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A Practical Several Moving Objects Area Extraction Using A Half-cosine Function Wavelet Network

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***Abstract*—This paper describes a practical several moving objects area extraction using a half-cosine function wavelet network. The network decomposes an image into weighted basis functions corresponding to spatial frequency. In this method, objects are distinguished by using a difference of object's size. First, moving objects area can be extracted from the weight image of the basis functions which constructs the reconstructed image by using frame difference. After that objects with different size are distinguished by using level-image difference. The proposed method enables measurement and area extraction of objects simultaneously. Moving objects area extraction from an image stream which includes several different-size objects is investigated. We show that the proposed basis function based method has robustness against background noise.**

***Keywords*—moving object detection, object area extraction, half-cosine function wavelet network, frame difference method, sapatial frequency**

I. INTRODUCTION

Moving object detection has an important role in today's intelligent systems, such as security system, alert system, robot control and so on [1-3]. As typical algorisms on moving object detection, frame difference [4], background subtraction [5], and optical flow [6] have been used widely. In recent years, the sophisticated technique [7] found in object tracking using features attracts researchers' attention. However, in general, newly image processing demands computational power therefore high-performance computer and dedicated image processor are needed [8].

We pay attention to a commonly used frame difference method as practical moving object detection algorithm. Although the frame difference method is simple, it has drawbacks, for example, weakness for local change in background or luminance, partial lack of pixels. Therefore, additional post processing, such as clustering, labeling, noise elimination, compensation of pixel lacks and so on, is necessary for object detection. Simple method having accuracy enough for practical use is demanded.

The drawbacks of a standard frame difference are caused by its pixel-based architecture. Therefore, in this paper, we propose a basis function based method. The method employs a half-cosine function wavelet network. In comparison with Gabor-filtering technique employing a Gaussian function, the proposed method using a half-cosine function which is compact and simple offers low calculation cost and is suitable for practical use. We have confirmed the validity of the network for feature extraction and area extraction [9, 10].

In this paper, a practical several moving objects area extraction employing the half-cosine function wavelet network using a difference of object size is described. The network has a multi-level structure and represents an image with a set of weighted basis functions which corresponds to spatial frequency. Basis functions corresponding to moving object area can be selected from the weight images of the reconstructed image by using frame difference each a level. Support area of the selected basis functions is the moving object area because of use of compact support. By specifying the level, object with size matched to the basis function in specified layer can be extracted. Objects with different size are distinguished by using level image difference.

We examine the extraction of moving object areas separately from an image stream includes moving three balls with different sizes and investigate robustness against background noise.

II. A HALF-COSINE FUNCTION WAVELET NETWORK

A. Basic Construction

The half-cosine wavelet network [11] is a kind of a basis function network and represents an object image as a linear conjunction of weighted basis functions. The output of the 2D type half-cosine function wavelet network $\hat{Y}$ is defined as

$$\hat{Y}(x,y)=\sum_{a=0}^{M}\sum_{bx=0}^{2^{a+1}-1}\sum_{by=0}^{2^{a+1}-1}W_{a,bx,by}\psi_{a,bx,by}(x,y)\,, \tag{1}$$

where a is a level, bx and by are a number of basis functions the x- and y-axis, respectively. M is a maximum number of the levels. $W_{a,bx,by}$ is a weight corresponds to a basis function $\psi_{a,bx,by}(x,y)$. The network has a multi-level structure, and each level consists of compactly supported basis functions whose support width corresponds to the spatial frequency. Here, the basis function $\psi_{a,bx,by}(x,y)$ is represented as;

when $a=0$, this is a special case,

$$\psi_{a,bx,by}(x,y)=1\,, \tag{2}$$

when $a\neq 0$,

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$$\psi_{a,bx,by}(x,y)=\begin{cases}\cos\{\pi\cdot r_{a,bx,by}(x,y)\} & 0<r_{a,bx,by}(x,y)<\dfrac{N}{2^a}, \\ 0 & otherwise\end{cases}$$

$$r_{a,bx,by}(x,y)=\sqrt{(x-x_{a,bx})^2+(y-y_{a,by})^2},$$

$$x_{a,bx}=\frac{N}{2^{a+1}}(bx+\frac{1}{2}),$$

$$y_{a,by}=\frac{N}{2^{a+1}}(by+\frac{1}{2}), \quad (3)$$

where N is a size of an image. As a level becomes high, the support size of the basis function becomes narrow.

B. Signal Process Flow of The Half-cosine Function Wavelet Network

The process flow of the half-cosine function wavelet network is shown in Fig.1. At first, an original image is decomposed into weighted basis functions in level 0. The next, an approximate image is reconstructed by using the weighted basis functions in level 0. After that, a target image at the next level is obtained by taking a difference of the original image and the reconstructed image. The decomposition is executed each level in the same manner, from low level to high as shown in Fig.1. Finally, the original image is represented as a set of weighted basis functions. $\hat{Y}$ represents a reconstructed image using the weighted basis functions. When all basis functions are used in reconstruction, $\hat{Y}$ is an approximate image of an original one. On the other hand, when selected basis functions are used, $\hat{Y}$ becomes a characterized image corresponding to a selection scheme.

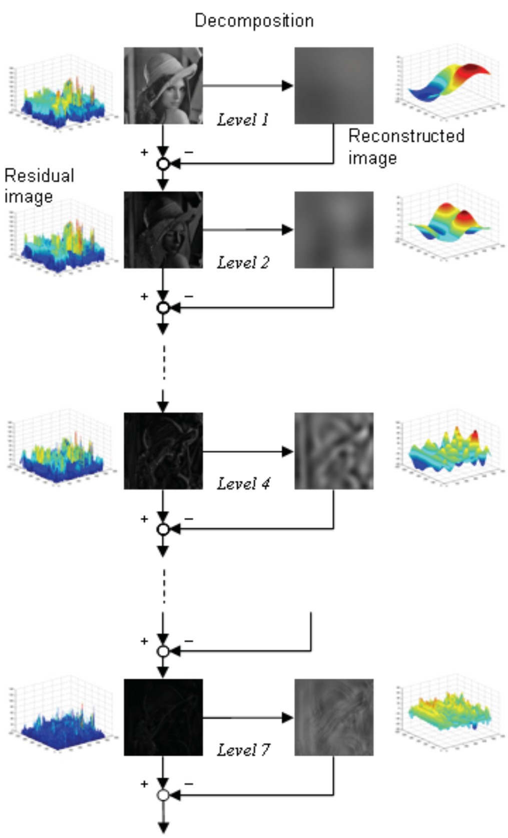

Figure 1. Process flow of the half-cosine function wavelet network.

C. Weight and Its Characteristic

The weight can be obtained by solving the minimization problem for $E_{a,bx,by}$ in Eq. (4).

$$E_{a,bx,by}=\frac{1}{2}\sum_{x=0}^{N/2^{a-1}}\sum_{y=0}^{N/2^{a-1}}\{Y(x,y)-W_{a,bx,by}\psi_{a,bx,by}(x,y)\}^2. \quad (4)$$

Here, the $E_{a,bx,by}$ is a quadratic form corresponding to the weight $W_{a,bx,by}$ therefore the weight can be determined by calculating the following equation.

$$W_{a,bx,by}=\frac{\sum_{x=0}^{N/2^{a-1}}\sum_{y=0}^{N/2^{a-1}}Y(x,y)\psi_{a,bx,by}(x,y)}{\sum_{x=0}^{N/2^{a-1}}\sum_{y=0}^{N/2^{a-1}}\psi^2_{a,bx,by}(x,y)}. \quad (5)$$

Fig.2 shows a weight change caused by the object movement for objects with different sizes (a half, the same, and double sizes of the basis function). In Fig.2, solid and dotted lines represent a target image and a basis function, respectively. When the support width of the basis function fits the target image, the change of the weight caused by object's movement becomes large as shown in Fig. 2. The weights are calculated only in the support area of each basis function because the proposed method employs a compact-support basis function. Therefore the support width of the basis function with large weight in lowest level represents the object's size. In this paper, we use the characteristic to extract a moving object of specific size.

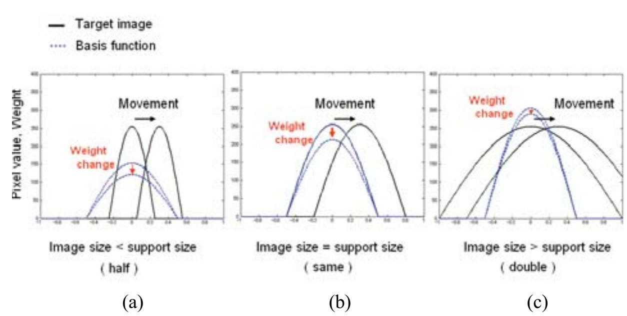

Figure 2. Weight change caused by the object movement for objects with different sizes. (a) image width < support size, (b) image width = support size, (c) image width > support size: Solid and dotted lines represent a target image and a basis function, respectively.

III. SEVERAL MOVING OBJECTS AREA EXTRACTION USING THE HALF-COSINE FUNCTION WAVELET NETWORK

We introduce a practical several moving objects area extraction method using the half-cosine function wavelet network. The proposed method extracts moving objects area based on the basis function by taking a frame difference for the weight images instead of pixel in an original image. The moving object area is constructed with the support areas of the basis functions with large differential weight exceeds a threshold corresponding to the difference weight image obtained by using frame difference.

A. Frame Difference for Weight Images

The moving object detection from weight images in level 2 by using a frame difference is shown in Fig.3. The weight image means a feature image constructed by weights of basis function in each level. Basis functions consisting area which includes moving objects can be selected as follows,

1) takes a frame difference between the weight image at time *t* and *t-1,*
2) takes a absolute value for each weights of the obtained difference weight image,
3) selects weights with large weight exceed a threshold,
4) finally, support areas of basis functions with selected weights are defined as a moving object area.

B. Area Extraction of Several Objects with Different Size in An Image

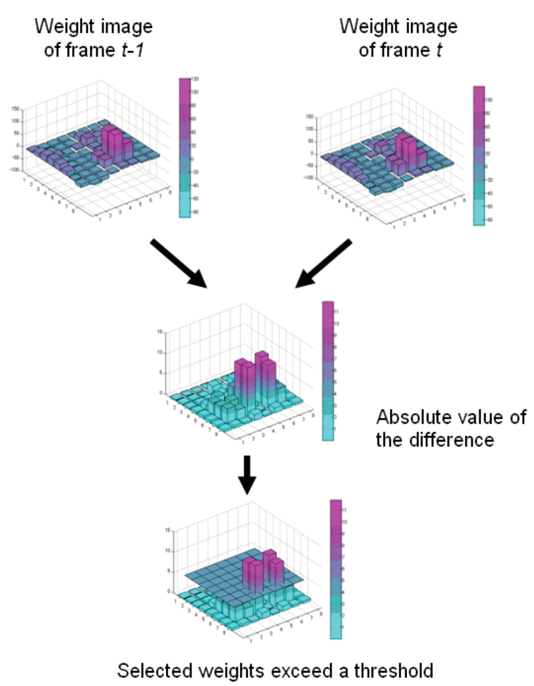

Figure 3. Moving object detection by taking a frame difference for weight images.

Support width of the basis function of the proposed network is corresponding to a spatial frequency. Therefore moving object with a specified size can be extracted by specifying the level. The extraction process of a moving object with a specified size is shown in Fig. 4. Fig. 4 is an example that only smaller ball is extracted from image stream which includes two moving balls with different sizes. Here, the area of lager ball is extracted from weighted image in level 2 and areas of two balls are extracted from that in level 3. As the result, as shown in Fig. 4, the small ball area can be obtained by subtracting the basis functions whose center coordinates exist in the selected area in level 2 from basis functions constructing an image of level 3.

In the proposed method, weights of the all basis functions are obtained through a series of decompositions each a level. Objects with size corresponding to spatial frequency of basis function in each level can be extracted simultaneously in the same manner.

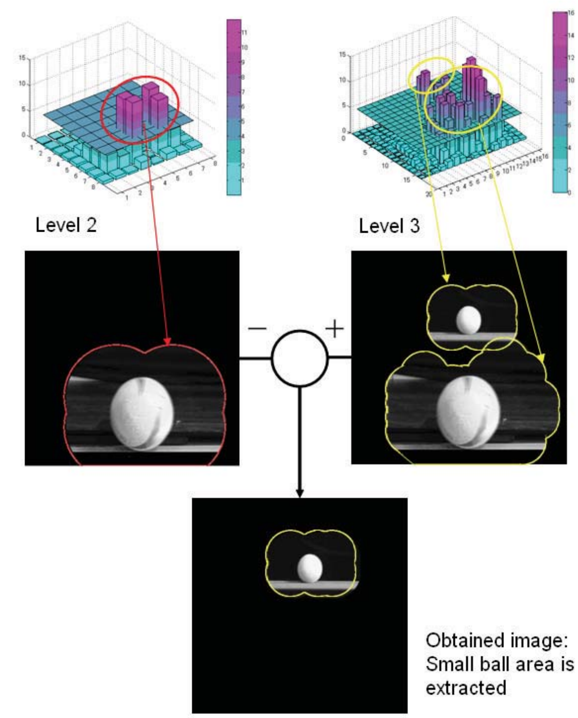

Figure 4. Extraction process of a moving object with a specified size.

IV. EXPERIMENTAL RESULTS OF SEVERAL MOVING OBJECTS AREA EXTRACTION

In order to confirm the validity of the proposed method, moving object area extraction from an image stream which includes several objects with different sizes is examined. Furthermore we investigate robustness of the proposed method against small changes in background. The threshold value = 5.0 for all experiments.

A. Moving Object Areas Extraction of Several Objects with Different Sizes in An Image Stream

We examine the extraction of several moving areas separately from an image stream includes moving three balls with different sizes. The extraction results show in Fig. 5. The diameters of the large, middle, and small balls are 20, 9, and 4 cm, respectively. The image is 512 x 512 pixels, gray-scale image. The image stream is obtained with frame rate 28 fps. Fig. 5 (a) is an original image. As shown in Fig. 5 (b), (c), and (d), each ball area can be extracted well individually. We also show the result using a standard pixel based frame difference in Fig. 5 (e). As shown in Fig. 5 (e), the result using a standard method has a lot of noise caused by small brightness change and lack of pixels in object area.

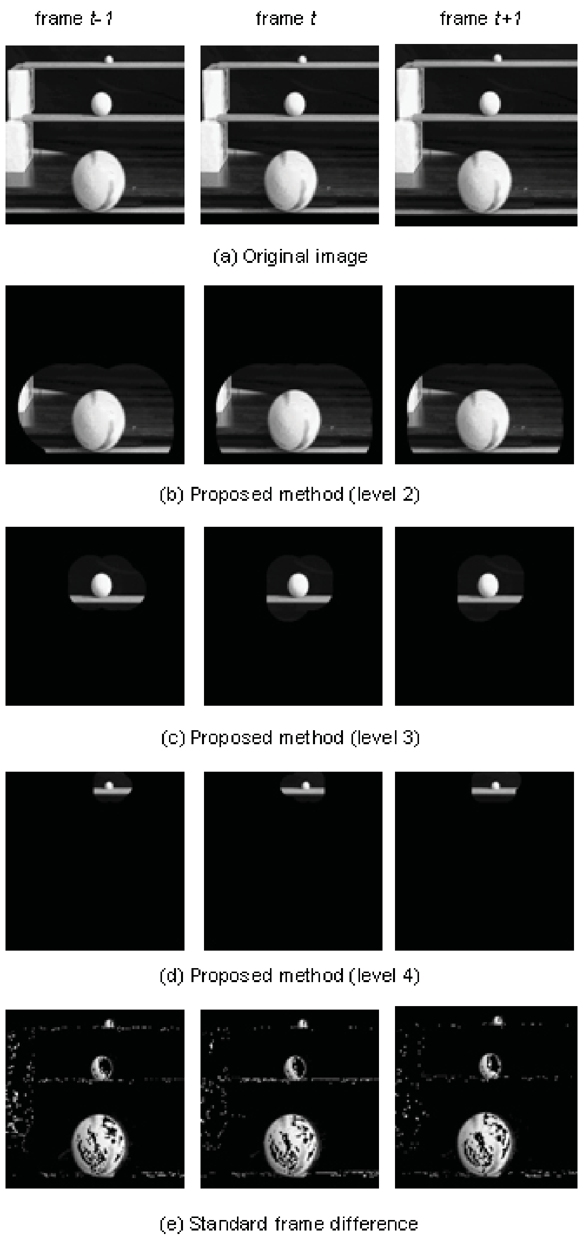

Figure 5. Extraction results of moving object areas separately from an image stream includes moving three balls with different sizes. (a) Original image, resuls of the proposed method (b) level 2, (c) level 3, (d) level 4, and (e) result using a standard frame difference.

B. Robustness against A Small Change in Background

The proposed method detects moving objects from the change on the weight space of basis functions. The method is strong against background noise with compared to a standard pixel based frame difference because of employing a basis function based approach.

We investigate robustness of the proposed method against the background noise. In this experiment, background noise is generated by ornaments put on the wall swayed by the wind of electric fan. The result of a moving object extraction from image stream with the background noise is shown in Fig. 6. Fig.6 (a), (b), and (c) are an original image, result of the proposed method, and that of a standard frame difference,

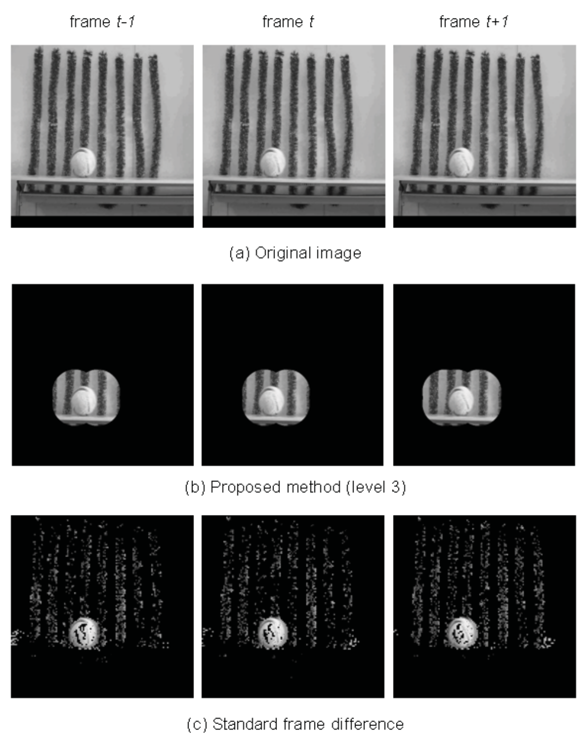

Figure 6. Robustness of the proposed method against the background noise.(a) Original image, results of (b) proposeed method, (c) a standard frame difference method.

respectively. The result of Fig. 6 shows that the proposed method is robust against the background noise.

V. CONCLUSION

A practical several moving objects area extraction method using the half-cosine function wavelet network was described. The performance for several moving objects area extraction was confirmed by experimental results using an image stream includes moving three balls with different sizes. In the proposed method, several moving objects area can be extracted separately by using a difference of object's size.

Generally a standard pixel-level frame difference method is necessary for additional process such as clustering, labeling, noise elimination, compensation of pixel lacks and so on, to extract target object area. On the contrary, the proposed method, basically, can extract area including moving objects directly without any additional process. The basis function of each level has different support size corresponding to spatial frequency therefore, by specifying the level, desire-size moving object can be extracted.

Experimental results said that the extracted area includes an extra part. We will improve the performance of object extraction by devising an arrangement of the basis functions and investigate the usage for real-world images.

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