An Efficient Video Object Segmentation Algorithm Based on Change Detection And Background Updating

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Abstract

In this paper, we propose a video object segmentation algorithm based on change detection and background updating that can quickly obtain video object from video sequence. The change detection is used to analyze temporal information between successive frames more efficiently than motion estimation. The combination both frame difference mask and background subtraction mask which is used to acquire the initial object mask and solve the uncovered background problem and still object problem. Moreover, the proposed boundary refinement is introduced to overcome the shadow influence and residual background problem. Finally, subjective and objective evaluations of the algorithm are demonstrated and the experimental results show that the spatial accuracy can be achieved above 95%.

Keyword：Change Detection, Background Update, and video object segmentation.

1. INTRODUCTION

Conventional video-coding standards, such as H.261/H.263 and MPEG-1/MPEG-2 that employ the frame-by-frame coding policy, can't provide high-level feature of video contents. The MPEG-4 coding standard [17] has introduced the concept of a video-object plane (VOP) as the basic coding element for supporting visual multimedia communication and will be applied to many multimedia content descriptions [18], and intelligent signal processing, such as, digital video surveillance system and video conference. Each VOP contains the shape and texture information of semantically meaningful object in the scene. In order to encode video objects using object-by-object in video sequences rather than frame-by-frame and achieve the content-based manipulation for video content, automatic video segmentation will play an important role of deriving VOP from video sequences in MPEG-4 video part. For many practicable multimedia applications of real-time demand, a fast and efficient video segmentation algorithm will be very important.

Nowadays, video object segmentation algorithm can be coarsely classified into two types, semi-automatic or automatic. In semi-automatic algorithm [8][20], user must first define a high level semantic object of interest to be segmented and detect the object's boundary in key frame by way of manual. After then the extracted object of interest region is used to segment this object occurred in the video sequences. The user interaction based algorithm can give better segmentation results than automatic algorithm, but it may be unsuitable in real-time applications due to the fact that an interest object needs to be specified by the user before the algorithm begins to execute.

For this reason, automatic video object segmentation algorithm have been developed and they are roughly classified into three types: the edge-feature based segmentation, spatial-temporal based segmentation, change detection based segmentation. The edge-feature based segmentation algorithm [9][12] utilize Canny edge detector to find edge information of each frame, and it can obtain correct segmentation object for stable moving-object, but this approach must to acquire a absolute background from video sequence and suffering a computation-intensive processing. In [10], based on the spatial-temporal segmentation approach, a watershed transform is used to separate a frame into many homogeneous regions and then each region is checked with the motion information. It brings about over-segmentation due to sensitive to noise, but it can give a good result of segmentation with high accurate boundaries. This problem can be solved by smoothing texture of image content, but it will make the performance of algorithm reduced. In the change detection based segmentation algorithm [2][3][13], the position and shape of the moving object can be detected by threshold the difference of two consecutive frames and them followed by a boundary fine-turning process with the spatial or temporal information to improve the result of segmentation.

Basically speaking, for the above three approaches, the segmentation algorithm based on the change detection technology will be more efficient than the other two types of segmentation algorithm which may be too computation-intensive to achieve the real-time purpose. The moving object obtained always suffers from the uncovered background situations, still object situation, light changing, shadow, residue background problem and noise due to the motion information is obtained by frame difference. To overcome these problems and enhance the performance, this paper proposes an efficient video segmentation algorithm by using the change detection and background updating technique. The proposed algorithm can be shown in figure 1. The Gaussian smooth is focused on reducing the noise effect of input frame. Then, the change detection, object region detection, and background updating are combined to extract a rough moving object. Finally, the accuracy of segmented object will be improved through an efficient boundary refinement with an appropriate amount of computations.

2. THE PROPOSED SEGMENTATION ALGORITHM

We proposed a video segmentation algorithm which is dedicated to separate the moving-object regions from other parts of the scene by using of motion information. Our idea behind this algorithm is to reduce the computational complexity. Thereby, the change detection is used to detect the difference between previous frame and current frame instead of the motion estimation. Then, both frame difference mask and background subtraction mask obtained from between difference background frame and current frame are combined to distinguish the type of object region in object region detection phase, in order to overcome the problems of uncovered background and still object. Therefore, we construct and maintain an updating background reference from the previous still object mask, which is used due to a static object or a region where moving object shift out their position are must to be renewed. Therefore, our approach, is aimed at the stationary object of a scene since the information of stationary object of a scene is more stable to make the constructed background to reliable and conform human visual perception. Because the background change owing to camera motion can be compensated by global motion estimation and compensation [13], the input sequence to our algorithm will be assumed to have been correctly compensated and thus the background is stationary. Finally, we also propose a novel object boundary refinement technology to improve the boundary of object to make the accuracy of segmented object to be increased. Also, the complexity in this process can be reduced. The details of each module in the proposed algorithm, as shown in figure 1, will be discussed in the following subsections.

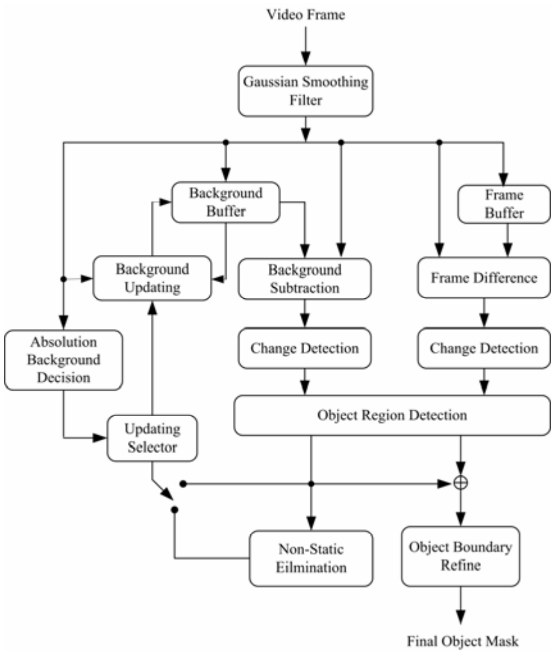
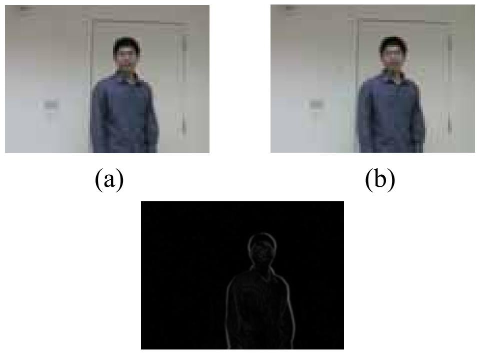


Figure 1. Block diagram of the proposed segmentation algorithm.



(a) (b) (c)

Figure 2. (a) The Lerry sequence at frame #64; (b) The Lerry sequence at frame #65; (c) The difference frame between (a) and (b).

2.1. Frame difference

The frame difference technique [1][15] which means the difference between two successive frames. It often is utilized in change detection based segmentation algorithm because of the effectiveness is conformable to our need. The difference frame includes two parts: foreground part and background part. The value on foreground area brings more higher than the background area because of the foreground region corresponding to moving region when background region corresponding to non-moving region. Besides, the difference value on background area is not zero due to the environmental effects, e.g., light change or noise effect. Hence, the external effect will lead the pixel in background part be dis-classified into foreground part in change detection, which discussed in next subsection. Moreover, the module of background subtraction in our algorithm is performed by differencing current frame and background frame. This step is very similar to the difference frame. Let $f_{t-1}(i,j)$ and $f_t(i,j)$ denote the video frame on different time instant, respectively, the difference frame can be achieved by the following equation:

$$DI_t(i,j) = |f_t(i,j) - f_{t-1}(i,j)| \quad (1)$$

Fig. 2 shows the example of difference frame for Lerry sequence.

2.2. Change detection

This major function of change detection is kernel operator in segmentation algorithm. The goal of change detection is to separate the difference frame into change region and unchange region, according to a threshold obtained from background estimation. In the reported research [1] which take the unchanged region of resulted change detection in previous frame as background part in the current frame. However, if the noise is introduced, this method will involve estimated error in the current frame and the following frame in video sequence. In our approach, the histogram-based change detection is proposed that is constructed from difference frame. Figure 3 shows the proposed block diagram of change detection, which adopts histogram-based statistic method. First, the parameter of background model is estimated from difference frame. Second, the pixel will be classified according to statistic parameter obtained from previous phase. The detail of this process will be described in the following subsection.

2.2.1. Histogram analysis

The histogram is constructed from difference frame, which can provide information of the gray-level distribution to analyze the characteristic of the difference frame. Let $His(p')$ be the maximum gray of bin at p' position of the histogram. To extract more informations about the background, both $His(p')$ and p' need to be obtained and them such two values will be used in the following estimation of the background model. Figure 4 shows the gray-level distribution of difference frame for figure 2.

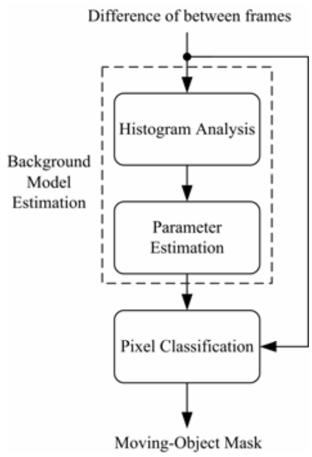


Figure 3. Block diagram of the change detection.

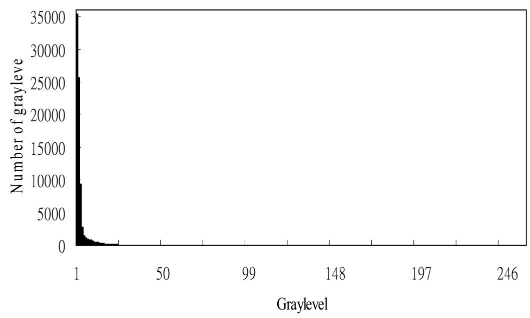


Figure 4. The histogram distribution of figure 2(C).

2.2.2. Parameters estimation

Generally, the model of background region of the difference frame can be regarded as Gaussian distribution due to the noise effect existed between inter-frames. Hence, the mean and standard deviation for the background model within a window, denoted as μ_b and std_b, respectively, need to be acquired. Firstly, the value of mean μ_b and standard deviation std_b, will be calculated at the site of p' with window size N. Then, μ_b and std_b will be obtained by averaging those values of μ_w and std_w, which can be described in the following equation:

$$\mu_{w_i}(p') = \frac{1}{N}\sum_{j=1}^{N} w_i(j)$$

$$std_{w_i}(p') = \sqrt{\frac{1}{N}\sum_{j=1}^{N}[w_i(j) - \mu_{w_i}(p')]^2}$$
$$for\ i = 1,2,\ldots,His(p')$$

$$\mu_b = \frac{1}{his(p')}\sum_{i=1}^{his(p')} \mu_{w_i}(p')$$

$$\sigma_b = \frac{1}{his(p')}\sum_{i=1}^{his(p')} std_{w_i}(p') \qquad (2)$$

2.2.3. Pixel classification

The pixel classification will classify the pixel on the difference frame into the change region or unchanged region according to the parameter of background model, which can be described as

$$\begin{aligned} &if\,(|\,DF(i,j) - \mu_b\,| > c * std_b) \\ &then\ \ foreground\ \ pixel \\ &else \\ &\quad background\ \ pixel \end{aligned} \qquad (3)$$

where $DF(i,j)$ is difference frame, and c is a constant.

Based on prior description, the threshold curves for Hall Monitor and Lerry sequence are shown in figure 5 and results of pixel classification are shown in figure 6, when constant value is 10.

2.3. Object region detection

The object region detection step, it is used to detect object region part in our algorithm. Table 1 lists the criteria for distinguishing the region, where “OFF” and “ON” mean the pixel on frame difference (or background subtraction) mask to be the unchanged and changed, respectively. A pixel is recognized as the background region if there is “OFF” in the corresponding pixel position of both background subtraction mask and frame difference mask. This case implies that there will be no any moving object existed in the region. If only the frame difference mask-bit is detected as change, but unchange for the background subtraction mask-bit, the pixel is classified into the uncovered background region. This problem is also critical issue for traditional change detection algorithm. Since both the uncovered background region and the moving region have

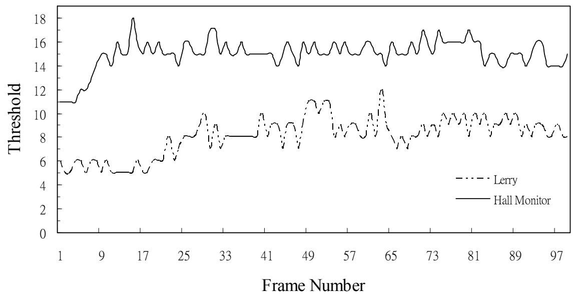
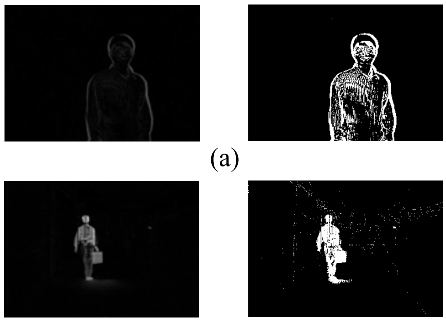


Figure 5. Threshold curve for Hall Monitor and Lerry sequence.


(a)

(b)

Figure 6. Results of pixel classification, where the left image is the frame difference and the right image is thresholded binary image for (a) Lerry sequence and (b) Hall Mointor sequence.

Table 1. Object Region Detection Rule

Region Description	Background SubtractionMask	Frame DifferenceMask
Background	OFF	OFF
Uncovered-background	OFF	ON
Still region	ON	OFF
Moving region	ON	ON

significant luminance change, distinguishing the difference between two regions is very difficult if only the frame difference mask is available. On the other hand, one of the problems is that the object may stop moving temporarily or move very slowly. This situation, namely still object case, the motion information disappears if we use the frame difference mask only. However, the background subtraction information is adopted in our algorithm so that this case can be discriminated from object mask. The final case describes the moving region identification with "ON" for the both frame mask, i.e., a pixel is part of moving region if the pixel is detected as change by both frame difference mask and background subtraction mask checking processes. Figure 7 shows the results of object region detection.

2.4. Background Updating

Basically, the major function of background updating is to renew a scene when moving-object shift out their original positions or its state is transformed to standstill. In the reported researches [4][6][16], a frame difference mask is fed into a kalman-filter to estimate the background needing to be updated. But this causes a large burden of computations since the kalman gain matrix requires to be updated frequently. Besides, this approach can't overcome the situation that the moving object occurs on the first frame of the video sequence captured. To reduce computation for a real-time purpose, our method use previous still region mask to construct and update background information. The block diagram of background updating can be illustrated in figure 8.

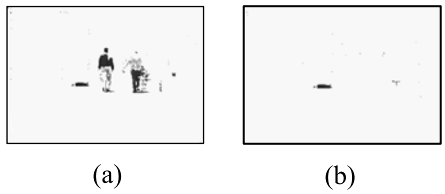


Figure 9. Non-static region effect. (a) Still region mask; (b) Static part region of moving-object is removed.

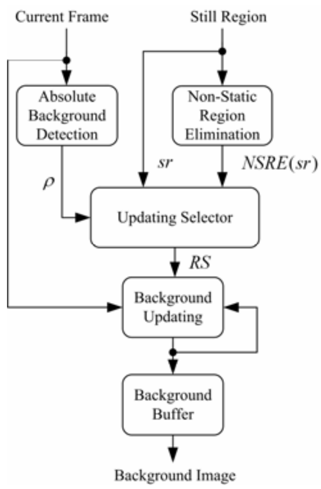


Figure 8. Block diagram of background updating.

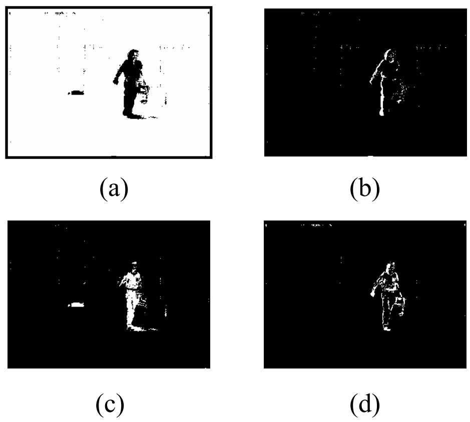


Figure 7. The results of object region detection for Hall Monitor sequence. (a) Background region; (b) Uncovered background region; (c) Still region; (d) Moving region.

2.4.1. Non-static region elimination

The input of background updating is still region mask which acquired from object region detection step. In general, the still region mask may contain the following three types of region: real still-region, light change, static part region of moving object. Based on our scheme of background updating, we hope the still region mask that only involves real still-region and light change among these regions. In order to realize this purpose, the concept of region adjacent graphic can be utilized to solve this problem. Besides, we find a fact that if a region identified as the static part region of moving object, it will connect to the region of moving region mask. Then, this region will be removed from still region mask. Thus the rule can be used to decide the region whether is the static part region of moving object or not. Figure 9 shows this situation when S_{th} is 150.

2.4.2. Updating selector

The non-static region elimination described previously which will be fail when a moving object existed at beginning of video frames due to the moving object region connect with a region where moving objects shift out their original positions. Hence, the entire connecting region will be removed so that no information used to renew a scene. This problem can be solved by using absolute background detection to decide whether the moving object existed in beginning of video frames or not, for each pixel site (i,j), the four-order moments [14] $m'_d(i,j)$ is evaluated on a moving window of $N_w = 9$ elements of the inter-frame difference $d_{1,n}(r,c)$ between first frame and *n*th frame.

$$m'_d(i,j) = \frac{1}{N_w} \sum_{(r,c)\in w(i,j)} (d_{1,n}(r,c) - m_\mu)^4$$

$$m_\mu(i,j) = \frac{1}{N_w} \sum_{(r,c)\in w(i,j)} d_{1,n}(r,c) \qquad (4)$$

Finally, the output of updating selector can be decided in following procedure, where σ_B denotes variance of background of $d_{1,n}(r,c)$.

$$RS = \begin{cases} sr, & if\ \rho > S_{th} \\ NSRE(sr), & otherwise \end{cases} \qquad (5)$$

$$\rho = \begin{cases} \rho + 1 & if\,(m'_d > 75 * \sigma_B{}^2) \\ \rho & otherwise \end{cases}$$

(a) (b)

Figure 10. Result of background updating. (a) Weather #255; (b) The updated background.

(a) (b)

Figure 11. Background updating of meeting room sequence. (a) Meeting room sequence at frame #350; (b) The updated Background at frame #350.

2.4.3 Background Updating

The basic strategy of background updating is that if a pixel is marked as change on RS map; the corresponding value in the stationary map is increased by one; otherwise, the corresponding pixel is cleared as zero. Thus, each pixel value in the stationary map indicates the change number of the corresponding pixel in the previous consecutive frame. This strategy of background updating is described as

$$SM_t(i,j) = \begin{cases} SM_{t-1}(i,j)+1, & if\ RS_t(i,j)\ is\ change\ pixel \\ 0, & otherwise \end{cases}$$

$$\begin{aligned} & If\ \ (t=1) \\ & \quad BI_t(i,j) = f_t(i,j) \\ & else \\ & \quad BI_t(i,j) = \begin{cases} f_t(i,j), & if\ SM_t(i,j) = F_{th} \\ BI_{i-1}(i,j), & otherwise \end{cases} \end{aligned} \qquad (6)$$

where SM is stationary map, BI is the background information, and F_{th} is a pre-defined constant. Figure 10 and figure 11 show the example for background updating when F_{th} is 5 for Weather sequence and Meeting room sequence, respectively.

2.5. Object boundary refinement technology

The coarse object region can be generated, that is, the union of moving region mask and still region mask, called as initial object mask. However, in practically, the characteristics and behavior of moving object are often not reliable and the environmental effect is also introduced. These phenomena will be a critical issue for affecting the accuracy of object boundary. Thus the proposed object contour refinement process will be used to improve the accuracy of the segmented object, which includes temporal coherence compensation, hierarchical boundary segmentation, and post-processing filter. The block diagram of boundary refinement is shown in figure 12.

2.5.1. Temporal coherence compensation

The goal of this process is to solve the problem of the fragmentary region of object because the motion information is not significant on object region when the object moves slowly or stops temporally. Generally speaking, the nature video signal exist high correlation between inter-frames, thereby, this feature can be used to compensate the fragmentary region of object through taking several frames of the initial object mask into count. The example can be shown in figure 13.

2.5.2. Hierarchical segmentation

The proposed hierarchical segmentation which is process of block based so that initial object mask must first be separate into block whose size is 16×16 and fill them before this functions executed, which shown in figure 14. We calculate the variance of the boundary block, denoted as V_{Bi}, if the variance is smaller than a threshold which obtained by difference of gradient of previous frame and current frame plus

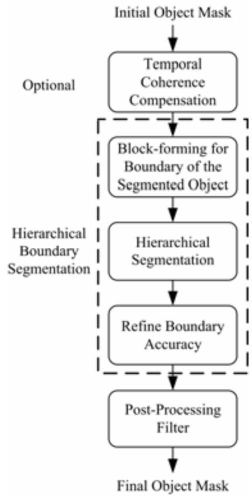
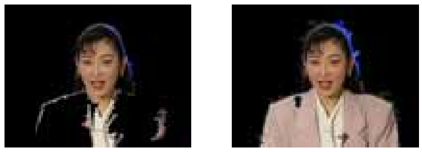


Figure 12. Block diagram of object boundary refinement.



(a) (b)

Figure 13. Temporal coherence compensation for Akyio. (a) initial object mask at frame # 29; (b) After using temporal coherence compensation for (a).

(a) (b)

Figure 14. Block-froming for boundary of the segmented object in the Thor sequence. (a) Initial object mask of frame #70. (b) Object mask fill and block division of (a).

a constant λ, the block is regarded as non-moving, and eliminated from the object region, this procedure of hierarchical segmentation can be shown as

$$
\begin{aligned}
&\textit{if } (V_{Bi} < V_{Diff(G(f_t),G(f_{t-1}))} + \lambda) \\
&\quad \textit{the block is removed} \\
&\textit{else} \\
&\quad \textit{the block is kept}
\end{aligned}
$$

$$
\begin{aligned}
&\textit{if } (blocksize = 16) \\
&\quad \lambda = 2 \\
&\textit{else if } (blocksize = 8) \\
&\quad \lambda = 1.5
\end{aligned}
$$

$$
\begin{aligned}
&else\,if\ \ (blocksize = 4)\\
&\quad \lambda = 1\\
&else\,if\ \ (blocksize = 2)\\
&\quad \lambda = 0.5
\end{aligned}
\qquad (7)
$$

Repeating the procedure for all sub-block's along the boundary until the non-moving sub-blocks are all removed. We can further divide the sub-block into 8×8, 4×4, and then 2×2, then more compact boundary can be obtained consequently, see figure 15.

2.5.3 Object boundary refinement

By way of the above step, a stable boundary of object can be obtained. However, interior of object will be erosion due to effect of hierarchical segmentation introduced and the thick background region still exited around the sharp of object. For first question, we can find the region where is non-union between initial object mask and hierarchical segmentation mask, then, if the value of gradient within this region is larger than a threshold, the corresponding pixel will be compensated to hierarchical segmentation mask, it can be shown in figure 16. In addition, the problem of thick background which closes to sharp of object will make the compression ratio of object-based compression to be reduced. Therefore, we use strategy of region growing to remove this area, and the seed obtained through applying the Laplacian operator on hierarchical segmentation mask. This result is illustrated in figure 17.

2.6. Post-processing filter

Up to now, the obtained object mask is nearly real object mask, but some noise is still existed in region mask regions because of irregular object motion and camera noise.

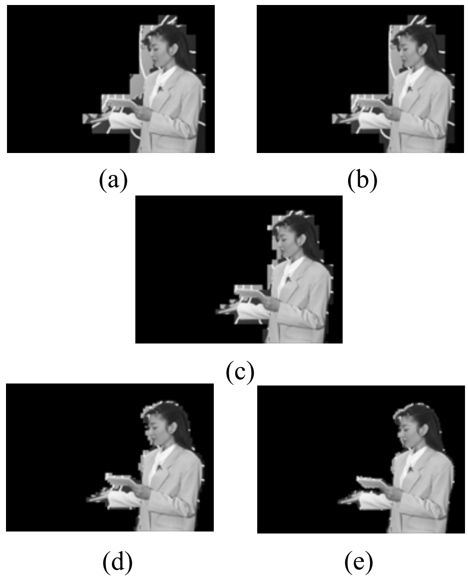


Figure 15. Hierarchical segmentation for Weather sequence. (a) Object mask fill and block division at frame #22; (b) The block size is 16×16; (c) The block size is 8×8; (d) The block size is 4×4; (e) The block size is 2×2.

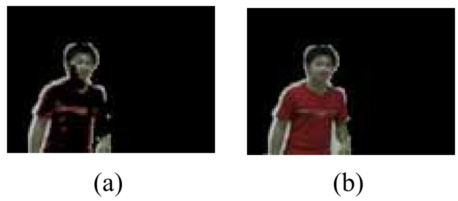


Figure 16. Remove effect of hierarchical segmentation. (a) The effect of hierarchical segmentation at frame #111; (b) After compensating the effect for (a).

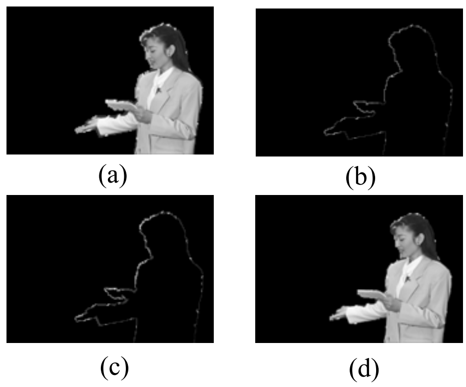


Figure 17. Remove the background region of the boundary by region growing. (a) The result of hierarchical segmentation with block 2×2; (b) The seed pixels of region- growing; (c) The grown region using seeds of (b); (d) The result of eliminating (c) from (a).

Also, the boundary may not be very smooth. Therefore, there are two parts in post-processing filter: noise region elimination and morphological smoothing processing, which will be described as follows.

2.6.1. Noise Region Elimination

We use the connected components algorithm [21] on the object mask to mark each isolated region, Then, we can remove the isolated region by considering their area. If the area of a region is small, it may be a noise region and can be eliminated from object mask.

2.6.2. Morphological Smoothness Processing

After removing the noise regions, the close and open operations [11] of morphological processing are employed to smooth the boundary of object with a 3 by 3 structuring element. Based on such a post-processing, the object mask is so refined that a better object mask with the more complete boundary. Figure 18 describes the post-processing, in which the subfigure (b) shows an object mask after noise-eliminating on subfigure (a) which obtained from object boundary refinement step and then the morphological close-open operation is employed on the mask of (b) to yield a final object mask, as shown in (c).

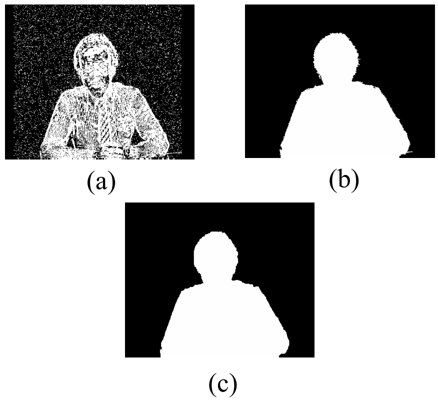


Figure 18. Post-processing: (a) the object mask after hierarchical segmentation; (b) the object mask after noise elimination; (c) the object mask after close-open operation.

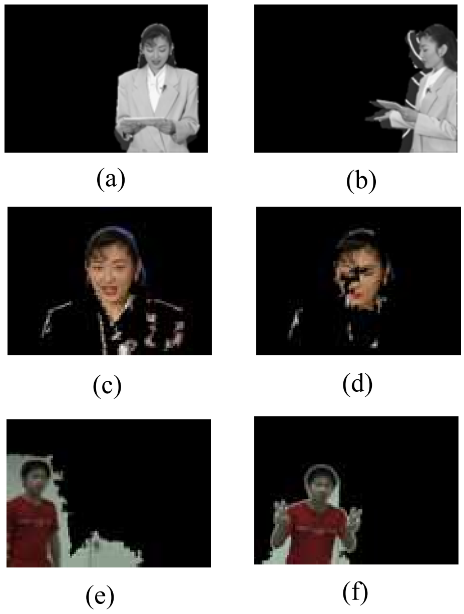


Figure 19. Initial segmentation results for Weather at (a) frame #28; (b) frame #243; for Akyio at (c) frame #30; (b) frame #130; and for Thor at (e) frame #72; (f) frame #100.

3. EXPERIMENTAL RESULTS

In this section, we will demonstrate the experimental results of the proposed video segmentation algorithm. The simulation results show that this algorithm can give accurate video segmentation results for the tested video sequences, and also solve both problems of shadow and residual background region which existed in conventional video segmentation algorithm. A reliable objective criterion, called spatial accuracy, is presented in section 3.1 to evaluate the segmentation result. Finally, in section 3.2, the segmentation results are presented to give subjective evaluation this algorithm, and objective evaluation in spatial accuracy is also shown.

3.1. Spatial accuracy evaluation

A reliable objective criterion [14], called spatial accuracy, is presented to evaluate the segmentation results which measure the distortion of the algorithm by accumulating the distortion area then subtracted by one. Spatial accuracy evaluation can be described as

$$Spatial\ accuracy = \left(1 - \frac{\sum_{(r,c)} M_t^{ref}(r,c) \oplus M_t^{seg}(r,c)}{\sum_{(r,c)} M_t^{ref}(r,c)}\right) \times 100\% \quad (8)$$

where $M_t^{ref}(r,c)$ is ideal alpha map, $M_t^{seg}(r,c)$ is final object mask generated with this algorithm and $\oplus$ is exclusive OR.

3.2. Simulation

This algorithm uses Weather, Thor and Akyio sequences for simulation. In figure 19, the segmentation results in initial object region for them are shown. For Weather, which has large motion and residual background region exited, and for sequence Akyio, which has only slight motion so that can not give satisfied results of segmented object region, as shown in figure 19(a)-(d). In figure 19(e)(f), the shadow affects the sequence Thor. In figure 20, the segmentation results corresponding to figure 19 after object boundary process applied. The phenomenon of residual background region has been removed in Weather, as shown in figure 20(a)(b). In figure 20(c)(d) illustrates the problem of fragmentary object can be overcome, and the shadow effect for Thor sequence is also eliminated, as shown in figure 20(e)(f).

Spatial accuracy chart for sequence Weather, Thor, and Akyio are shown in figure 21. From figure 21, we can find out that the spatial accuracy for them can be hold above 95%, which means the accuracy is quite high, and human eye will not pay attention to such small error.

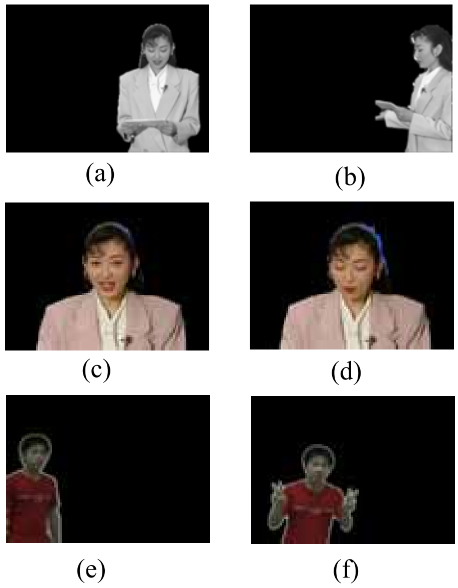


Figure 20. The results after executing object boundary refinement process for Weather at (a) frame #28; (b) frame #243; for Akyio at (c) frame #30; (b) frame #130; and for Thor at (e) frame #72; (f) frame #100.

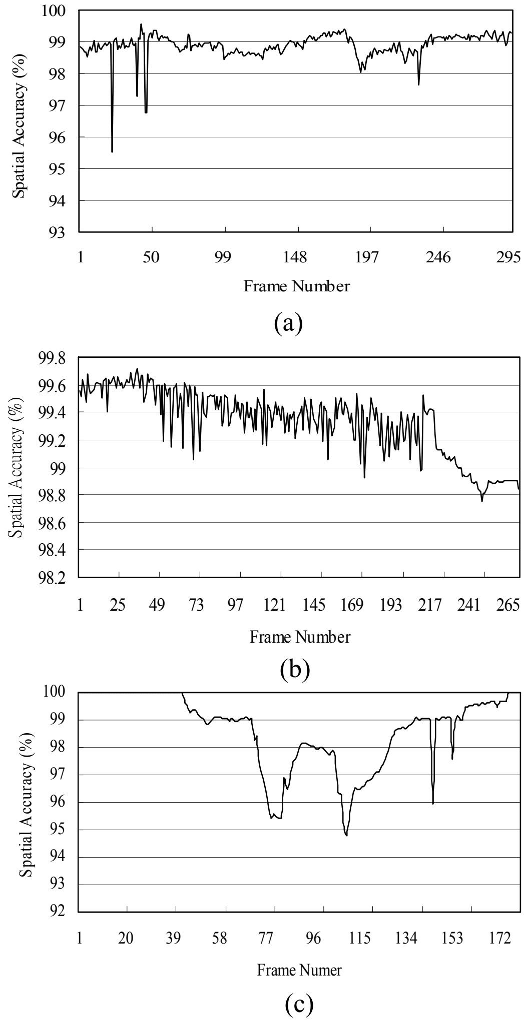


Figure 21. Spatial accuracy curve for (a) Weather; (b) Akyio; (c) Thor.

4. CONCLUSIONS

In this paper, we propose an efficient video segmentation algorithm based on change detection and background updating. Because of no complex operator is adopted in our algorithm and the simple change detection is used to obtain the motion information, thus the effect of proposed method can be increased greatly. Besides, the proposed non-static region elimination can remove the moving region from still region mask, it will more correctly make the background updating to renew a scene. Finally, a novel object boundary refinement method is presented which in order to eliminate the shadow effect or light change, and solve the residual background problem. After the process of object boundary refinement is applied, the quality of our method is already kept above 95%, and the time cost is small than the conventional temporal-spatial based video segmentation algorithm. From the experimental results, it reveals that the proposed segmentation algorithm will be more attractive the other algorithms.

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