Recovery Method based Particle Filter for Object Tracking in Complex Environment

Yuhi Shiina and Takeshi Ikenaga
Waseda University, Tokyo, Japan
E-mail: yuhi.s-wasedaism@ruri.waseda.jp Tel/Fax: +81-3-5286-2350

***Abstract*—Object tracking is a key process for various image recognition applications, and many algorithms have been proposed in this field. Especially, particle filter has possibility for tracking objects steadily thanks to prediction using many particles. However, other objects that are a similar color or shape with a tracking object hijack a tracking region if there were such objects nearby the tracking object. It is a critical problem. This paper proposes a recovery method based particle filter by focusing a feature regions attached to an object. This proposal tracks both a feature region and an object including the region at once. This proposal utilizes a recovery method that pulls a tracking region back to an appropriate position using the prior frame's distance and angle between the two tracking regions when the tracking region is hijacked by other objects. Some video sequences including complex environment have been tested for evaluating this proposal. The experimental results show that this proposal can track a specified person in the sequences, while conventional method cannot track the person. This result represents that recovery method of proposal effectively works when other objects hijack the tracking region.**

I. Introduction

Object tracking is applied to various fields, which include surveillance, sports scenes and museum entrance security and so on. In addition, many algorithms, such as kalman filter [1][2], extended kalman filter [3], Mean-Shift [4], Cam-Shift [5], SIFT [6] and particle filter [7][8] and so on, have been proposed for object tracking. They have good features each of them.

However, object tracking includes many problems. For example, object confusion is a problem that other objects of a background are a similar color or shape with a tracking object. In addition, occlusion is a critical problem that other objects of backgrounds hide the tracking object. These problems make it difficult to track an object steadily. Also, it is a problem that an object has irregular motion, such as sudden change of direction, stop and start. It is necessary to solve these problems for robust object tracking. For instance, sports scenes include object confusion due to existence of many audiences. Surveillance and entrance security include this problem owing to other objects of background that are a similar color or shape with a tracking object as well as sports scenes.

To solve these problems in complex environments, this proposal utilizes particle filter. While kalman filter predicts an object's position using deterministic only one solution, particle filter tracks an object based on prediction using many particles. Hence, particle filter can track objects steadily.

Reference [9] proposed a hybrid filter based on the combination of multiple particle filtering (MPF) and Rao-Blackwellized particle filtering (RBPF) by exploiting the structure in the state-space model. This method solves the problem of tracking multiple targets in complex scenarios that standard particle filtering (SPF) requires large number of particles to obtain an accurate estimate of the high-dimensional state vector.

Reference [10] proposed extended particle filter with clustering process (XPFCP). It has solution for tracking multiple and dynamic objects in complex environments.

However, these methods have a problem that radar network and stereovision are required for tracking. In contrast, this paper proposes a recovery method based particle filter to solve complex environment without using such devices. It focuses on feature region attached to an object, and tracks both a feature region and an object including the region simultaneously. It utilizes a recovery method that pulls a tracking region back to an appropriate position using the prior frame's distance and angle between the two tracking regions when the tracking region is hijacked by other objects or background.

II. Particle Filter

Particle filter can apply to state space model with non-linear and non-Gaussian, and becomes reality robust tracking based on prediction using many particles. Also, since it has simple algorithm and possibility of parallel computation, it is easy to implement this algorithm. This algorithm is described in detail below and Fig. 1 shows its concept.

1) **Initialization**
   Generating N particles with initial stage distribution.
2) **Prediction**
   In above particle, generating predicted particles in time t with below process.
   a) In N particles, generating system noise based on specified distribution.
   b) Translating each particle in time t-1 based on state transition model with system noise, predicted particles in time t are generated.
3) **Calculation of likelihood (Measurement)**
   Calculating the likelihood of each predicted particle.
4) **Filtering**
   Resampling N particles based on the likelihood of predicted particles group, generate new particles in time t.

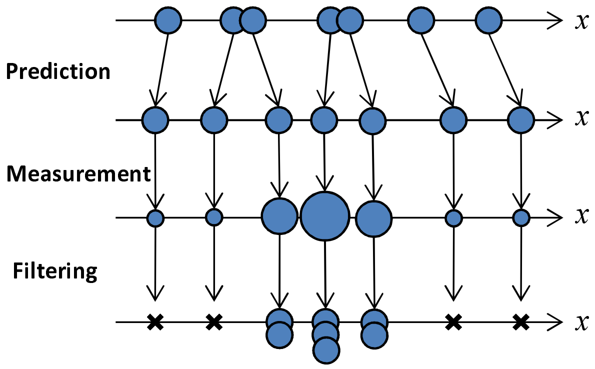

Fig. 1. Algorithm of particle filter.

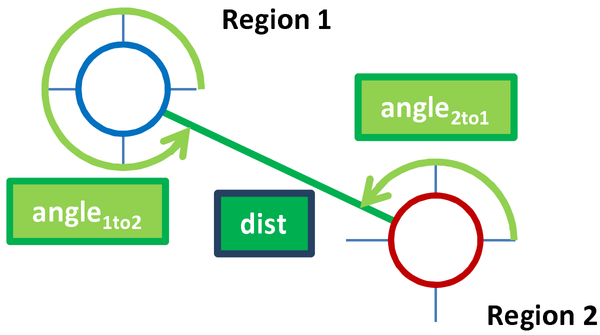

Fig. 2. Information between two tracking regions.

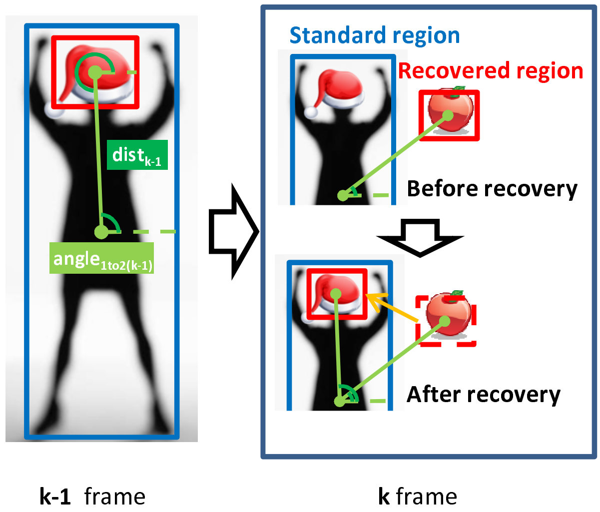

Fig. 3. Example of pullback method.

5) **Updating the time and return back 2)**

In Prediction step, this algorithm predicts object's next position, and translates particles around the predicted position. After that this step, the likelihood of each particle is calculated in Measurement step. Ascribing the particle having highest likelihood to an object, this algorithm can track the object.

III. Proposed Method

This paper proposes a recovery method based particle filter by tracking both a feature region and an object including the region at once. It pulls a tracking region back to an appropriate position when tracking fails due to complex environment. A feature region is a part of an object to distinguish the object and other objects. For example, shoes, bags or color of hair are ascribed to feature regions. This proposal has three key points in below.

1) Pullback method
2) Pullback timing
3) Decision of recovered region and standard region

These points are described in detail below.

A. Pullback Method

By tracking two tracking regions simultaneously, it is possible to catch critical information, which is distance and angles. Fig. 2 describes it. Proposed method uses this information for pullback.

First, in $k-1$ frame, the distance and angles between a feature region and an object including the region are gained. Second, in k frame, if a tracking region fails to track, pullback method pulls one back to an appropriate position predicted using the distance and the angle in $k-1$ frame. Concretely, this method is described by (1) and (2).

$$x_{rec(k)} = x_{std(k)} + dist_{k-1} \cdot cos(angle_{1to2(k-1)}) \qquad (1)$$

$$y_{rec(k)} = y_{std(k)} - dist_{k-1} \cdot sin(angle_{1to2(k-1)}) \qquad (2)$$

In these equations, $x_{rec(k)}$ and $y_{rec(k)}$ represent x and y coordinate of recovered region in k frame. $x_{std(k)}$ and $y_{std(k)}$ describe x and y coordinate of standard region in k frame. Also, $dist_{k-1}$ is distance between two tracking regions in $k-1$ frame, and $angle_{1to2(k-1)}$ represents the angle from region 1 to region 2 in $k-1$ frame. Since down direction is positive in y coordinate, the second term in (2) has negative sign. Thus, in this case, (1) and (2) represent that region 1 (standard region) pulls region 2 (recovered region) back to an appropriate position using distance and angle in $k-1$ frame. By using this method, it is enabling to pull the recovered region back to a correct position when tracking fails owing to complex environment. Fig. 3 shows an example using (1) and (2) in conditions that an object (a person) and feature region (a red hat) are region 1 and region 2.

B. Pullback Timing

To improve tracking accuracy using effective pullback method, it is necessary to determine a timing to apply the method. Hence, it is a second key point to decide the pullback timing. In this paper, a threshold is set up on inter-frame displacement of each region so as to determine the pullback timing.

To set the threshold in displacement, distance and angle are utilized effectively. Proposal applies pullback method when one of the two conditions in below is fulfilled.

1) Angle changes over a threshold in inter-frame

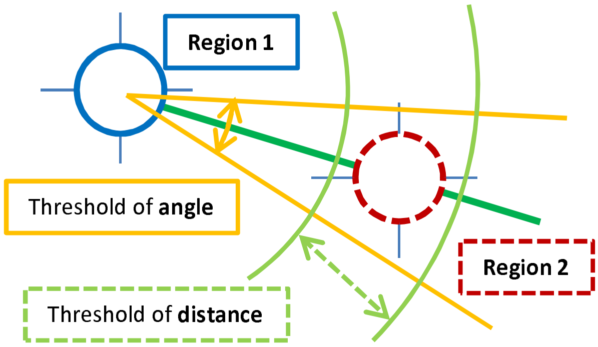

Fig. 4. Concept of threshold for distance and angle.

2) Distance changes over a threshold in inter-frame

Fig. 4 shows these conditions. In Fig. 4, region 2 is allowed to move inside of the trapezoidal range around region 2.Hence, pullback method is applied when a tracking region moved over the range. In fact, recognition of inter-frame displacement is done for each region. Using this pullback timing, proposal can pull a tracking region back to an appropriate position when tracking fails.

C. Decision of Recovered Region and Standard Region

Since tracking accuracy decreases if a standard region were the region that cannot track an object steadily, it is important to decide the standard and recovered region surely. In this paper, comparing the difference of inter-frame displacement, standard and recovered region are determined.

Fig. 5 gives this concept. In particle filter algorithm, a particle having highest likelihood among many translated particles is selected as a tracking object. Thereby, if there are objects that are a similar color or shape with the tracking object in the environment, a tracking region is hijacked by these objects. In that case, an inter-frame displacement of the region widely changes, also tracking fails. Because a particle translated far from a tracking object are recognized as the tracking object. Eventually, it is able to regard the region as the recovered region. Conversely, since another region with small difference of inter-frame displacement has a high possibility to track the tracking object effectively, the region is regarded as the standard region for pullback method. Consequently, comparing the difference of inter-frame displacement of each region, proposal can decide standard and recovered region for pullback.

IV. Experimental Results

This proposal is evaluated by implementing on the software in C language environment. Some video sequences including complex environment have been tested for evaluating. The video is FullHD size (1920 × 1080), progressive and 60 fps (frame per second). In this experiment, this proposal and conventional method is applied to tracking a specified person. In this paper, one sequence's result is showed. The person passes to back through the scene. Then object confusion often

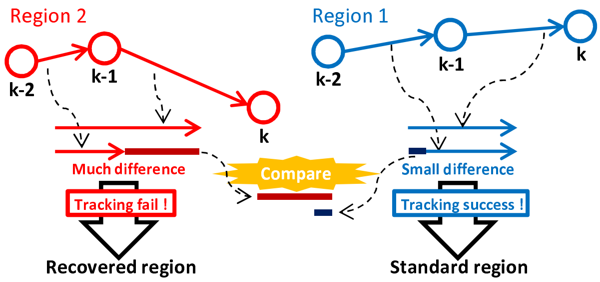

Fig. 5. Decision of standard and recovered region.

happens due to passing pedestrian near by the person. In addition, the person's scale changes drastically through the scene.

This proposal utilizes a method that translates particles based on effective prediction step using two state transition models which have different properties [11]. Using this prediction method, it is able to track an object with irregular motion, which is sudden change of direction, stop and start. Also, in measurement step, the combination of HSV histogram, gradient orientation histogram and difference information is used. Superimposing difference information to measurement, tracking successes for an object with much movement thanks to weight for moving object.

In above environment, while conventional method [11] selects only person as a tracking object (ellipsoidal region), proposal chooses person and bag as a tracking object (ellipsoidal region) and feature region (circle region). Then, tracking accuracies of two methods are compared. 100 particles are used for tracking of one region, and 50 particles are assigned each model that is utilized in prediction step. In addition, the threshold of angle and distance is 20° and 7 for this scene. The result is evaluated by comparing each frame image showing tracking process, and described a graph that represents an error between ground truth and experimental data in each frame. The error is acquired from (3).

$$error = \sqrt{(x - x_g)^2 + (y - y_g)^2} \tag{3}$$

x and y represent experimental values, also x_g and y_g describe true values in (3).

Fig. 6 shows results of each frame. Firstly, in Fig. 6 (a), while tracking successes in Frame 172, the tracking region moves upper in Frame 206. This result describes that color confusion happens due to mistake the pants wore the person and the outer wore the other male. On the other hand, in Fig. 6 (b), it is enable to track the person steadily. This result shows that proposed method can continue to track the person using recovery method when the tracking region moves upper direction.

Fig. 7 represents a gap between true values and experimental values in each frame. In Fig. 7, while both of methods can track the person until Frame 150, the error of conventional method increases after Frame 150. In contrast, proposed method becomes reality robust tracking through the scene.

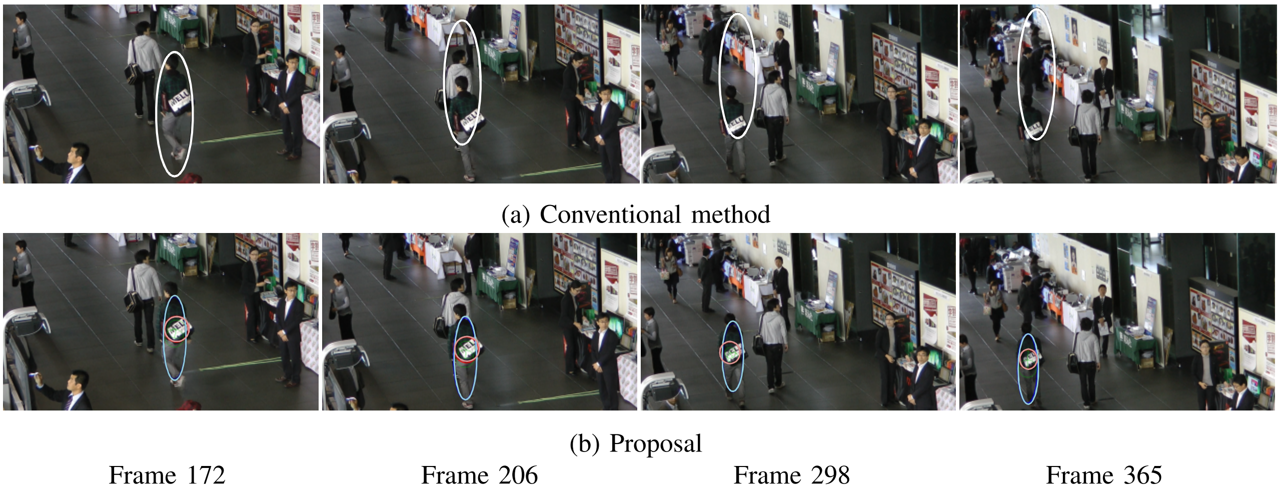

Fig. 6. Result of specified person tracking((a) Conventional method (b) Proposal).

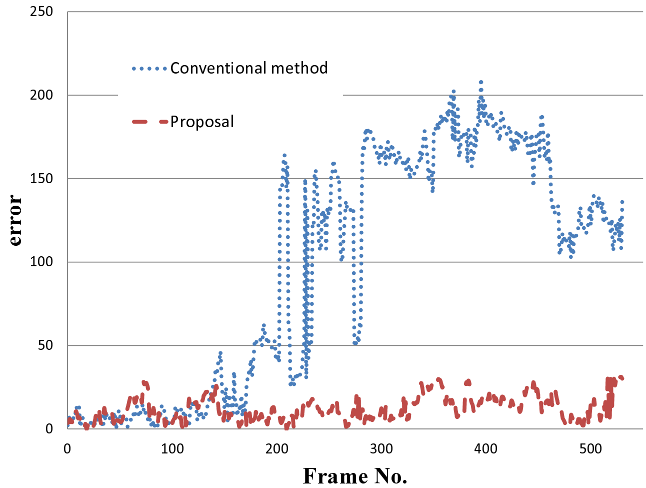

Fig. 7. Error of specified person tracking.

Eventually, using this proposal which tracks both the bag and the person having the bag simultaneously, it is possible to track the person steadily in complex environment.

V. Conclusions

This paper proposes a recovery method based particle filter. It utilized the recovery method that pulls a tracking region back to an appropriate position using the prior frame's distance and angle between two tracking regions when tracking fails due to complex environment.

Some video sequences including complex environment have been tested for evaluating this proposal. The experimental results show that this proposal can track a specified person in the sequences, while conventional method cannot track the person. This result represents that the recovery method of proposal works effectively when other objects hijack the tracking region.

However, in sports scene, since players of same team wear same uniform, it is difficult to track each player distinctly. Proposed method cannot solve this problem owing to less feature region of same team players. So we try to exploit advanced method for solution of this problem.

Acknowledgment

This work was supported by KAKENHI (23300018).

References

[1] R. E. Kalman, "A new approach to linear filtering and prediction problems," *Trans. ASME - Journal of Basic Engineering*, pp. 35-45, 1960.

[2] E. Cuevas, D. Zaldivar and R. Rojas, "Kalman Filter for vision tracking," *Technical Report B 05-12, Freie Universitat Berlin, Fachbereich Mathematik und Informatik*, Aug. 2005.

[3] I. J. Ndiour, and P. A. Vela, "A local extended kalman filter for visual tracking," *Decision and Control (CDC), 2010 49th IEEE Conference on*, pp.2498-2504, Dec. 2010.

[4] D. Comaniciu, V. Ramesh, and P. Meer, "Kernel-based object tracking," *Pattern Analysis and Machine Intelligence, IEEE Transactions on*, Vol. 25, No. 5, pp. 564-577, May. 2003.

[5] X. M. Dong, and K. Yuan, "A ROBUST CAM SHIFT TRACKING ALGORITHM BASED ON MULTI-CUES FUSION," *Advanced Computer Control (ICACC), 2010 2nd International Conference on*, Vol.1 pp.521-524, Mar. 2010.

[6] D. G. Lowe, " Distinctive image features from scaleinvariant keypoints," *Int.Journal of Computer Vision*, Vol. 60, pp. 91-110, 2004.

[7] G. Kitagawa, "Monte Carlo filter and smoother for non-Gaussian nonlinear state space models," *Journal of Computational and Graphical Statistics*, Vol. 5, No. 1, pp. 1-25, 1996.

[8] E. Cuevas, D. Zaldivar, and R. Rojas, "Particle filter in vision tracking," *Av. Revolucion, No. 1500, C.P. 44430, Guadalajara, Jal., Mexico*, Aug. 2005.

[9] P. Chavali, and A. Nehorai, "Multiple Rao-Blackwellized particle filtering for target tracking in urban environments," *Computational Advances in Multi-Sensor Adaptive Processing (CAMSAP), 2011 4th IEEE International Workshop on*, pp. 409-412, Dec. 2011.

[10] M. Marron, J. C. Garcia, M. A. Sotelo, D. Fernandez, and D. Pizarro, " "XPFCP" : An extended Particle Filter for tracking multiple and dynamic objects in complex environments," *Intelligent Robots and Systems, 2005. (IROS 2005). 2005 IEEE/RSJ International Conference on*, pp. 2474-2479, Aug. 2005.

[11] Y. Shiina, and T. Ikenaga, "Dual Model Particle Filter for Irregular Moving Object Tracking in Sports Scenes," *APSIPA Annual Summit and Conference (ASC 2011)*, Oct. 2011.