

# Motion based Particle Filter for Human Tracking with Thermal Imaging

Chandrashekhar N. Padole

Department of Informatics, University of Beira Interior  
Covilha, Portugal (Europe)  
[chandupadole@yahoo.com](mailto:chandupadole@yahoo.com)

Luís A. Alexandre

Department of Informatics, University of Beira Interior  
Covilha, Portugal (Europe)  
[lfbaa@di.ubi.pt](mailto:lfbaa@di.ubi.pt)

**Abstract**—Motion Tracking has been applied in many recent applications like surveillance, advance driver assistance system (ADAS), non-cooperative biometrics, virtual reality, etc. Current research in this field includes making tracking system more robust and reliable. Imaging modality to be used in motion tracking also includes thermal imaging (FIR) in addition to the visible imaging. We propose here a motion tracking algorithm using only thermal imaging. The particle filter uses motion based features pre-processed with Wigner distribution. The comparison between the performance measure obtained for thermal and visible imaging is also presented. The results obtained with the proposed system show the robustness of the algorithm. Additionally, the algorithm has less computational complexity as calculation of motion based features requires fewer computations.

**Keywords**-Particle Filter, Motion Tracking, Thermal Imaging, Wigner distribution

## I. INTRODUCTION

Recent advances in digital storage and video hardware's has lead to new applications like surveillance, advance driver assistance system, non-cooperative biometrics, virtual reality etc. The cheaper cost and easy availability of imaging modality has attracted researcher's attention in motion tracking system to be applied in number of applications. The main objective of motion tracking is to analyze the apparent motion in image sequences. Supplementary to visible imaging, recently, thermal imaging has been exploited in applications like motion tracking and face recognition. This has attracted attention from computer vision researchers towards this new imaging modality. There are some attempts to include thermal imaging along with visible camera through data fusion techniques. However, if only one of the modalities is used and reliable results are obtained with it, the system would benefit from the cost saving and higher processing speed.

In applications like outdoor surveillance, where the background temperature is largely different from human beings, thermal imaging can become crucial in identifying the moving person and in tracking them. This fact has primarily motivated us to use only thermal imaging for motion tracking of human beings. Another advantage of thermal imaging is that it cannot sense the shadow or light illumination, which is normally a bottleneck in most of the motion tracking systems based on visible wavelength. Thus, thermal imaging becomes

more suitable for motion tracking in outdoor environments in day time as well as night time, where shadows, non-uniform illumination and low light (night time) are dominating elements, making tracking more complex. Thermal imaging camera output is gray scale image leading to less data processing as compared to the visible color camera. On the other side, clutters like cool body, variation in temperature across same subject, blowing winds with different temperature gradients, person overlap while crossing each other, put challenges in thermal imaging and will have to be handled intelligently in order to achieve efficient and reliable performance from motion tracking system using thermal imaging only.

We present here an approach to track the human motion using thermal imaging only. This algorithm uses the particle filter based on motion features of object. The results are compared with the motion tracking in visible grayscale imaging implemented using particle filter based on motion features.

The remaining part of the paper is organized as follows. Section 2 presents state of the art of motion tracking. Section 3 discusses the theory of particle filter. Implementation methodology and performance measures are described in section 4. Experimental results and discussion are included in section 5. Finally paper is concluded with highlighting main issues and future work.

## II. STATE OF THE ART: MOTION TRACKING

The typical motion tracking system is shown in figure 1, which is normally composed of imaging system, image processing algorithm to give location of moving objects and display device to show path of object and/or signal generation logic to detect the event.

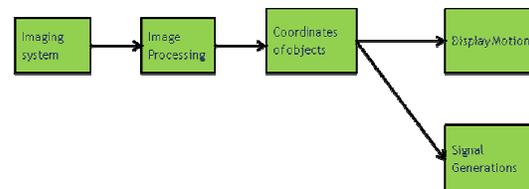


Figure 1. Typical Motion Tracking System

We acknowledge the financial support given by "FCT -Fundacao para a Ciencia e Tecnologia" and "FEDER" in the scope of the PTDC/EIA/69106/2006 research project" BIOREC: Non-Cooperative Biometric Recognition".

Our work is towards the development of motion tracking algorithm to be applied on the images captured from thermal camera. The algorithmic approach of motion tracking system is depicted in figure 2.

Object detection can be achieved with following steps:

- Image subtraction between successive frames is relatively easy approach
- If required, morphological operators can be used
- Segmentation may be required

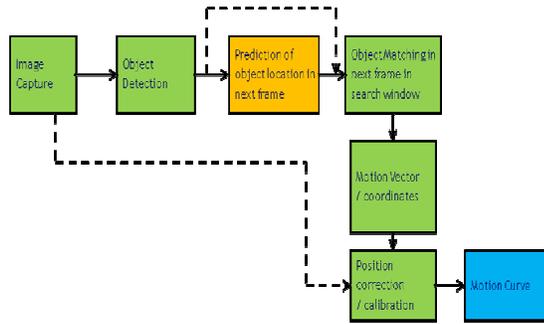


Figure 2. Generalized Motion Tracking Algorithm

Motion tracking using motion estimation involves the matching of a moving object in the surrounding of its location in the next frame. There are the following approaches for finding the best matching unit [3, 4, 5]; pixel based (computationally complex), block based, region based and mesh based (triangle, hexagonal, content based).

The process of best matching unit to estimate the motion vector includes search, based on similarity criterion, across the pixels in close vicinity in next frame. This search window is typically 15x15 pixels and leads to heavy computations. In order to reduce these computations, several optimization techniques appear in the literature: 2-D logarithmic search [6], TSS [7], NTSS [8], FSS[9], two step multiple local winners based [10] and conjugate direction search [11].

Kalman filter [12] and particle filter [13] are the two popular and advanced algorithms in the field of motion tracking. These methods are widely used in the visible camera based motion tracking.

### III. PARTICLE FILTER

The particle filter is a technique to implement a recursive Bayesian filter by Monte Carlo solution. Particle filter is advantageous over the Kalman filter, especially when the quantity to be estimated has multimodal distribution and it is not Gaussian. In particle filter, the key idea is to represent the required posterior density function by a set of random samples with associated weights and then compute estimates based on

these samples and weights. The basic data flow graph of particle filter is depicted in figure 3.

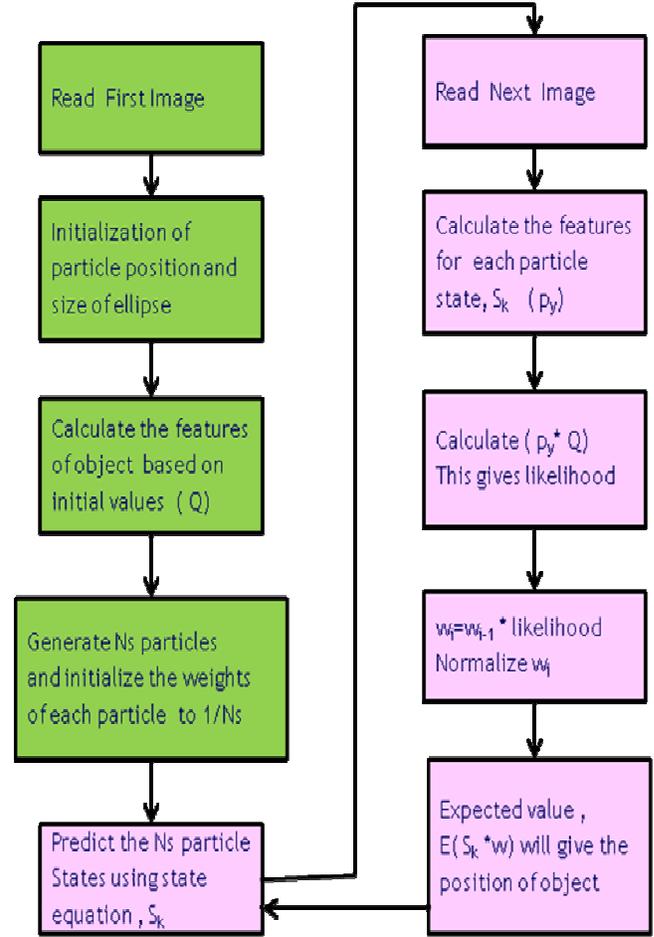


Figure 3. Particle Filter : Typical data flow diagram

### Degeneracy Problem

This is a common problem with the particle filter. In this problem, after few iterations, it is likely to have particles with negligible weights. The variance of the important weights will only increase over time and thus it is impossible to avoid the degeneracy phenomenon. Because of degeneracy, large computational effort is required to update particles whose contribution to the approximation to  $p(x_k|z_{1:k})$  is almost zero. A measure of degeneracy of the algorithm is the effective sample size,  $N_{eff}$  and given by

$$N_{eff} = \frac{N_s}{1 + \text{var}(w_k^{*i})} \quad \dots(1)$$

where  $w_k^{*i}$  is true weight of particle and is given by

$$w_k^{*i} = p(x_k^i | z_{1:k}) / q(x_k^i | x_{k-1}^i, z_k) \quad \dots(2)$$

This cannot be evaluated exactly, but an estimate  $\hat{N}_{eff}$  of  $N_{eff}$  can be obtained by

$$\hat{N}_{eff} = \frac{1}{1 + \sum_{i=1}^{N_s} (w_k^{*i})^2} \quad \dots(3)$$

where  $w_k^{*i}$  is now normalized weight of particles

Thus, particle filter with re-sampling is presented in figure 4.

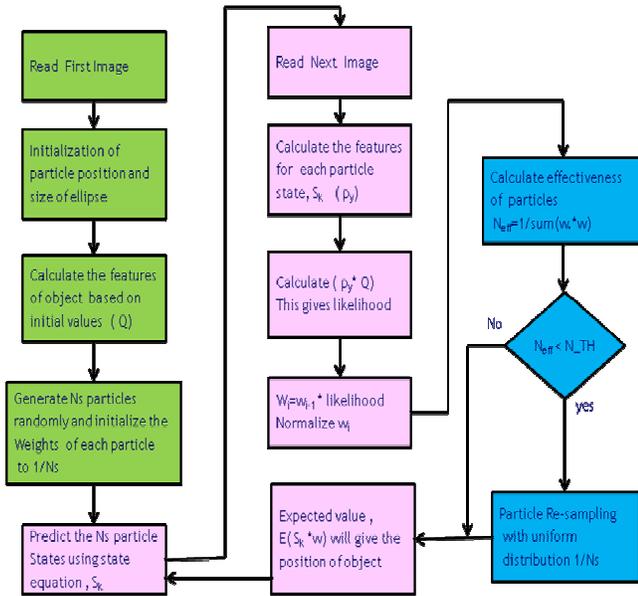


Figure 4. Particle Filter with re-sampling

#### IV. METHODOLOGY

The particle filter implemented here is based on motion information only. The current frame image is subtracted with previous frame image to get a difference image. This difference image is enhanced by Wigner distribution [1]. Thus, enhanced image carries motion information about object. In order to avoid the noisy information of motion, thresholding is done to get binary image, indicating white pixel as a motion component. However, the deviation from precise thresholding value does not affect the performance of tracking as it will have an effect uniformly across the whole frame. The feature vector for each particle is the sum of motion component within a particle region and leads to a single element feature vector for updating the weights for each particle.

We have calculated three measures, controlled tracking length, average MSE and number of redistribution; defined below to evaluate the performance of motion based particle filter for tracking the human beings using thermal imaging. The experiment was repeated for different values of particles in particle filter. Further, performance obtained from thermal imaging is compared with visible grayscale imaging.

##### A. Controlled Tracking Length

The controlled tracking length is defined as the number of frames for which tracking was recoverable even if in some frames localization of object gets diverted. The experiment is stopped when localization becomes uncontrolled and was not able to come back on the track of object.

##### B. Average MSE

Before performing experiment, the video sequence was annotated manually for the location of objects. The mean square error, MSE, in each frame is calculated from the difference between the x- and y- components of annotated object localized point and estimated point by particle filter. This MSE is averaged over the frames up to controlled tracking length to obtain the average MSE.

##### C. Number of redistribution

To avoid the degeneracy, the redistribution of particles and associated weights is performed, when the total normalized weight of particle filter,  $N_{eff}$ , comes below the predefined threshold,  $N_{th}$ . The number of times redistribution is performed across the controlled tracking length is termed as number of redistribution.

#### V. EXPERIMENTAL RESULT

The algorithm was developed in MATLAB and applied on the database available on OTCBVS website [14]. We used the third database, namely, OSU Color and Thermal Database. This database includes six image sequences, each of around 1500 frames (exact number varies from sequence to sequence). The first three sequences are from one location with pedestrians. The remaining sequences are taken from a different location. We have used first sequence, color (to be converted into grayscale) and thermal, for the evaluation of particle filter.

The parameters of particle filter are given below:

Initial / redistribution of weights of particle	= uniform distribution
Number of Particles, N	= 10, 50, 100, 200, 300, 500
Redistribution Threshold	= $3N/4$
Shape of particle	= rectangle

The performance of motion based particle filter is presented in table 1. In same table, the performance of motion based

TABLE I. PERFORMANCE MEASURES AND COMPARISON OF MOTION BASED PARTICLE FILTER WITH THERMAL AND VISIBLE IMAGING

Number of Particles	Thermal Imaging			Visible ( grayscale ) Imaging		
	Controlled Tracking Length	Average MSE	Number of Redistribution	Controlled Tracking Length	Average MSE	Number of Redistribution
10	225	41.27	170	75	50.18	34
50	295	11.76	79	113	26.86	16
100	450	8.76	68	158	53.19	18
200	426	9.81	34	113	21.64	5
300	390	6.77	24	261	16.07	10
500	288	6.44	12	110	26.16	3

particle filter in thermal imaging is compared with visible (grayscale) imaging. The superior results obtained with thermal imaging proves it to be a good candidate for the imaging modality to be used in motion tracking for human beings. The important measure, average MSE, is plotted in figure 5 , for thermal and visible imaging. It is interesting to note that because of the good contrast obtained in thermal imaging , it outperforms the visible imaging in this measure.

## VI. CONCLUSION AND FUTURE SCOPE

As motion tracking of human beings is becoming an important system block for most of the application, it is crucial to understand which kind modality can give reliable performance in motion tracking. We have presented here the motion based particle filter with thermal imaging. It is evaluated for different numbers of particles corresponding to different computational complexity. The performance of thermal imaging is also compared with visible imaging. The results show the superiority of thermal imaging over the visible imaging for the human tracking.

Future work is to find out the more efficient feature vector to be used for particle filter and also to combine different types of feature vectors in order to boost up the performance of motion tracking for human being in thermal imaging.

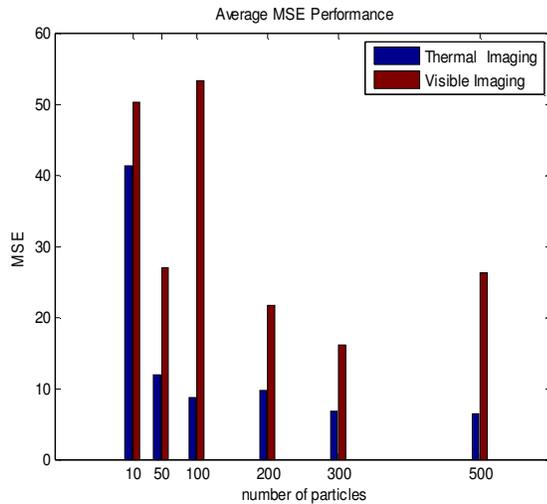


Figure 5. MSE performance for thermal and visible imaging

## REFERENCES

- [1] C. Padole , L. A. Alexandre, "Wigner Distribution based Motion Tracking of Human Beings using Thermal Imaging ", to be appeared in IEEE CVPR 10, OTCBVS 10 workshop , 2010
- [2] E. Herrero, C. Orrite, A. Alcolea, A. Roy, J.J. Guerrero, C. Sagüelles, "Video-Sensor for Detection and Tracking of Moving Objects" IbPRIA, Pattern Recognition and Image Analysis, LNCS 2652, pages 346-353, 2003.
- [3] Van Beek, P.J.L.; Tekalp, A.M.; Puri, A.; "2-D mesh geometry and motion compression for efficient object-based video representation " International Conference on Image Processing, 1997. Proceedings., Volume: 3 , 1997 , Page(s): 440 - 443 vol.3
- [4] Altunbasak, Y.; Murat Tekalp, A.; Bozdagi, G.; "Two-dimensional object-based coding using a content-based mesh and affine motion parameterization" ,International Conference on Image Processing, 1995. Proceedings., Volume: 2 ,1995 , Page(s): 394 - 397 vol.2

- [5] Badawy, W.; Bayoumi, M.; "A mesh based motion tracking architecture" ,The 2001 IEEE International Symposium on Circuits and Systems, 2001. ISCAS 2001. Volume: 4 ,2001 , Page(s): 262 - 265
- [6] Jain, J.; Jain, A.; "Displacement Measurement and Its Application in Interframe Image Coding", IEEE Transactions on Communications, Volume: 29 , Issue: 12, 1981 , Page(s): 1799 - 1808
- [7] [http://www.ece.cmu.edu/~ee899/project/deepak\\_mid.htm](http://www.ece.cmu.edu/~ee899/project/deepak_mid.htm)
- [8] Reoxiang Li; Bing Zeng; Liou, M.L.; "A new three-step search algorithm for block motion estimation ", IEEE Transactions on Circuits and Systems for Video Technology, Volume: 4 , Issue: 4 1994 , Page(s): 438 – 442
- [9] Lai-Man Po; Wing-Chung Ma; "A novel four-step search algorithm for fast block motion estimation ", IEEE Transactions on Circuits and Systems for Video Technology, Volume: 6 , Issue: 3 ,1996 , Page(s): 313 - 317
- [10] Hsien-Hsi Hsieh; Yong-Kang Lai; 2A novel fast motion estimation algorithm using fixed subsampling pattern and multiple local winners search "The 2001 IEEE International Symposium on Circuits and Systems, 2001. ISCAS 2001. Volume: 2 Page(s): 241 - 244 vol. 2
- [11] Srinivasan, R.; Rao, K.; "Predictive Coding Based on Efficient Motion Estimation",IEEE Transactions on Communications, Volume: 33 , Issue: 8 ,1985 , Page(s): 888 - 896
- [12] C. Stauffer and W. E. L. Grimson. " Learning patterns of activity using real-time tracking", IEEE Transaction on Pattern Analysis and Machine Intelligence, 22(8):747-757, 2000.
- [13] M Isard and A Blake," CONDENSATION—Conditional Density Propagation for Visual Tracking", International Journal of Computer Vision 29(1), 5–28 (1998)
- [14] Davis, J., Sharma, V., "Background-subtraction using contour-based fusion of thermal and visible imagery". Computer Vision and Image Understanding 3(2-3) (2007) 162-182