratan rata-rata adalah 80.862%. Akurasi tinggi yang dicapai dengan metode ini bisa digunakan untuk sistem pelacakan waktu-nyata.*

*Kata kunci: bayesian, filter partikel, prediksi, update*

### Abstract

*Particle filter for object tracking could achieve high tracking accuracy. To track the object, this method generates a number of particles which is the representation of the candidate target object. The location of target object is determined by particles and each weight. The disadvantage of conventional particle filter is the computational time especially on the computation of particle's weight. Particle filter with Gaussian weighting is proposed to accomplish the computational problem. There are two main stages in this method, i.e. prediction and update. The difference between the conventional particle filter and particle filter with Gaussian weighting is in the update Stage. In the conventional particle filter method, the weight is calculated in each particle, meanwhile in the proposed method, only certain particle's weight is calculated, and the remain particle's weight is calculated using the Gaussian weighting. Experiment is done using artificial dataset. The average accuracy is 80,862%. The high accuracy that is achieved by this method could use for the real-time system tracking*

*Keywords: particle filter, bayesian, prediction, update.*

## 1. Introduction

The objective of object tracking in computer vision is finding the location of the target in input data. This object tracking is used in many applications, such as gait recognition, automatic surveillance system which detects the abnormal movements [1-3], smart transportation, and etc [4]. Therefore, currently many researchs have been done in order to develop object tracking methods to achive a better performances, *i.e.* accuracy and computational time.

Particle filter (PF) method is used in many human object tracking since it is robust to noisy image [5-9]. PF method has two main stages, i.e. prediction and update. In the prediction stage, particles are generated. These particles are the representation of candidate target object's location. Hence, as the number of generated particles is increased, then the number of representation of candidate target object's location is increased. In the update stage, the weight of each predicted particle will be calculated based on the measurement. Therefore, the larger weight value of the predicted particle is the larger probability of the particle being candidate of target object's location.

As the number of the generated particles is increased, then the accuracy of tracking is increased.  However, this will caused the computational time in the update stage is increased, i.e to calculate the weight of each particle.  Hence in this research, particle filter with Gaussian is used for human tracking since the method can reduce the required computational time compare to conventional method of particle filter.  The paper is organized as follows, section two explains the proposed method, section three discusses the experiments that had been done, and the final section is the conclusion.

## 2. Particle Filter with Gaussian Weighting

The objective of human tracking is to find the location of the target object in each frame from data video input.  The Particle Filter method (PF) is used by the many researchers because of its advantages, i.e. the method is not limited to Gaussian linear problem only, it is robust to noisy image, it is simple algorithm, and etc.  Hence this method can be used and implemented to more complex environment.

Generally, there are two main stages in the PF method, i.e.:

1.  Prediction. A number of $M$ particles are generated at time $t$, $x_t^{[m]}$, $m$=1,2,3,...,$M$. These particles are randomly generated based on particles at time t-1and distributed using the state transition model $p(x_t|x_{t-1})$ as follows,

$$x_t^{[m]} \sim p(x_t \mid x_{t-1}^{[m]})$$

(1)

2.  Update.   The predicted particles from the first stage are updated based on the measurement using the resampling process. The weight of each particle is used as the measurement in this stage.  This weight represents how close predicted particles to the actual target object's location.  In the resampling process, the particles with larger weight will have a larger probability to be regenerated in the process; on the contrary, the particles with smaller weight will have smaller probability to be regenerated.  The result particles from resampling process is the objective of tracking using PF method.

In human tracking process, generated particles are the representation of candidate of target object's location, and shown in Figure 1. In human tracking process, PF method would follow the movement of target object in each frame using the prediction and update stage. Furthermore, PF method generates number of candidate target object's location hence more generated candidate location then the tracking accuracy is expectably increased.  Prediction stage which has objective to predict the current location of target object based on the previous tracked location can be seen in Figure 2
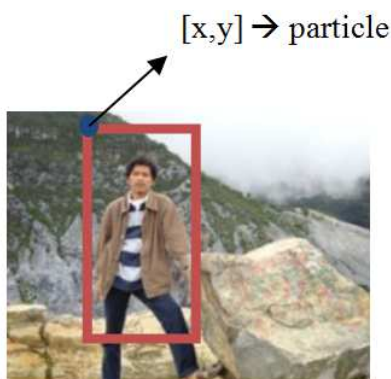


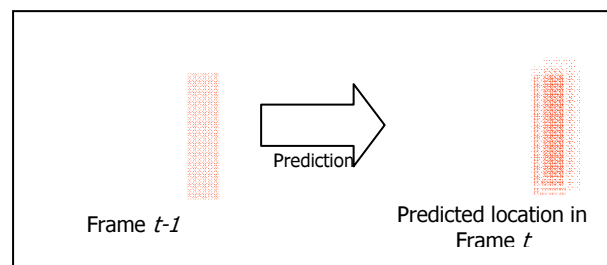Figure 1.  Particle representation in human tracking process



Figure 2.  Prediction Stage in Human Tracking Process

Second stage in PF method is update stage.  In this stage, predicted particles are updated based on the new measurement which is current frame from data video.  Resampling

process is included in the stage.  All predicted particles are resampled based on each weight. Larger weight particle will have larger probability to be regenerated in the resampling process; on the contrary, smaller weight particle will have smaller probability to be regenerated.    The result of the resampling process is the location of target object in the current frame.  The update stage in tracking process is shown in Figure 3.
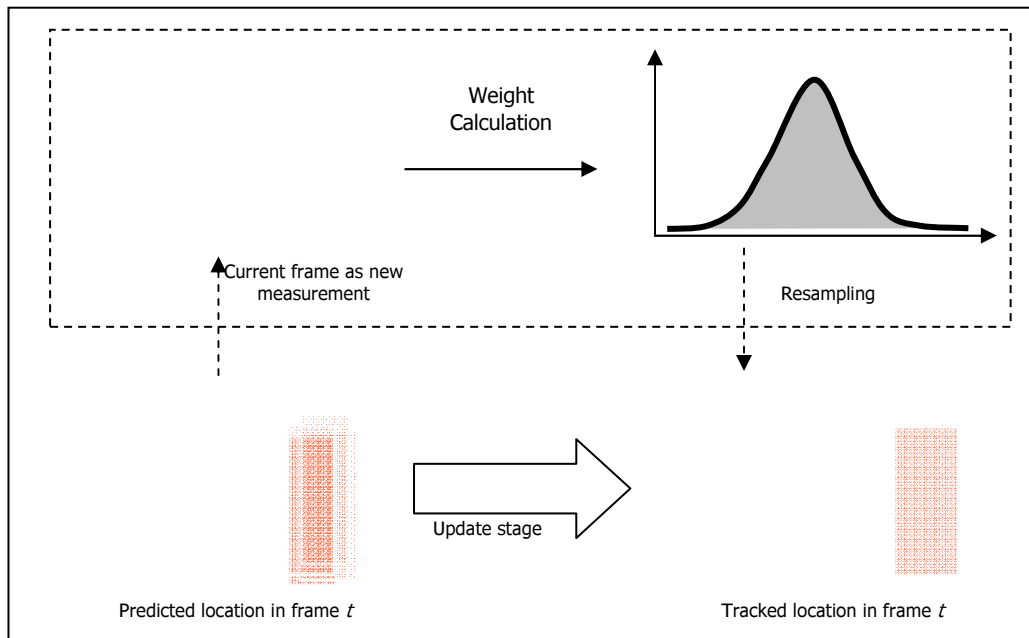


Figure 3. Update Stage in Human Tracking Process

Many generated particles in prediction stage then many candidate location of target object in the current frame.  Therefore the probability that the actual target object location in the group of candidate target location is bigger.  Hence the accuracy of tracking will be increased. However, many generated particles then more computational time are required for the weight calculation in update stage.  This research modified the PF method; hence the high accuracy of tracking is maintained meanwhile the computational time is reduced.

Particle Filter with Gaussian weighting (PFG) is derived from the conventional PF method.  Based on the observation, the weight calculation of each predicted particles process requires the most computational time of whole stage in PF method.  Furthermore, the particle will have large weight value if it is close to the actual target object location, and the particle will have small weight value if it is far from the actual target object location.  This characteristic of weight value is similar to the form of Gaussian distribution.  Therefore, PFG is developed based on the characteristic [10].  In the conventional PF method, the particle's weight is calculated in each particle.  Meanwhile, the PFG method, only weight of few particles are calculated, to find the mean and variance of Gaussian distribution, and the weight of remain particles are calculated using the Gaussian distribution.

The PFG method consists of two additional stages.  First, weight calculation of  few particles to find mean and variance value and build Gaussian distribution with these values. Second, calculate of all particles weight based on the Gaussian distribution.  In the first stage, repeated halving principle algorithm is used to find the mean value.  This algorithm divides the problem into two sub problems repeatedly until the goal of algorithm is achieved.

The following is the pseudocode of the algorithm to find the mean value in the first stage of PFG.

```
//Sorted Particles, the number of particles = n
//last → the last index of particles (n-1)
//first → the first index of particles (0)

While (last-first>=4)
{
    mid  = (first + last ) /2;
    mid1 = (first + mid) /2;
    mid2 = (last + mid) /2;
    meanCandidate=max (Weight(mid), Weight(mid1), Weight(mid2));
    if meanCandidate=Weight(mid)
            first=mid1;
            last=mid2;
    if meanCandidate=Weight(mid1)
            first=first;
            last=mid;
    if meanCandidate=Weight(mid2)
            first=mid;
            last=last;
}
```

Variance value can be calculated using the Eq. 2 [10], as follows,

$$\sigma = \frac{FWHM}{2.355},$$

(2)

where FWHM is Full Width Half Maximum (see Figure 4)

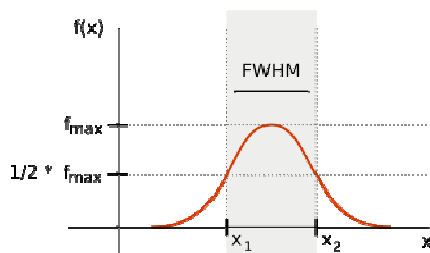FWHM value is calculated based on the mean particle. The FWHM illustration can be seen in Figure 4.



Figure 4. Full Width Half Maximum [10]

Table 1. Example of Artificial data for the experiment

| Video Data | Number of Frame | Example of Frame Image |
|---|---|---|
| 1 | 20 | |
| 2 | 15 | |
| 3 | 43 | |

The second stage of PFG is Gaussian weighting. In this stage, the Gaussian distribution is used to calculate all predicted particles weight as follows,

$$p(x1, x2) = \frac{1}{\sqrt{2\pi\sigma_1\sigma_2}} e^{-\frac{1}{2}\left\{\frac{(x_1-\mu_1)^2}{\sigma_1^2} + \frac{(x_2-\mu_2)^2}{\sigma_2^2}\right\}},$$

(3)

where $(x_1,x_2)$ is the location of predicted particle, and $p(x_1,x_2)$ is the weight of the particle.

## 3. Results and Analysis

Artificial data is used as an experiment in this research. There is variance number of target object in data video. The example of data video that are used for the experiment is shown in Table 1.

In this research, the Grey Level Co-occurrence Matrix (GLCM) [12] is used as the extraction process in the tracking system, and backpropagation neural network as the classification process to determine wether the tracked object is the target object which is human or not the target object. Ten particles are generated in the experiment in each data video. The tracking result of the data video is depicted in Figure 5.



Figure 5. Example of tracking result

Table 2. The tracking accuracy in all experiment data

| Video data | Accuracy rate |
|---|---|
| 1 | 57,14 |
| 2 | 100 |
| 3 | 100 |
| 4 | 47,17 |
| 5 | 100 |
| Average | 80,862 |

Tracking accuracy in all data video is shown in Table 2.

As seen in the result of tracking accuracy table, the PFG method could achieve high tracking accuracy in average, i.e. 80.862%, even though the weight of all particles was not calculated one by one. Unfortunately in some data video, this method achieved lower tracking accuracy. With some improvement in another process of tracking, for instance, the feature extraction process, this PFG method is promising for the object tracking process.

## 4. Conclusion

Particle filter with Gaussian weighting (PFG) is used in this research to track the human location in data video. In the conventional Particle Filter method, the weight particles are calculated one by one, hence the method requires high computational time. Meanwhile, in the PFG, weights of few particles are calculated to find the mean and variance value and build the weight Gaussian distribution. From the distribution, all weight particles are calculated. Therefore, this method will reduce the computational time especially in the weight calculation process. From the experiment, this method achieved tracking accuracy 80.862% in average. With more improvement in other process, this method is promising for object tracking in real-time system.

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