Kalman Filter Based Multiple Objects Detection-Tracking Algorithm Robust to Occlusion

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  - Data association
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Introduction

- This paper considers the problem of simultaneously tracking one or more objects in video sequence.
- In particular, our paper focuses on the cases where several objects occlude each other.

Introduction

- Contrary to single object tracking, there are many problems in multiple objects tracking.

- One of the important problems is matching between targets and observations.

Introduction

- Another important problem is the occlusion.
- To solve this problem, Shiloh et al. [4] , Chang et al. [5] , and Dockstader [6] overcame occlusion in multiple objects tracking using multiple camera.
- Tao Yang et al. [9] used feature correspondence for occlusion handling in dynamic scenes.

Introduction

- [4] S.L. Dockstader, and A. M. Tekalp, "Multiple Camera Tracking of Interacting and Occluded Human Motion“
- [5] Ting-Hsun Chang, Shaogang Gong, and Eng-Jon Ong, "Tracking Multiple People under Occlusion Using Multiple Cameras“
- [6] S.L. Dockstader, and A. M. Tekalp, "Multiple Camera Fusion for Multi-Object Tracking“
- [9] Tao Yang, Stan Z.Li, Quan Pan, and Jing Li, "Real-Time Multiple Objects Tracking with Occlusion Handling in Dynamic Scenes"

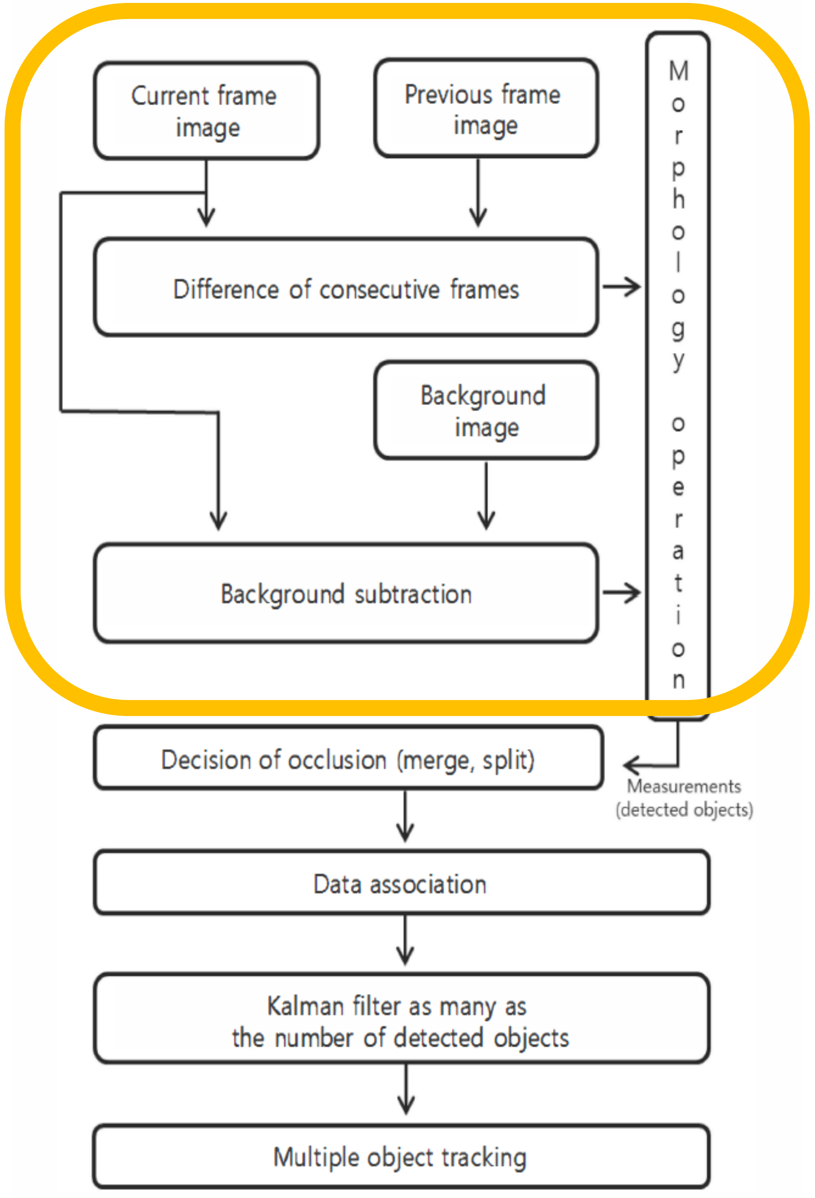
Introduction

- To deal with multiple objects tracking in dynamic scenes, we proposed a Kalman filter based tracking algorithm.

- The Kalman filter can handle the Occlusion properly.

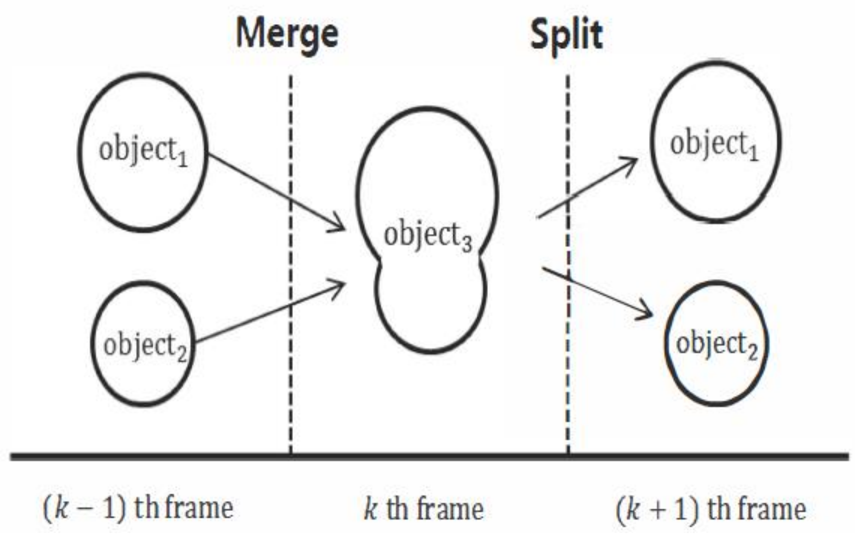
Proposed methods system overview

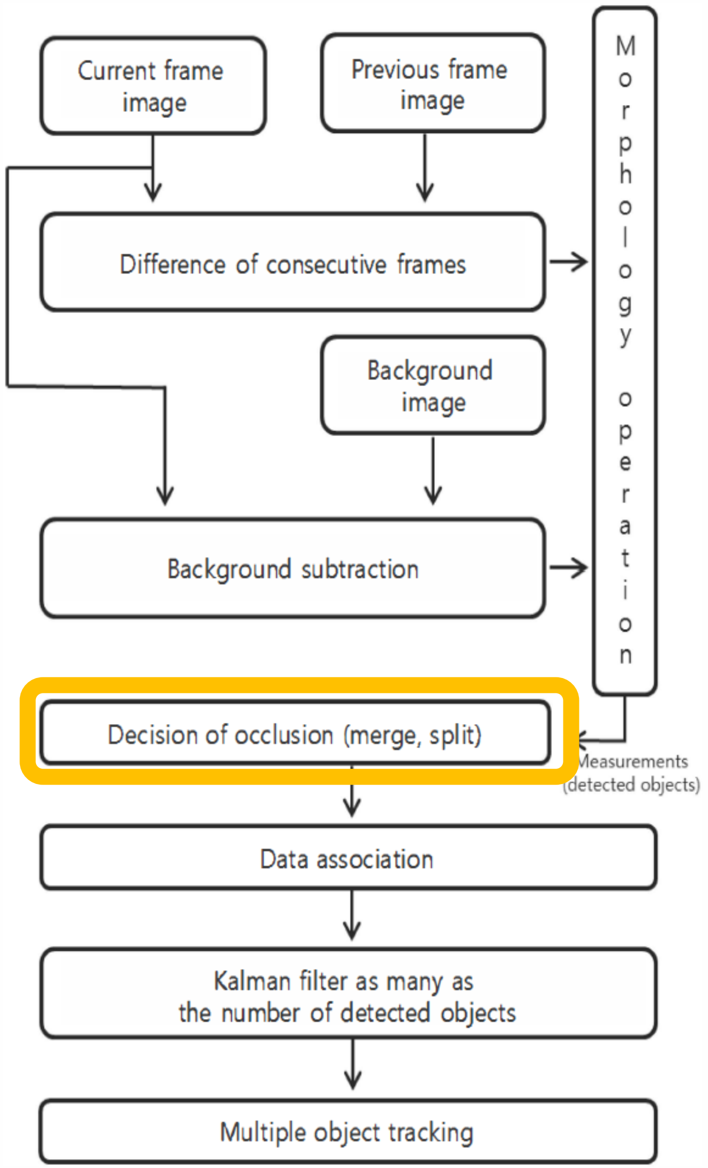
- A background subtraction and motion information is used for detecting multiple moving objects.



Proposed methods system overview

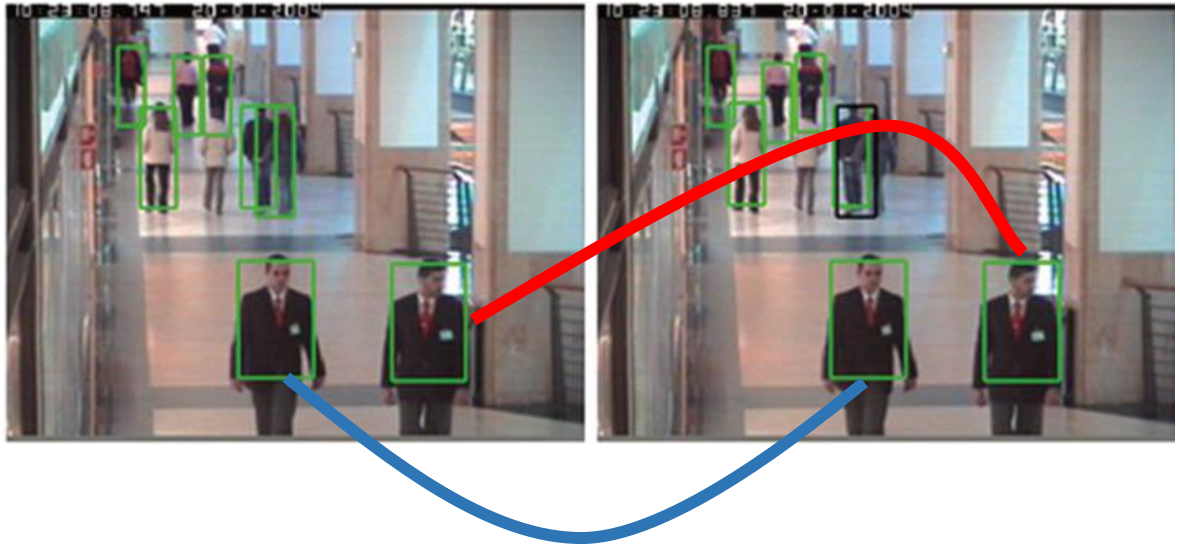
- We need to know whether “merge” or “split” occur because we need to do data association .

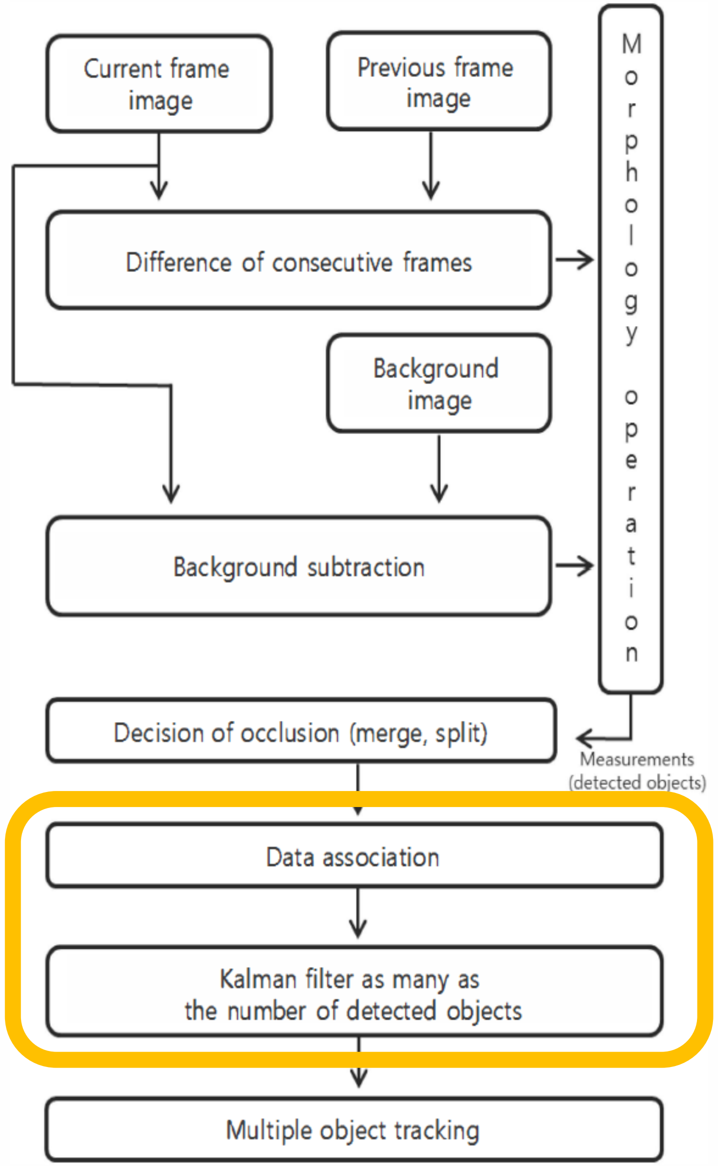




Proposed methods system overview

- The kalman filter need a correct measurement, so we need Data association.

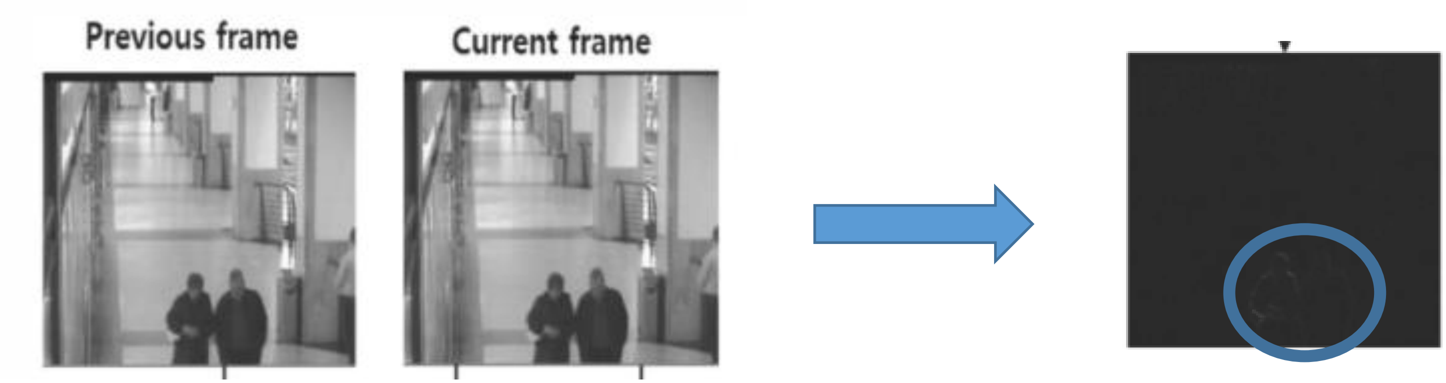




Proposed methods
moving object detection

- To obtain the information such as positions and the number of pixels that objects occupy, we should detect multiple objects in the frame.
- First, difference of consecutive frames is used to detect the change area of frames.

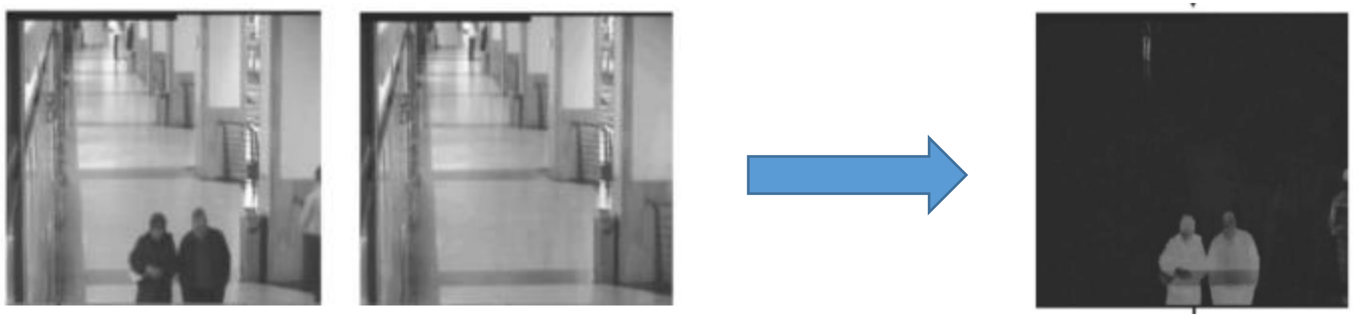
$$\mathrm{FD_t}(x,y) = \begin{cases} 0 & if\ |I_t(x,y) - I_{t-1}(x,y)| < \tau_{FD} \\ 1 & if\ |I_t(x,y) - I_{t-1}(x,y)| \geq \tau_{FD} \end{cases} \quad (1)$$



Proposed methods
moving object detection

- The algorithm may not detect all of moving objects. Therefore, our algorithm utilizes also background subtraction.

$$BS_t(x,y) = \begin{cases} 0 & if\ |I_t(x,y) - B(x,y)| < \tau_{BS} \\ 1 & if\ |I_t(x,y) - B(x,y)| \geq \tau_{BS} \end{cases} \qquad (2)$$

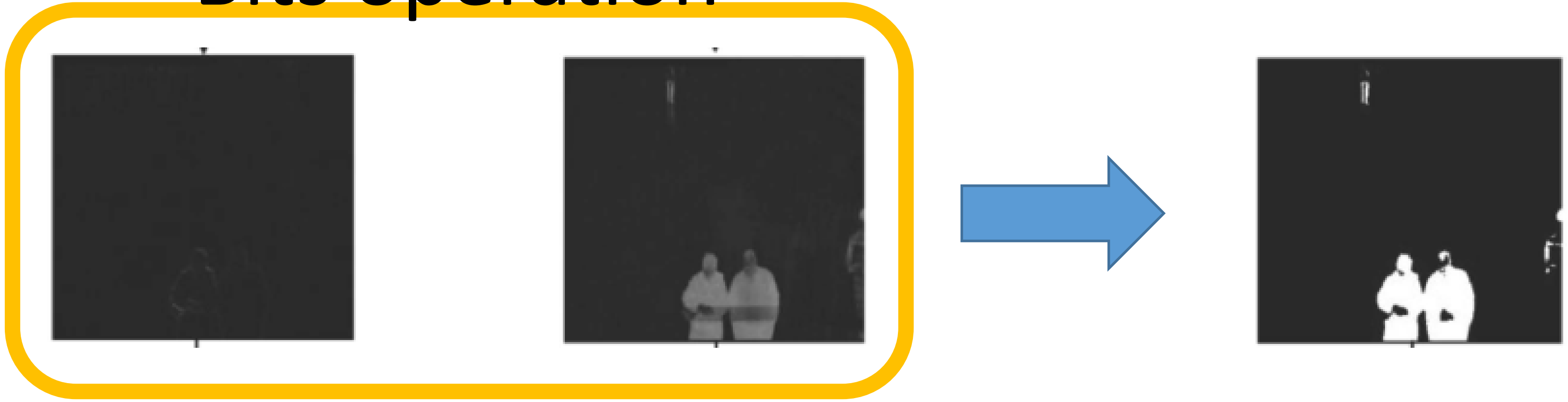


Proposed methods
moving object detection

- Then a bit operation is used.

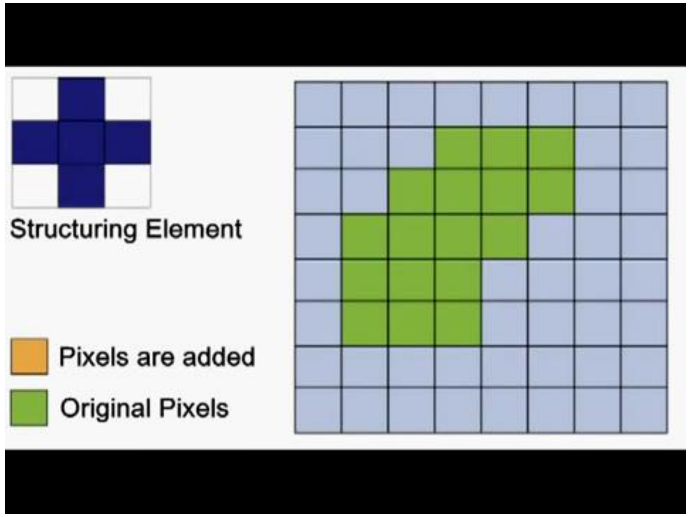
$$\mathrm{BM}_t(x, y) = BS_t(x, y) \cup (BS_t(x, y) \cap FD_t(x, y)) \quad (3)$$

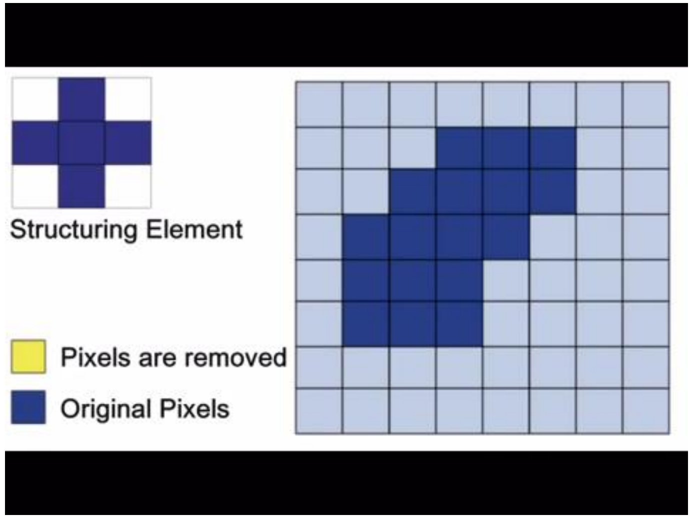
Bits operation



Proposed methods
moving object detection

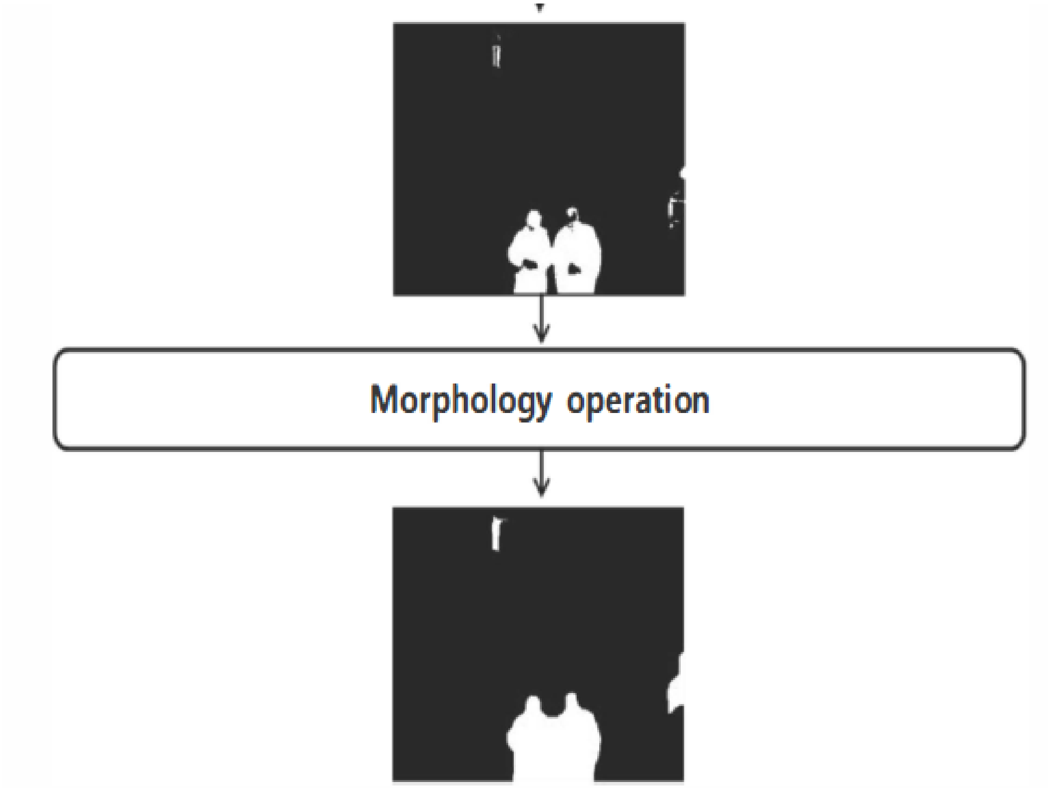
- Finally, morphology operations are applied in order to get precise information.
- Dilation and Erosion are used.





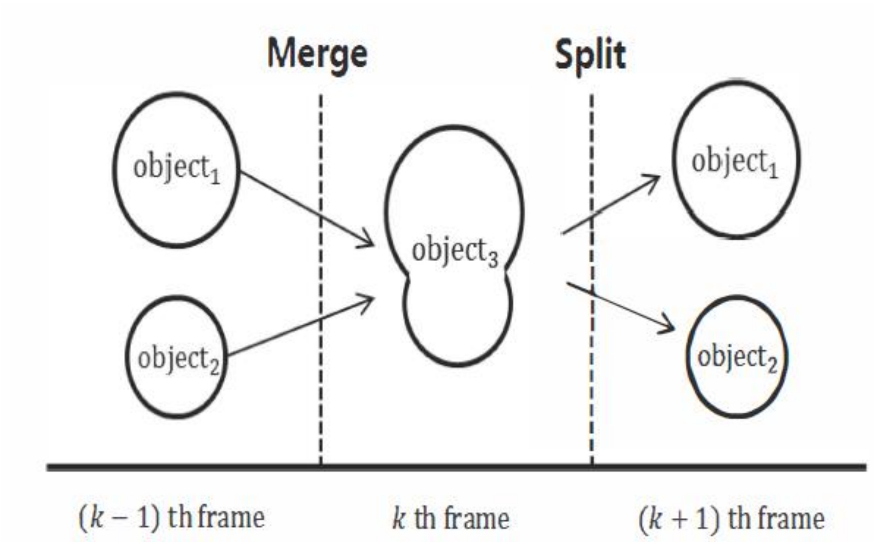
Proposed methods
moving object detection

$$\mathrm{ME_t}(x,y) = Erode\left(Dilate\left(BM_t(x,y)\right)\right) \qquad (4)$$



Proposed methods
Decision of occlusion

- Occlusion essentially includes merge and split problems.
- This section covers how to determine which case is occurred.
- The algorithm can distinguish it using ratio variation.
- The ratio is define as $R = \dfrac{height}{weigth}$



Proposed methods
Decision of occlusion

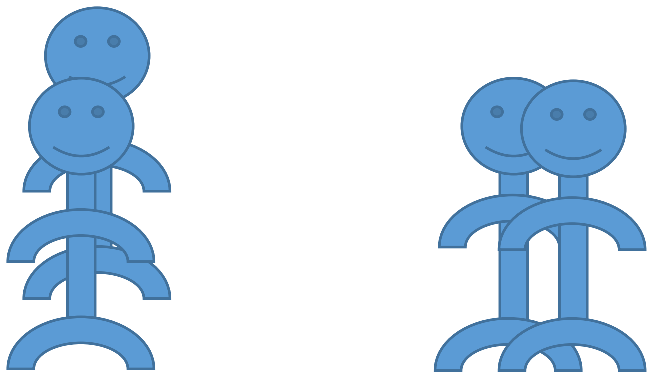
- Merge problem

$$R_i = \frac{Height_i}{Width_i} \quad (14)$$

Merge condition is expressed as follows:

$$R_k^i > \tau_{ratioUp}, \quad i = 1, \dots, m \quad (15)$$

$$R_k^i < \tau_{ratioDown}, \quad i = 1, \dots, m \quad (16)$$



Proposed methods
Decision of occlusion

- Split problem:
  - Split problem always occurred after merge problem happened.
  - We use the fact that the ratio of split object is similar to it of the single object.

$$\tau_{ratioDown} < R_k^i < \tau_{ratioUp}, \quad i = 1, \dots, m \qquad (17)$$

Proposed methods
Data association

- In multiple objects tracking system, we can obtain multiple measurement through detection.
- In order to track objects correctly, we have to distinguish them correctly.
- Two features are used:
  - Distance
  - Area

Proposed methods
Data association-Distance

- Distance is used between the latest positions of targets (obtain by kalman filter) to be tracked and the positions of the obtained measurements (obtain by background subtraction).

$$D_k(i,j) = \frac{\left|\sqrt{\left(p_{x_j}^{k-} - z_{x_i}^{k}\right)^2 + \left(p_{y_j}^{k-} - z_{y_i}^{k}\right)^2}\right|}{max\left|\left(p_{x_j}^{k-} - z_{x_i}^{k}\right)^2 + \left(p_{y_j}^{k-} - z_{y_i}^{k}\right)^2\right|}, \begin{array}{l} i = 1, \dots, m \\ j = 1, \dots, n \end{array} \quad (18)$$

P_{xj}^{k-} , P_{yj}^{k-}: center position obtain from j^{th} kalman filter in $k-1^{th}$ frame

Z_{xi}^{k} , Z_{yi}^{k} : center position obtain from i^{th} measurement in k^{th} frame

Proposed methods
Data association-Area

- Another factor is the area that objects occupy

$$A_k(i,j) = \frac{\left|A_k^i - A_{k-1}^j\right|}{max\left|A_k^i - A_{k-1}^j\right|}, \quad \begin{matrix} i = 1, \ldots, m \\ j = 1, \ldots, n \end{matrix} \qquad (19)$$

- The smaller this value is, the higher the probability of the corresponding measurement being true is.

Proposed methods
Data association

- By combining of Eqs. (18) - (19), we define the cost function.
  - If merge or split problem occurred, cost function depends on only distance.

$$C_k(i,j) = D_k(i,j) \tag{20}$$

  - Otherwise, if merge or split problem doesn’t occur, the cost function consists of distance and area.

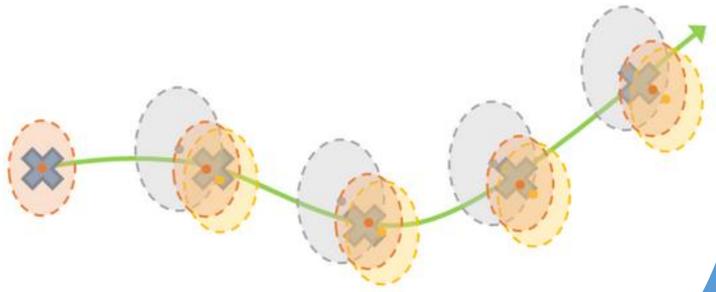
$$C_k(i,j) = \alpha D_k(i,j) + \beta A_k(i,j) \tag{21}$$

Where $\alpha+\beta = 1$, and these two parameter can be set experimentally.

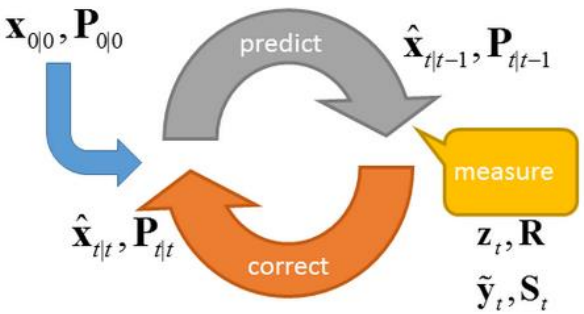
Proposed methods
Data association

- Then we can assume that i^{th} measurement correspond to j^{th} object if $C_k(i, j)$ has the smallest value.

Proposed methods
Kalman filter



- Predict, measure, correct cycle iteratively estimates the state at each time step



$$\hat{\mathbf{x}}_{t|t-1} = \mathbf{F}_t \hat{\mathbf{x}}_{t-1|t-1}$$

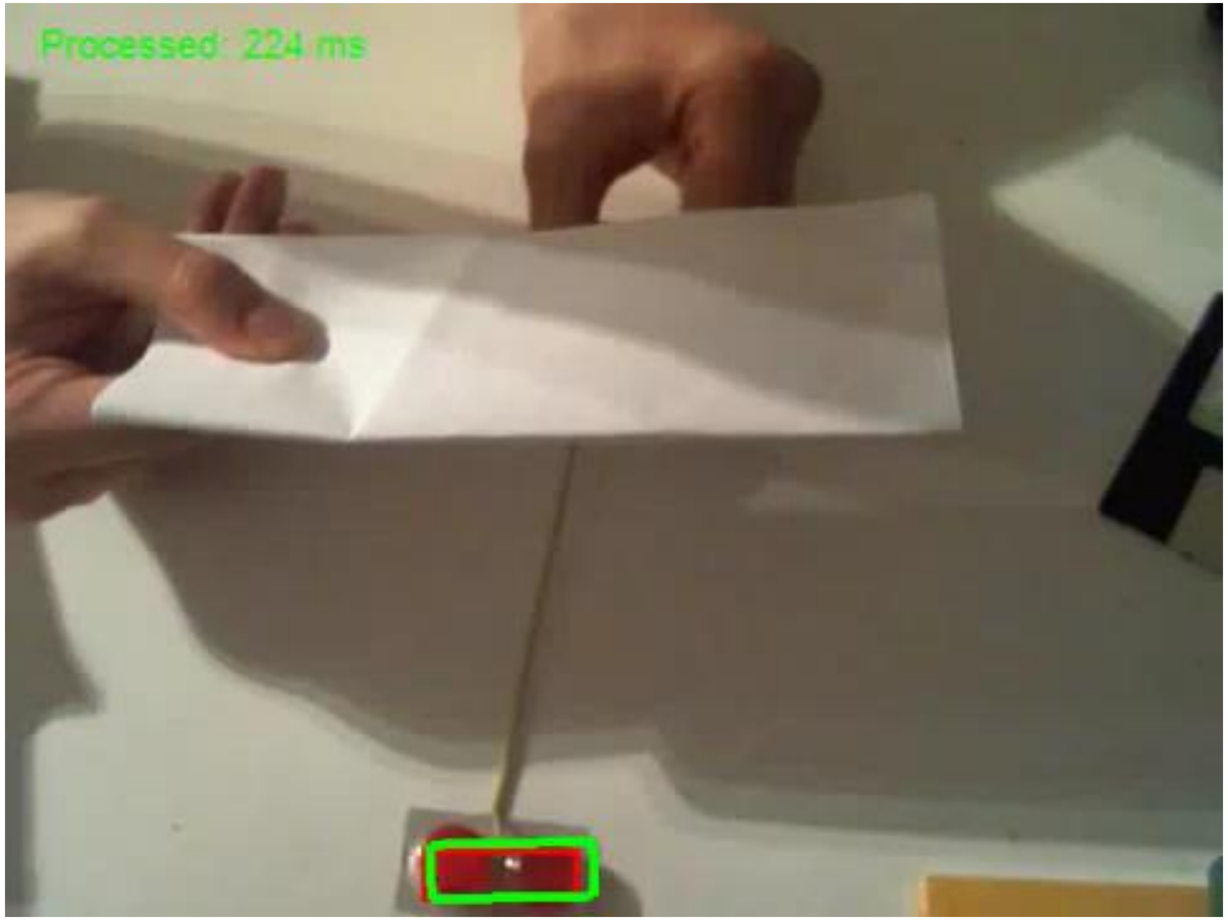
$$\mathbf{P}_{t|t-1} = \mathbf{F}_t \mathbf{P}_{t-1|t-1} \mathbf{F}_t^{\mathrm{T}} + \mathbf{Q}_{t-1}$$

$$\mathbf{K}_t = \mathbf{P}_{t|t-1} \mathbf{H}_t^{\mathrm{T}} \mathbf{S}_t^{-1}$$

$$\hat{\mathbf{x}}_{t|t} = \hat{\mathbf{x}}_{t|t-1} + \mathbf{K}_t \left(\mathbf{z}_t - \mathbf{H} \hat{\mathbf{x}}_{t|t-1} \right)$$

$$\mathbf{P}_{t|t} = \left(I - \mathbf{K}_t \mathbf{H}_t \right) \mathbf{P}_{t|t-1}$$

Proposed methods
Kalman filter

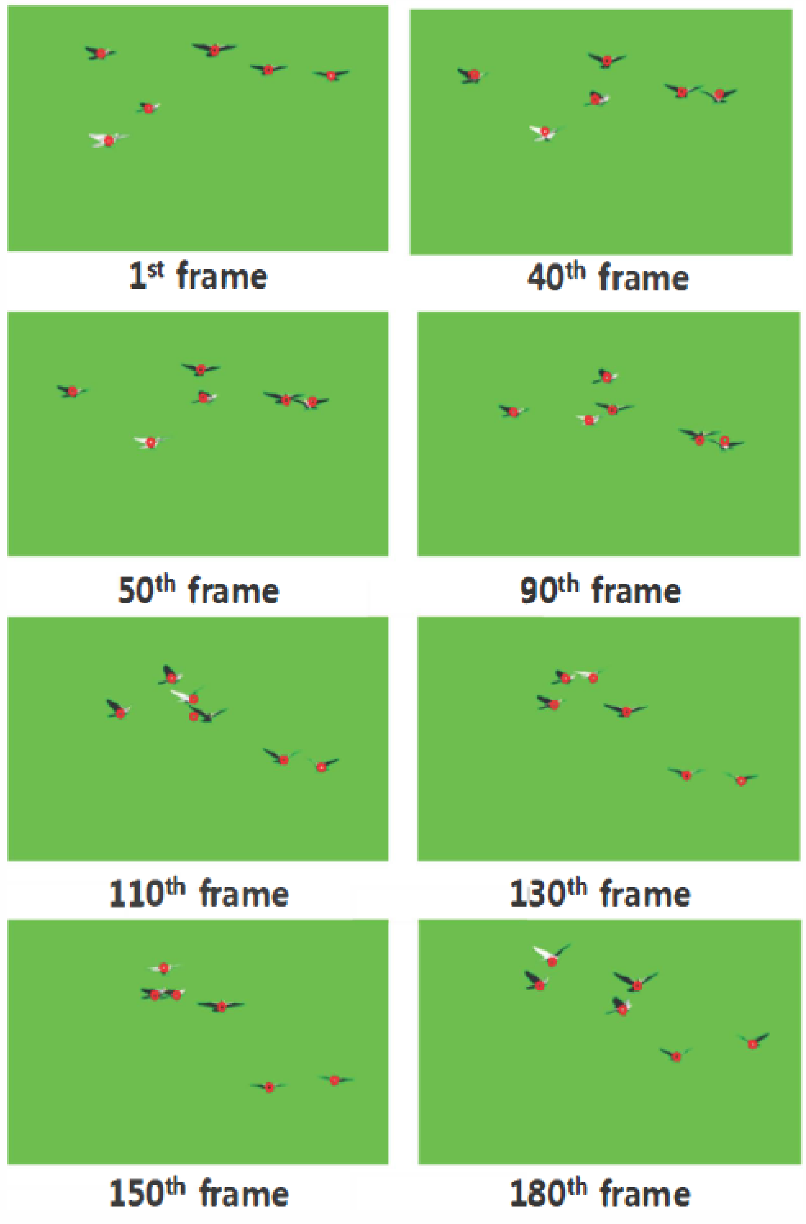


Experiment result

- The experiment is implemented using Matlab 2012a on the Microsoft windows 8 and Intel Pentium CPU G620 with 8G RAM.

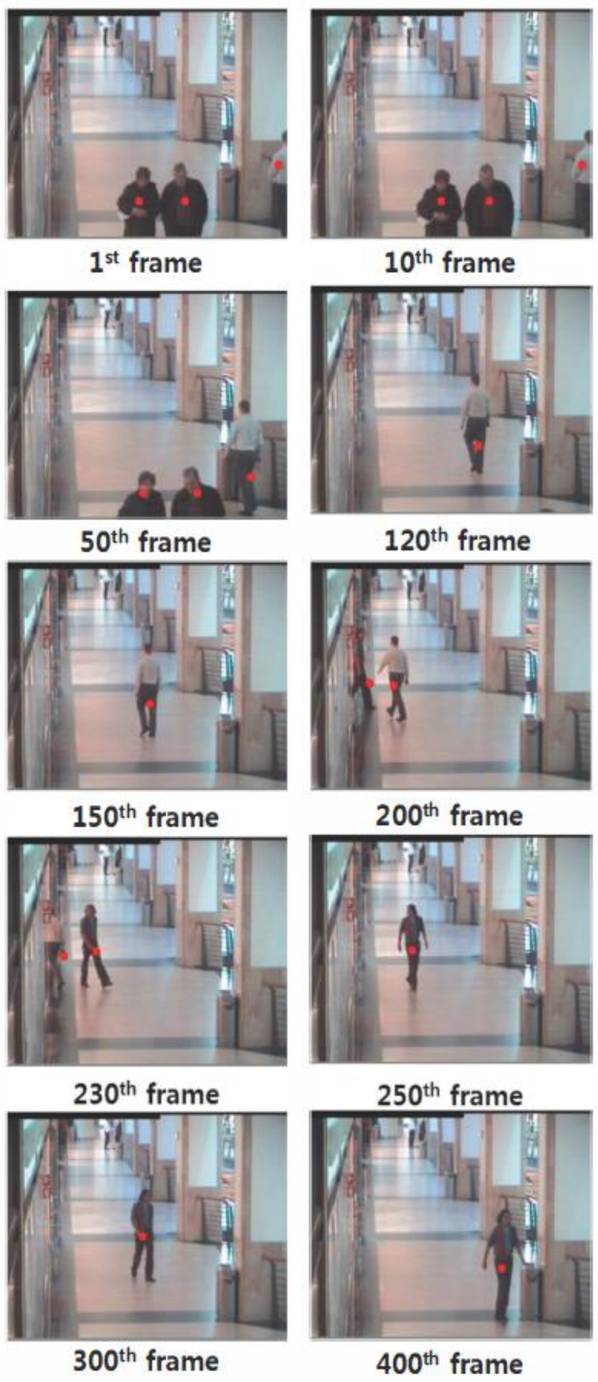
Experimental result

- Birds has the same color, so it is hard to distinguish them with color feature.



Experimental result

- In 10^{th} frame, occlusion occur.
- But this algorithm can recognize them as two objects instead of one.



Experimental result

- Real time tracking algorithm.
- Average calculation time per frame.

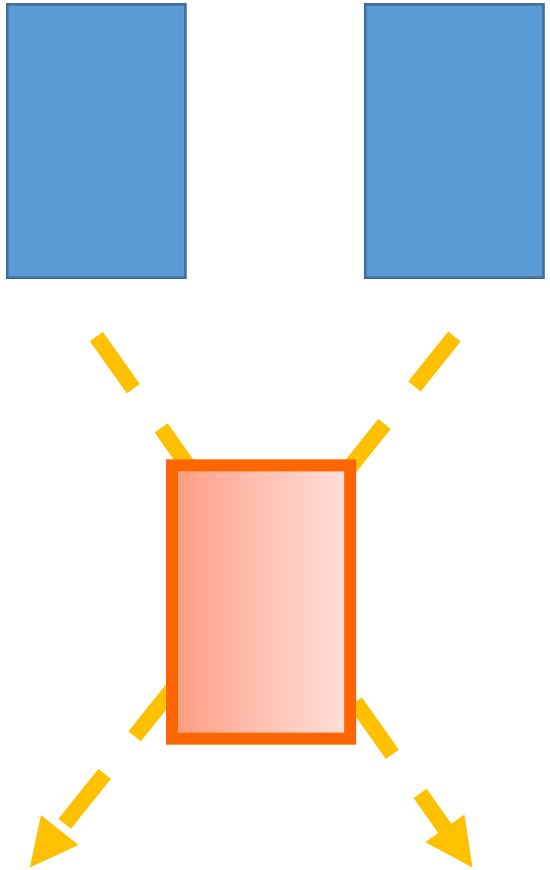
Table 1 calculation time of each case

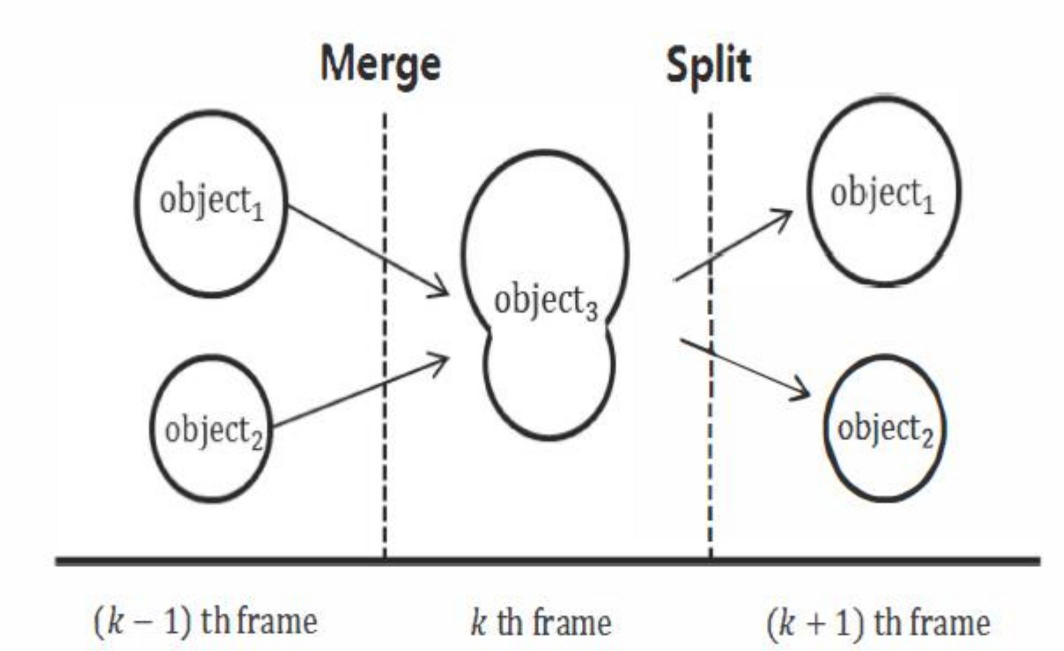
	First video	Second video
Time(s)	0.00236	0.00197

Conclusion

- This paper deal with data association problem by setting the cost function.
- Also, occlusion related to merge and split is solved.
- Finally, through the experiment results, we showed that the
- Proposed algorithm is suitable for real-time multiple tracking.

Confuse





Merge
Split
object_1
object_2
object_3
object_1
object_2
$(k-1)$ th frame
k th frame
$(k+1)$ th frame