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

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Outline

• Introduction
• Proposed methods
  • System overview
  • Moving object detection
  • Decision of occlusion
  • Data association
  • Kalman filter tracking
• Experiment result
• Conclusion
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


• [5] Ting-Hsun Chang, Shaogang Gong, and Eng-Jon Ong, "Tracking Multiple People under Occlusion Using Multiple Cameras“


• [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.

\[
FD_t(x, y) = \begin{cases} 
0 & \text{if } |l_t(x, y) - l_{t-1}(x, y)| \leq \tau_{FD} \\
1 & \text{if } |l_t(x, y) - l_{t-1}(x, y)| \geq \tau_{FD} 
\end{cases} \hspace{1cm} (1)
\]
Proposed methods
moving object detection

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

\[ BS_t(x, y) = \begin{cases} 
0 & \text{if } |l_t(x,y) - B(x,y)| < \tau_{BS} \\
1 & \text{if } |l_t(x,y) - B(x,y)| \geq \tau_{BS} 
\end{cases} \]  \hspace{1cm} (2)
Proposed methods moving object detection

• Then a bit operation is used.

\[
BM_t(x,y) = BS_t(x,y) \cup (BS_t(x,y) \cap FD_t(x,y))
\]  

(3)
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

\[ ME_t(x,y) = Erode \left( \text{Dilate} \left( BM_t(x,y) \right) \right) \] (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 \( R = \frac{\text{height}}{\text{weight}} \)
Proposed methods
Decision of occlusion

• Merge problem

\[ R_i = \frac{\text{Height}_i}{\text{Width}_i} \]  \hspace{1cm} (14)

Merge condition is expressed as follows:

\[ R^i_k > \tau_{\text{ratioUp}}, \quad i = 1, \ldots, m \]  \hspace{1cm} (15)

\[ R^i_k < \tau_{\text{ratioDown}}, \quad i = 1, \ldots, m \]  \hspace{1cm} (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.

\[ \tau_{ratioDown} < R_k^i < \tau_{ratioUp}, \quad i = 1, \ldots, m \] (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).

\[ D_k(i,j) = \sqrt{\frac{(p_{xj}^k-p_{xi}^k)^2+(p_{yj}^k-p_{yi}^k)^2}{\max[(p_{xj}^k-p_{xi}^k)^2+(p_{yj}^k-p_{yi}^k)^2]}} \quad \text{for } i = 1, \ldots, m \quad \text{and } j = 1, \ldots, n \] (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

\[ A_k(i,j) = \frac{|A_k^i - A_{k-1}^j|}{\max |A_k^i - A_{k-1}^j|}, \quad i = 1, \ldots, m, \quad j = 1, \ldots, n \] (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.
    \[ C_k(i, j) = D_k(i, j) \]  
    \[ (20) \]
  • Otherwise, if merge or split problem doesn’t occur, the cost function consists of distance and area.
    \[ C_k(i, j) = \alpha D_k(i, j) + \beta A_k(i, j) \]  
    \[ (21) \]

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

\[
\hat{x}_{t|t-1} = F_t \hat{x}_{t-1|t-1}
\]

\[
P_{t|t-1} = F_t P_{t-1|t-1} F_t^T + Q_{t-1}
\]

\[
K_t = P_{t|t-1} H_t^T S_t^{-1}
\]

\[
\hat{x}_{t|t} = \hat{x}_{t|t-1} + K_t (z_t - H \hat{x}_{t|t-1})
\]

\[
P_{t|t} = (I - K_t H_t) P_{t|t-1}
\]
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\textsuperscript{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

<table>
<thead>
<tr>
<th>Time(s)</th>
<th>First video</th>
<th>Second video</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0.00236</td>
<td>0.00197</td>
</tr>
</tbody>
</table>
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