Level Set Based Simultaneous Background Image Modeling and Foreground Segmentation

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ABSTRACT

We propose a level set based energy functional that deals with the problem of background modeling and object segmentation in a coupled way such that the two processes mutually constrain each other, and from which a level set based Euler-Lagrange equation can be derived. Due to the mutual constraining, the temporal change of the scene is reflected in the construction of the reference background image quickly, while a clean background image can be obtained with a relatively small number of frames. Furthermore, due to the direct implementation of the Euler-Lagrange equation, the algorithm works in real-time.

PROPOSED MODEL

We search for the background image B and the segmented image sequence $I(t)$ as the solution that minimizes the following energy functional:

$$E(B,\phi) = \int_{\Delta t}\int_{\Omega} F(\phi)\left[\alpha - (B - I(t))^2\right] d\mathbf{r}dt \tag{1}$$

where B is the background image, ϕ is the level set function, $I(t)$ is the frame at time=t, Ω is the domain of the image, Δt is a certain time interval along the temporal axis, α is a positive constant parameter, and $F(\phi)$ is a function of ϕ defined as follows:

$$F(\phi) = \begin{cases} k\frac{\phi-\phi_{min,\phi\geq 0}}{\phi_{max,\phi\geq 0}-\phi_{min,\phi\geq 0}} + (1-k), & \text{if } \phi \geq 0 \\ \\ k\frac{\phi-\phi_{min,\phi<0}}{\phi_{max,\phi<0}-\phi_{min,\phi<0}}, & \text{if } \phi < 0 \end{cases} \tag{2}$$

where $\phi_{max,\phi\geq 0}$ and $\phi_{min,\phi\geq 0}$ are the maximum and the minimum values of ϕ in $\{\phi \geq 0\}$, respectively, and $\phi_{max,\phi<0}$ and $\phi_{min,\phi<0}$ are the maximum and the minimum values of ϕ in $\{\phi < 0\}$, respectively, and k is a constant lying in the interval $0 \leq k \leq 1$.

The energy functional is minimized with respect to the background image B and the level set function ϕ, which are the solutions being sought.

EXPERIMENTAL RESULTS

Figure 1 compares the segmented foreground images and the estimated background images obtained by different methods. The simple averaging, median, and the proposed method all use 10 sampled frames, which are sampled every second frame, i.e., have a frame rate of 15 fps. For Gaussian modeling based methods, 10 frames are too few and have been excluded from the comparison. As can be observed, the averaging method and the blending method leave "tails" of the moving objects in the background image, which again affects the foreground segmentation. The median method shows better results similar to the proposed algorithm, but the computational cost is larger due to the sorting process. Figure 2 compares the proposed method with the blending method in the case that the moving object comes to a static state. It can be seen that the proposed scheme reflects the static object in the background image faster than the blending method.

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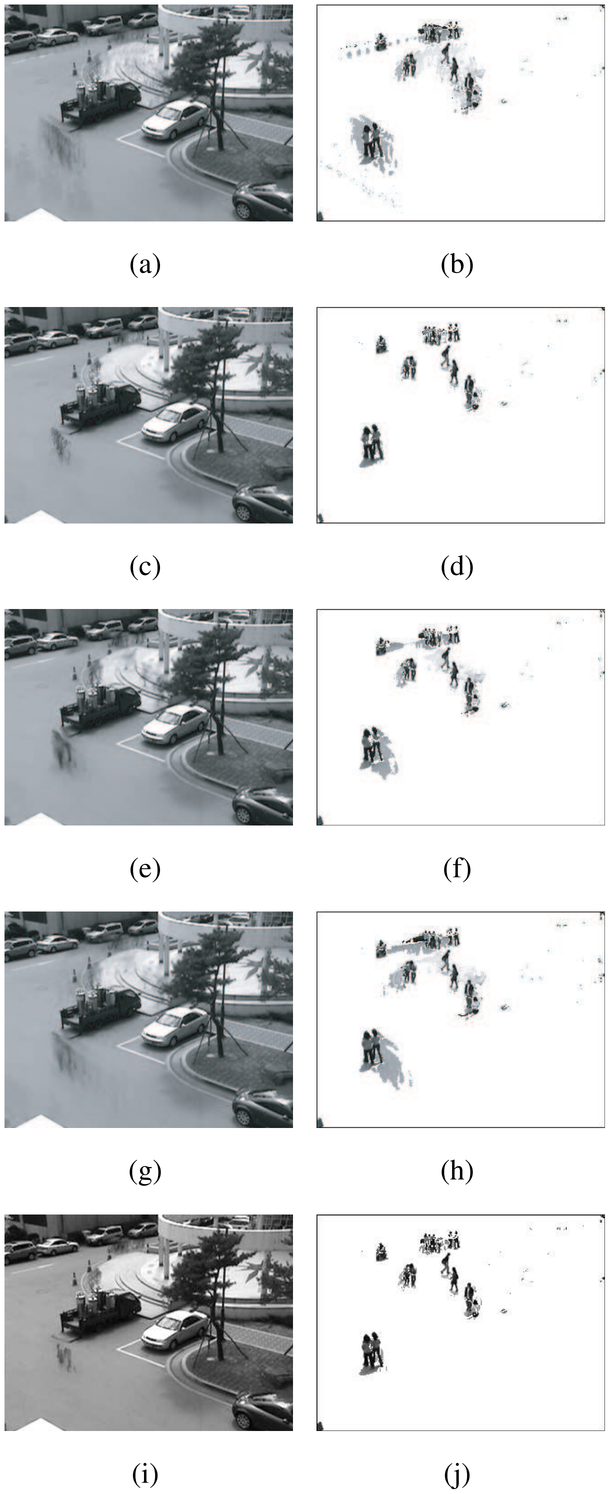

Figure 1. The first column shows the estimated background images obtained by (a) averaging (c) median (e) blending with blending parameter 0.1 (g) blending with blending parameter 0.05 (i) proposed method. The second column shows the corresponding segmented foreground, where the foregrounds in (b),(d),(f) and (h) have been obtained by thresholding with threshold value of 30, and the foreground in (j) has been obtained by the proposed method with $\alpha = 30$.

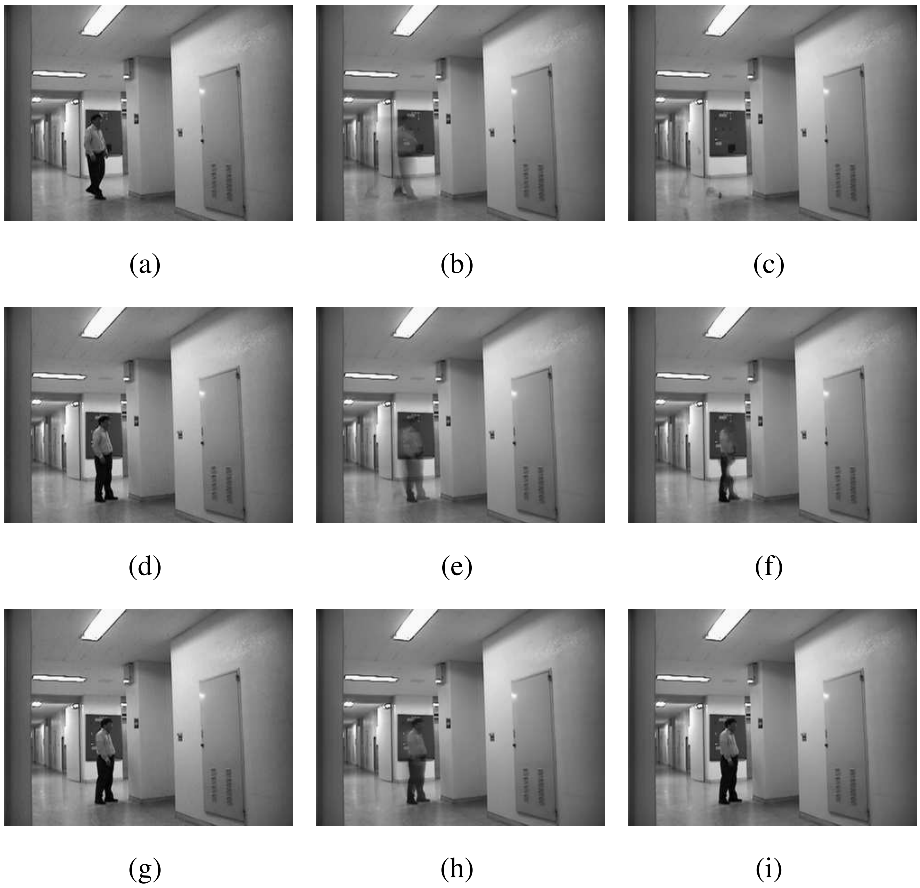

Figure 2. Comparison of the estimated background image when the moving object comes to a static state. The first column shows the frame image, the second shows the estimated background image obtained by the blending method, and the third shows that obtained by the proposed method. The first, second, and the third row correspond to the frame 226, 235, and 243, respectively.