EE 264 : Image Processing and Reconstruction

Final Project

Video Segmentation Based on Image Change Detection for Surveillance Systems

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1. Introduction and Project Scope

Using images to identify regions that have undergone some significant change is of widespread interest due to numerous amounts of applications in diverse disciplines [1]. These areas of interest include: remote sensing, video surveillance [2-4], medical diagnosis and treatment [5], civil infrastructure [6], and underwater sensing [7]. Even though there is a huge difference between the applications, the way to approach the problem is very similar. Every change detection method requires employing some processing steps and main algorithms.

Figure 1 shows the general ideal about the image change detection. The multiple temporal images are input and the change detection processes is performed to automatically identify and analyze regions that have undergone spatial or spectral changes. The main idea is to identify the set of pixels that have undergone under some significant change between the last image of the sequence and the previous images. These groups of pixels create what is often known as the change mask. Detecting and representing this change mask provides valuable information for the applications described before. This area is known as image understanding, which includes the object detection, object tracking, object classification, object Structure Analysis and identification, and video Encoding.

A conventional approach for the detection of targets or changes in images is to pairwise subtract successive images in the sequence. A change of each pixel is detected if a difference value exceeds pre-set thresholds. However, this method will yield effective results only if the signal to noise ratio is very high. In addition, the uncovered background, still object situation, light changing, and shadow effects will also degrade the detecting accuracy. Many other algorithm and physical models are proposed to deal with various situations. These common processing steps and core decision methods for change detection algorithms includes significance and hypothesis testing, predictive models, the shading model, and background modeling.

In this final project, I will use the image change detection for segmentation algorithm [8-10], and basically this algorithm is for surveillance system. The paper

I referred is [11]. The image change technique and the application involved in this paper is marked as the red word in Fig. 1. In the rest of the report, I will describe the system block diagram and functionalities of each block in Sec. 2. Then, I will go through the algorithm in more detail in Sec. 3. Afterward, the implementation and simulation results will be shown in Sec. 4. Finally, the discussion and the conclusion will be made in Sec. 5.

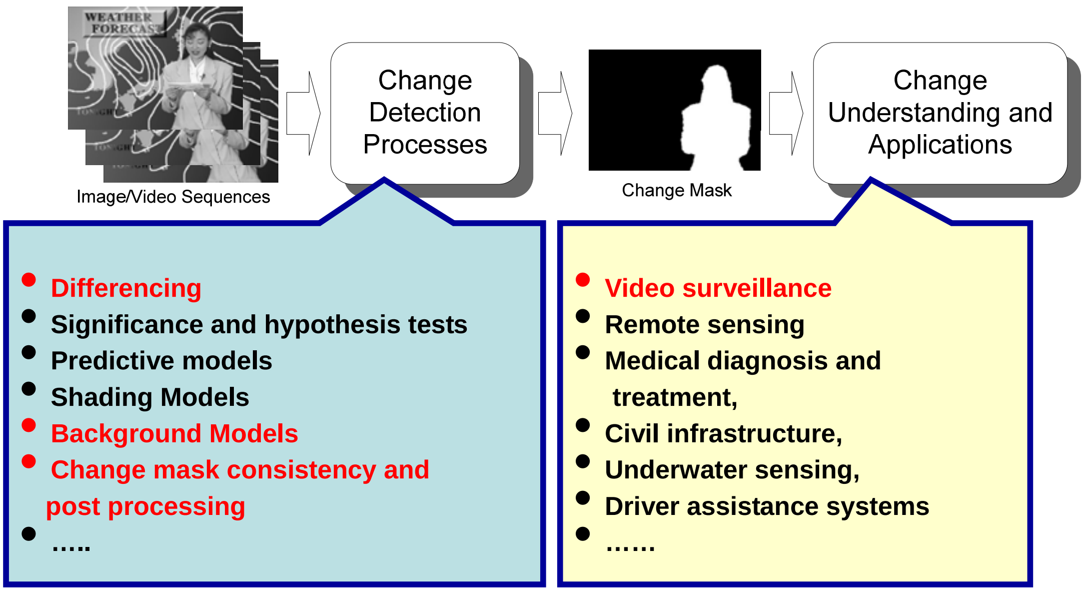


Fig. 1. Basic of image change detection.

2. Video Segmentation Algorithm Based on Image Change Detection for Surveillance systems

This algorithm is designed for stable camera situations. That is, the camera is still, and there is no significant light changing and shadows. The block diagram is shown in Fig. 2. There are four main parts in this algorithm: Frame/Background Difference, Background Registration, Object Detection, and Post processing. The first step is to calculate the frame difference mask by thresholding the difference between two consecutive input frames. At the same time, the background difference mask is generated by comparing the current input image and the background image stored in the background buffer. This background difference mask is our primary information for object shape generation.

In the second step, according to the frame difference mask of past several frames, pixels which are not moving for a long time are considered as reliable background in the background registration. This step maintains an up-to-date background buffer as well as a background registration mask indicating whether the background information of a pixel is available or not.

In the third step, an initial object mask is constructed from the background difference mask and the frame difference mask. If the background registration mask indicates that the background information of an pixel is available, the background difference mask is used as the initial object mask. Otherwise, the value in the frame difference mask is copied to the object mask.

The initial object mask generated in the third step has some noise regions because of irregular object motion and camera noise. Also, the boundary region may not be very smooth. In the last step, these noise regions are removed and the initial object mask is filtered to obtain the final object mask.

The details of each step will be discussed in the next section.

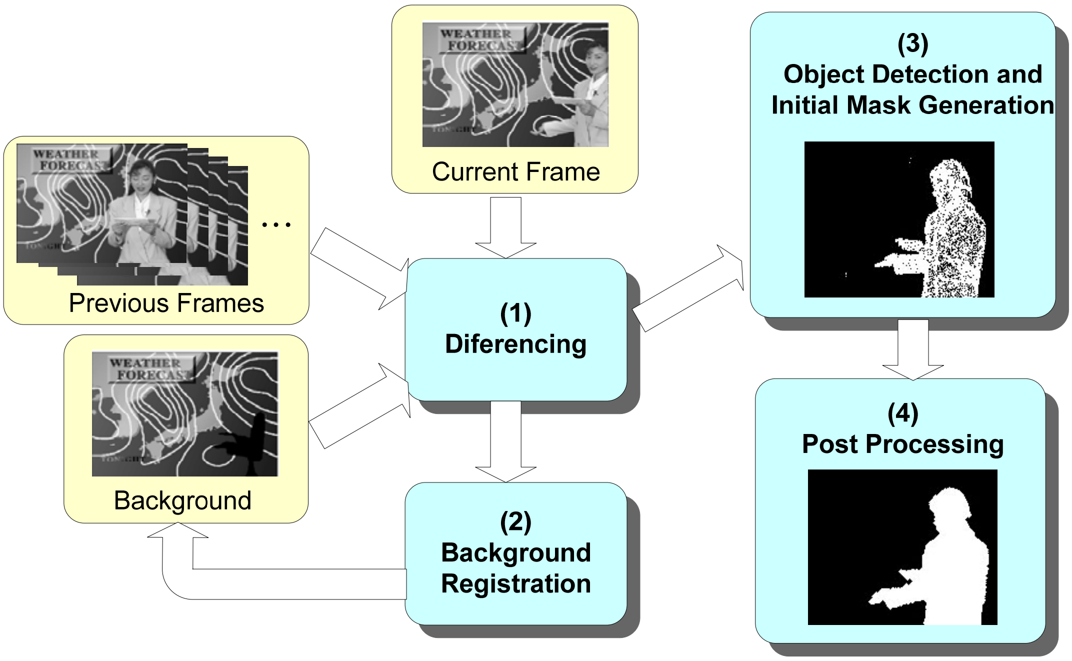


Fig. 2. Block diagram of this video segmentation algorithm based on image change detection.

3. Detailed Algorithm Description

Step I - Frame/Background Difference

The differencing includes frame differencing and background differencing. In the frame difference, the frame difference between current frame and previous frame is calculated and thresholded. It can be presented as

$$FD(x,y,t) = |I(x,y,t) - I(x,y,t-1)|$$
$$FDM(x,y,t) = \begin{cases} 1 & \text{if } FD \geq Th \\ 0 & \text{if } FD < Th \end{cases}$$

Where I is frame data, FD is Frame Difference, and FDM is Frame Difference Mask. Note that there is a parameter needed to be set in advance.

The procedure of background differencing is similar to that of frame difference. What is different is that the previous frame is substituted by background frame. After background differencing, another change detection mask named Background Difference Mask is generated. The operations of Background Differencing can be presented as

$$BD(x,y,t) = |I(x,y,t) - BG(x,y,t-1)|$$
$$BDM(x,y,t) = \begin{cases} 1, & \text{if } BD \geq Th \\ 0, & \text{if } BD < Th, \end{cases}$$

where BD is background difference, BG is background frame, and BDM is Background Difference Mask, respectively.

Step II - Background Registration

The goal of background registration step is to construct a reliable background information from the video sequence. According to FDM, pixels not moving for a long time are considered as reliable background pixels. The procedure of Background Registration can be shown as

$$SI(x,y,t) = \begin{cases} SI(x,y,t-1)+1, & \text{if } FDM = 0 \\ 0, & \text{if } FDM = 1 \end{cases}$$
$$BG(x,y,t) = \begin{cases} I(x,y,t), & \text{if } SI(x,y,t) = Fth \\ BG(x,y,t-1), & \text{else} \end{cases}$$
$$BI(x,y,t) = \begin{cases} 1, & \text{if } SI(x,y,t) = Fth \\ BI(x,y,t-1), & \text{else} \end{cases}$$

where SI is Stationary Index, BI is Background Indicator, and BG is the background information. The initial values of BI, BG, and BI are all set to “0.” Stationary Index records the possibility if a pixel is in background region. If is high, the possibility is high; otherwise, it is low. If a pixel is “not moving” for many consecutive frames, the possibility should be high. When the possibility is high enough, the current pixel information of the position is registered into the background buffer. In addition, Background Indicator is used to indicate whether the background information of current position exists or not.

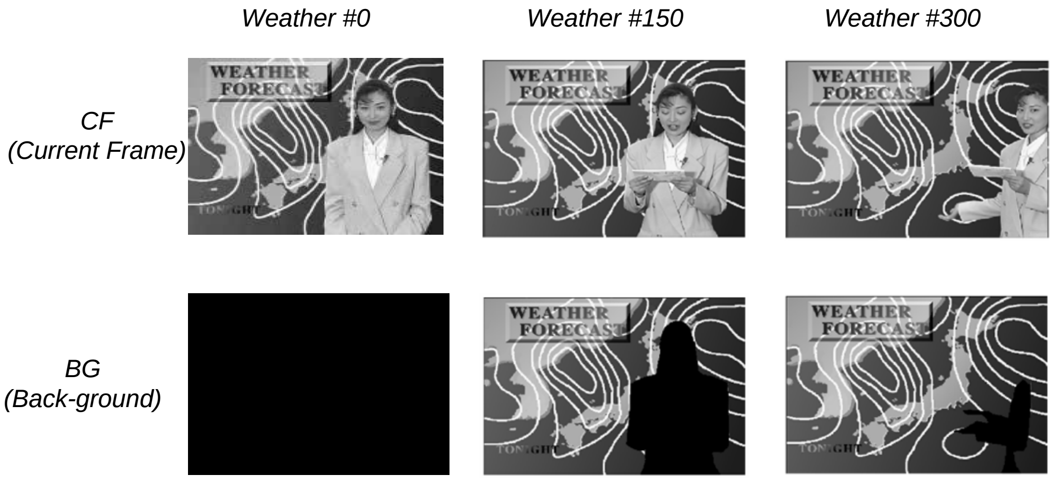


Fig. 3. Illustration of background registration technique. The upper row shows the original frames while the bottom row shows the registered background information.

Fig. 3 shows the results of Background Registration. The original frames are shown in the upper row of the figure, and the registered background information is shown in the bottom row of the figure. In the registered background information, the black parts indicate the regions where background information is not available until that time, which is caused by being covered by the foreground object. Obviously, more and more background information is available as more and more frames are input into the system. Since the number of frames of sequence Weather is 300, the last image shows the total background information we can get from the sequence. The black parts there are the parts which are covered by the foreground object in entire sequence.

Note that a background updating function is also included in Background Registration. That is, if background changes, new background information will be updated into the background buffer. Fig. 4 shows an example.

Step III – Object Detection

Both of FDM and BDM are input into Object Detection to produce Initial Object Mask. The procedure of Object Detection can be presented as the following equation.

$$IOM(x,y,t)=\begin{cases} BDM(x,y,t), & \text{if } BI(x,y,t)=1 \\ FDM(x,y,t), & \text{else.} \end{cases}$$

Table I lists the criteria for object detection. For the first two cases listed in Table I, the background information is not yet available, so the frame difference information is used as the criterion for separating object from background.

TABLE I Object Region Decision

Situation	FDM	BDM	BI	IOM
Stationary	0	–	0	0
Moving	1	–	0	1
Background	0	0	1	0
Moving object	1	1	1	1
Still object	0	1	1	1
Uncovered background	1	0	1	0

For cases 3 to 6 in the decision table, the criteria are background difference because the background information exists. If both the frame difference and the background difference are significant, the pixel is part of a moving object. On the other hand, if both the frame difference and the background difference are insignificant, the pixel should not be included in the object mask. Therefore, for the third and fourth cases in Table I, our result is the same as the result of using only the frame difference for change detection.

Cases 5 and 6 are situations that frame difference based change detection cannot handle properly, but the background difference works. One of the problems that confuse the conventional change detector (only frame difference is used) is that the object may stop moving temporarily or move very slowly. In these cases, the motion information disappears if we check the frame difference only. However, if we have background difference information, we can see very clearly that these pixels belong to the object region and should be included in the object mask. For case 6, since both the uncovered background region and the moving object region have significant luminance change, distinguishing the uncovered background from the object is not very easy if only the frame difference is available. In this algorithm, the uncovered background region is handled correctly because we recognize that this region matches the background information even though frame difference suggests significant motion.

Fig. 4. Background updating function. The red circuits are new background information, which will be updated into the background buffer.

Step IV – Post Processing

The Initial Object Mask (IOM) generated by Object Detection usually has some noise regions because of irregular object motion and camera noise. Also, the boundary may not be very smooth. Therefore, there are two parts in Postprocessing: noise region elimination and boundary smoothing.

The connected component algorithm [12] can mark each connected region with a special label. Then we can filter these regions by their area. If the area of a region is small, it may be a noise region and can be eliminated. Background regions, which are indicated by “0” in IOM, are first filtered. That is, background regions with small area are eliminated. This process eliminates holes in the change detection mask, which often occur especially when the texture of foreground objects is insignificant. Then foreground regions, which are indicated by “1” in IOM, are then filtered. This process removes noise regions. Next, the morphological close–open operations [13] are applied to smooth the boundary of object mask.

Fig. 5 shows the effect of Post processing. Fig. 5(a) is, where the white parts are those indicated by “1” in IOM, and the black parts are those indicated by “0” in IOM. After noise region elimination, the mask can be improved as shown in Fig. 5(b). After boundary smoothing, the improved mask is shown in Fig. 5(c). Finally, the generated foreground object is shown in Fig. 5(d).

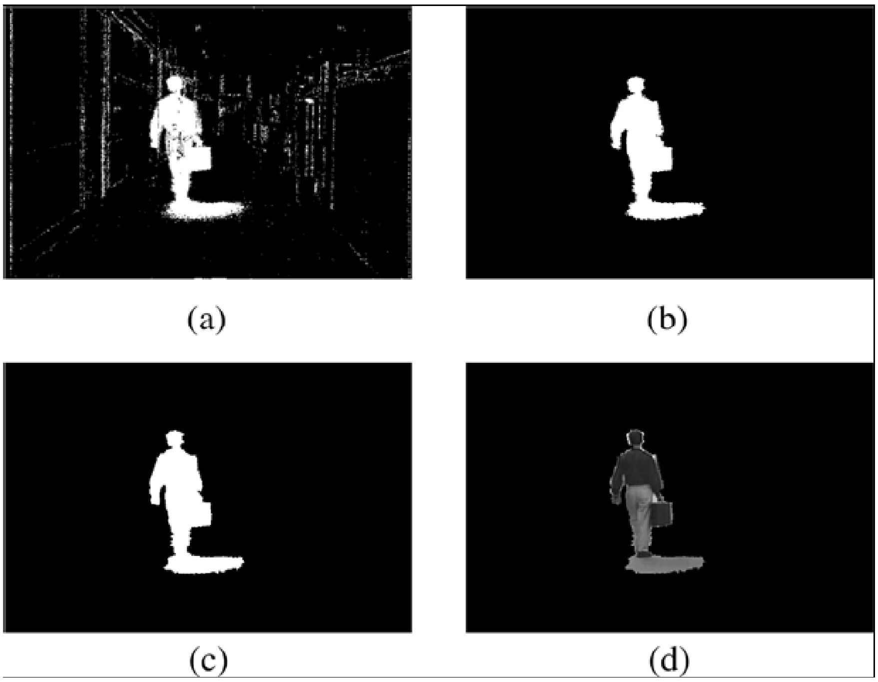


Fig. 5. Illustration of postprocessing. (a) Initial object mask; (b) after noise elimination; (c) after morphological closing operation; (d) generated foreground object.

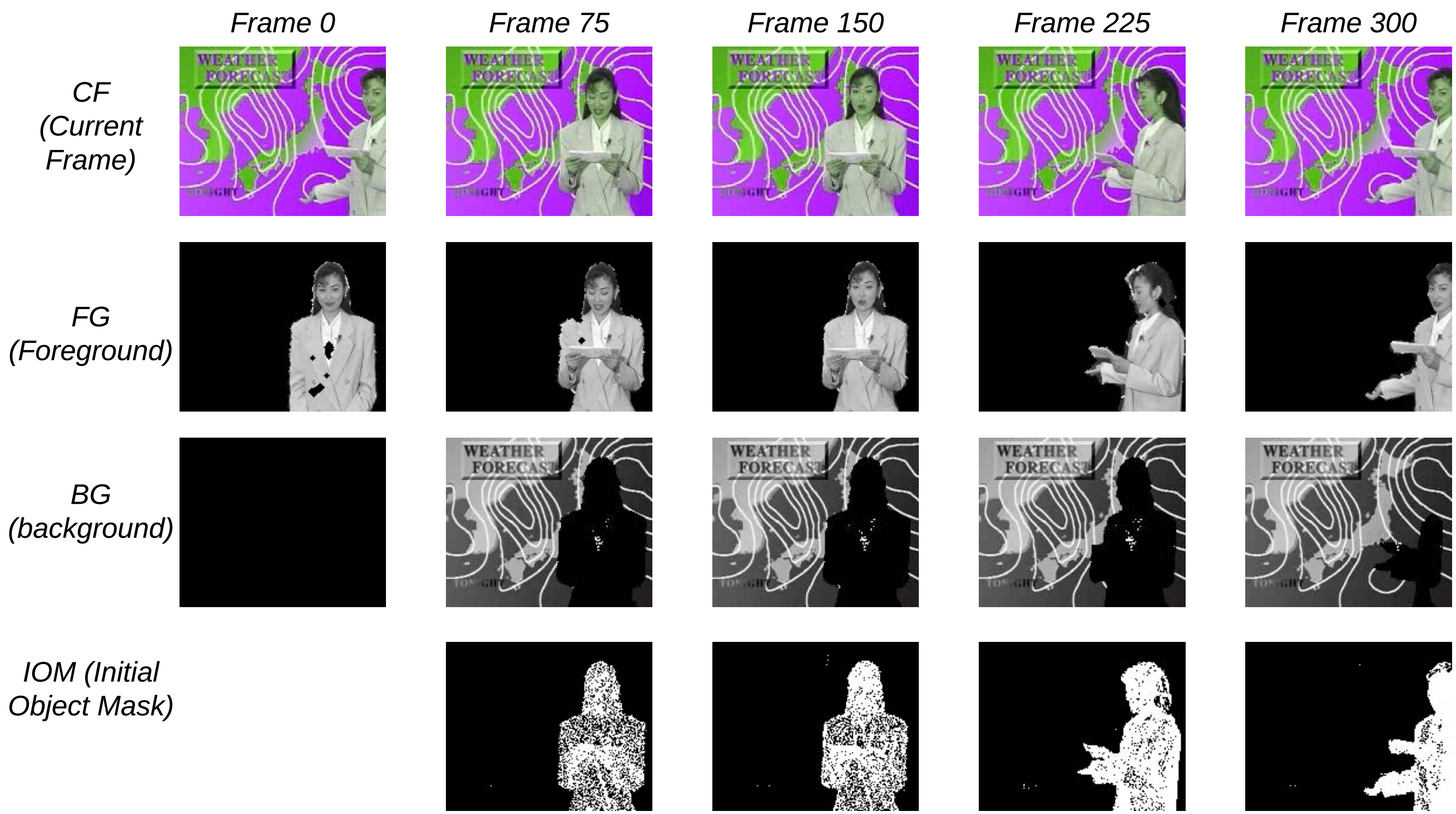
4. Implementation and Simulation Results

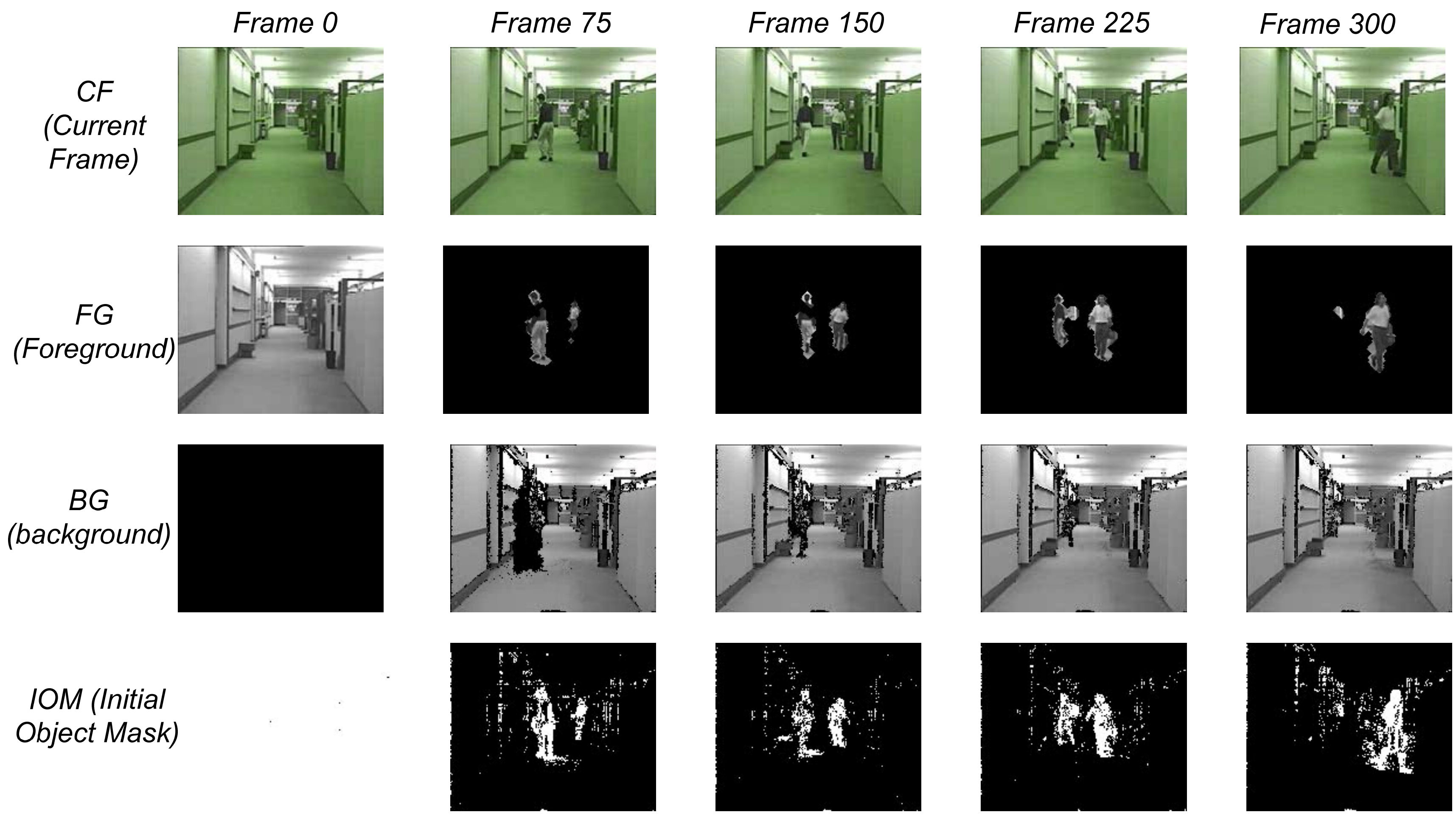
The entire implementation of segmentation has been done using Matlab. The input is the raw video in YUV 4:2:0 format, and the output is the foreground, background, object masks avi files. The parameters that can be adjusted are the video size, the threshold for differencing, and the group size for noise rejection.

The algorithm has been tested on two standard test videos:

- Weather in QCIF (176x144), 30fps, YUV 4:2:0 video.
- Hall monitor in QCIF (176x144), 30fps, YUV 4:2:0 video.

Note that only the luminance part of the video are used for the simulation. The simulation results are shown in the following:


Frame 0
Frame 75
Frame 150
Frame 225
Frame 300
CF (Current Frame)
FG (Foreground)
BG (background)
IOM (Initial Object Mask)
WEATHER FORECAST


Frame 0
Frame 75
Frame 150
Frame 225
Frame 300
CF (Current Frame)
FG (Foreground)
BG (background)
IOM (Initial Object Mask)

5. Discussion

For this image-change-detection based segmentation algorithm for surveillance system, some issues are discussed as follows:

- The speed is high, but not robust.
- Performance degradation occurs with the uncovered-background situation, still object situation, light changing, shadow, and noise.
- Post-process can promote the performance and enhance the noise rejection ability, but the efficiency lose a lot (much more run time is required).
- Should have automatical thresholds decision algorithm for real application.
- Some limitations:
  - Cannot deal with strong light sources.
  - Texture and luminance of background should be different with the foreground moving object.
  - Cannot deal with camera moving, zoom, rotation.
  - Designed for moving objects segmentation, and background should never move.

6. Conclusion

In this project, I implement a moving segmentation algorithm based on image change detection for surveillance system. A background registration technique is used to construct reliable background information from the video sequence. Then, each incoming frame is compared with the background image. If the luminance value of a pixel differ significantly from the background image, the pixel is marked as moving object; otherwise, the pixel is regarded as background. Finally, a post-processing step is used to remove noise regions and produce a more smooth shape boundary. My results are not as good as the ones shown in this paper. But the basic ability of change detection and segmentation is essentially demonstrated through the Matlab implementation. However, after this work, I think the algorithm has many limitations and more better techniques should be included in order to make the system robust.

7. Reference

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