

An Efficient Algorithm for Object Tracking Using Dual Tree Complex Wavelet Transform

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Abstract

In this paper an efficient method for tracking a moving object in a video scene is described. Many algorithms for tracking of moving object using real wavelet transform have been developed. This method uses dual tree complex wavelet transform for tracking of the object. One of the most critical tasks in object tracking is the identification of moving object in the scene. For this purpose optical flow based segmentation method is used. This method is very simple and intelligent enough for determining the moving area in the scenes. Dual tree complex wavelet transform is used here for tracking because there is problem of shift variance and directional selectivity in real wavelet transform. In proposed method only complex wavelet coefficients are used for tracking of the object no other parameter is needed. Also Dual tree complex wavelet transform do not suffer from shift variance and directional selectivity.

Key words: Dual tree complex wavelet transforms, optical flow, Shift variance.

Introduction:

Using object tracking algorithms we estimate the trajectory of the moving object in the video scene [1]. There are many areas where object tracking is used now a day like video compression, sport video analysis for extracting the highlights, surveillance systems etc [2]. There are algorithms [3] for tracking which segment each frame of the video for tracking. If our goal is to track the object then this process is time taking and not necessary [8]. This method uses feature based tracking method. Here complex wavelet

coefficient is used as feature. Proposed tracking algorithm proceeds in two steps.

1. For finding the object of interest in the scene Horn-Schunck method for optical flow computation is used here.

2. In first step we find segmented threshold image of the moving object in the video. Further in second step we find the boundary of the object and apply the tracking algorithm.

In proposed method only two frames of the moving video sequence is taken and the segmentation algorithm for finding the moving object is applied. Further for tracking dual tree complex wavelet transform is used. Due to its shift invariance feature, it is very much helpful for tracking algorithm. Whole paper is organized as – section 1 describes the moving area detection process and its experimental results. Section 2 Describes the dual tree complex wavelet transform. Section 3 describes the shift invariant property of the dual tree complex wavelet transform. Section 4 describes the tracking algorithm used and its result of on an input video is shown. Finally in the last section conclusion is given.

1. Segmentation process

1.1 Optical flow computation for finding moving object

The Optical Flow estimates the direction and speed [7] of object motion from one image to another or from one video frame to another using either the

Horn-Schunck or the Lucas-Kanade method [4]. In present method Horn-Schunck method for optical flow computation is used.

For finding optical flow between any two image we have to solve the optical flow constraint equation [4] given by.

$$I_x u + I_y v + I_t = 0. \quad (1)$$

I_x , I_y and I_t are the spatiotemporal image brightness derivatives, u and v are horizontal vertical optical flow respectively.

For computing the values of u and v it is assumed that optical flow is smooth over the entire image. Using Horn-Schunck method estimates $[u, v]^T$, that minimizes the equation [4] given below.

$$E = \iint (I_x u + I_y v + I_t)^2 dx dy + \alpha \iint \left[\left(\frac{\partial u}{\partial x} \right)^2 + \left(\frac{\partial u}{\partial y} \right)^2 + \left(\frac{\partial v}{\partial x} \right)^2 + \left(\frac{\partial v}{\partial y} \right)^2 \right] dx dy \quad (2)$$

$\frac{\partial u}{\partial x}$ and $\frac{\partial u}{\partial y}$ are the spatial derivatives of the optical velocity component u , and α scales the global smoothness term. The Horn-Schunck method minimizes the previous equation to obtain the velocity field, $[u, v]$, for each pixel in the image, which is given by the following equation [4].

$$u_{x,y}^{k+1} = u_{x,y}^{-k} - \frac{I_x [I_x \bar{u}_{x,y}^k + I_y \bar{v}_{x,y}^k + I_t]}{\alpha^2 + I_x^2 + I_y^2}$$

$$v_{x,y}^{k+1} = v_{x,y}^{-k} - \frac{I_y [I_x \bar{u}_{x,y}^k + I_y \bar{v}_{x,y}^k + I_t]}{\alpha^2 + I_x^2 + I_y^2} \quad (3)$$

$[u_{x,y}^k, v_{x,y}^k]$ is the velocity estimate for the pixel at (x,y) . $[\bar{u}_{x,y}^k, \bar{v}_{x,y}^k]$ is the neighborhood average of $[u_{x,y}^k, v_{x,y}^k]$. For $k=0$, the initial velocity is 0. Using equation (2) and (3) Value of u and v are computed iteratively.

1.2 Segmentation Algorithm

1. Take first and last frames of the video sequence.
2. Convert them to gray level image,

2. Dual-Tree Complex Wavelet Transform

further determine optical flow using Horn-Schunck method between these two images.

3. Thus we find the magnitude square value of the optical flow $|u|^2$.
4. Find mean value of the $|u|^2$ for the first image and compare its value with magnitude square value of the optical flow at each pixel location in the image.
5. If $|u|^2$ at any pixel is greater than or equal to the mean value. Then keep its pixel value 1, otherwise assign it 0.

Further by using median filter and morphological closing operations, we get the threshold image of the moving object in the video scene.

1.3 Experimental Result of Segmentation Process

We take a 240x320 frame size video of basket ball game and applied the segmentation algorithm for finding the moving object in first frame of the video sequence taken for tracking purpose. The threshold image of the moving object in the first frame is shown below.

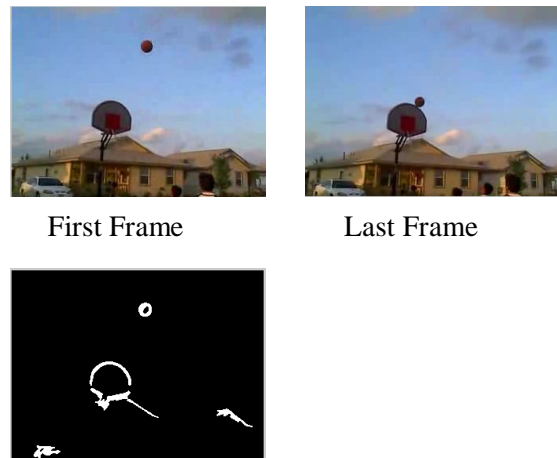


Figure 1 .Threshold image of the moving object detected in the first frame

Dual-Tree complex wavelet transform is an effective way of implementing an analytic wavelet transform and it was introduced by Kingsbury in 1998 [6]. It was having properties like shift

invariance, Directional selectivity and perfect reconstruction. It was noted that approximate shift invariance can be achieved with a real discrete wavelet transform by doubling the sampling rate at each level of the tree, which is achieved by computing two parallel subsampled wavelet trees a and b respectively. The filters in one tree must provide delays that are half a sample different from those in the other tree. Greater symmetry between the two trees occurs if each tree uses Odd and even filters alternately from level to level, but this is not mandatory. Here figure 2 [9] shows the dual tree complex wavelet transform of the signal x over 3 levels

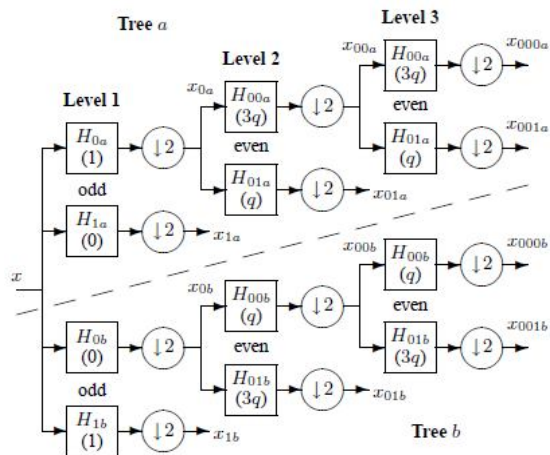


Figure 2. Dual-Tree Complex Wavelet Transform over 3 levels

3. Dual -Tree Complex Wavelet Transform with reduced Shift variance

If a little shift in the input signal causes an unpredictable change in the transformed coefficients, we say that transform is shift sensitive. This shift invariant property of dual complex wavelet transform is shown in following figure 3.[6]. Fig3.a shows the input signal and the shifted signal. Fig 3.b shows the real coefficients computed using the conventional real discrete wavelet transform. Fig 3.c. shows the magnitude of the complex coefficients computed using the dual-tree complex discrete wavelet transform.

Figure 3 [6]

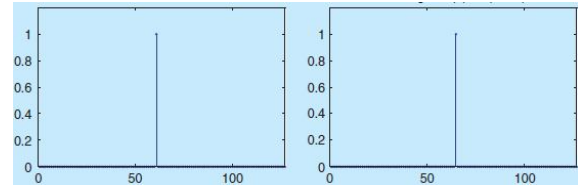


Figure 3.a Original Signal and shifted signal.

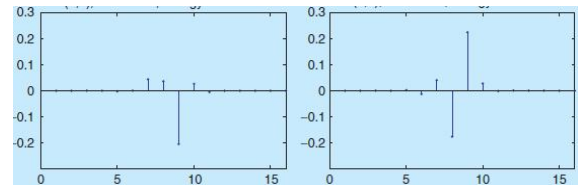


Figure 3.b. Real discrete wavelet coefficients of the original signal and the shifted signal.

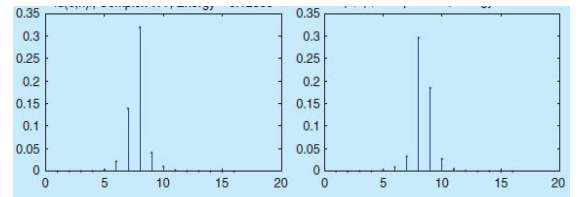


Figure 3.c. Magnitude of the complex wavelet coefficients of the original signal and the shifted signal computed using dual tree complex wavelet transform

Form this figure it is indicated that the nature of the magnitude and energy of the dual tree complex wavelet coefficients of the input signal and shifted signal remains approximately same.

4. Tracking Process

In object tracking the moving object is detected across subsequent frames [7], object can be translated as well as rotated among the various frame. Hence we need such a feature of the object which is invariant among different frames with respect to rotation and translation. And due to shift invariance [5] property of dual tree complex wavelet transform [6] it was found that dual tree complex wavelet transform of the object is approximately same in subsequent frames. Hence it is very use full for tracking purpose.

4.1 Tracking Algorithm

In previous step after finding the threshold image of the moving object we can easily define a bounding box around the object. Let O_T , O_B , O_L , O_R are top, bottom, left and right boundary of the object.

1. Let centroid of the object bounding box in first frame be (C_1, C_2) .
2. Hence $C_1 = O_T + \text{round}((O_B - O_T)/2)$;

$$C_2 = O_L + \text{round}((O_R - O_L)/2);$$

3. Find DT complex wavelet transform of the first frame. And compute the centroid of the object in high pass sub image in wavelet domain.

$$\begin{aligned} \text{top} &= \text{floor}(O_T/2) \\ \text{bottom} &= \text{floor}(O_B/2) \\ \text{left} &= \text{floor}(O_L/2) \\ \text{right} &= \text{floor}(O_R/2) \end{aligned}$$

4. $\text{height} = \text{bottom} - \text{top} + 1$;

$$\text{breadth} = \text{right} - \text{left} + 1;$$

5. Centroid of the object in first frame in DT CWT domain is given by.

$$\begin{aligned} CX_1 &= \text{top} + (\text{round}((\text{bottom} - \text{top})/2)) \\ CX_2 &= \text{left} + (\text{round}((\text{right} - \text{left})/2)) \end{aligned}$$

6. For the first frame, we find the energy for the wavelet coefficients corresponding to centroid (CX_1, CX_2) of the object in each of the six high pass subimages.

7. for frame_2 to $\text{total_number_of_frames}$ do

$$\text{Search_length} = 6$$

for each of the six high pass sub images do

for $i = (\text{top} - \text{Search_length})$ to $(\text{bottom} + \text{Search_length} - \text{height} + 1)$ do

for $j = (\text{left} - \text{Search_length})$ to $(\text{right} + \text{Search_length} - \text{breadth} + 1)$ do

Find the energy of each bounding box having boundaries $[i, (i + \text{height} - 1), j, (j + \text{breadth} - 1)]$

end

end

find the difference of energy of each box of the wavelet coefficients in the current sub image with the energy of the bounding box of wavelet coefficients in the corresponding sub image in the first frame.

Find the minimum energy difference and corresponding boundary values $[T1, B1, L1, R1]$.

Find the centroid corresponding to this boundary value for current high pass sub image.

end

Calculate mean value of the centroid computed for all six high pass subimages.
Let it be (C_{M1}, C_{M2})

Centroid of the object boundary in original image $(C_1, C_2) = (2 * C_{M1} + 2 * C_{M2})$.
end

Thus we get the centroid of the moving object bounding box in each frame of the video. Experimental result of this algorithm is shown below.

Exeperimental Result of the Tracking Process

We Applied this tracking algorithm to many videos of the basket ball game. We have shown our result

on 10 frames of one video of frame size 240x320. Proposed method for tracking gives much better result. The result of the tracking is shown below.



Frame 1



Frame 2



Frame 3



Frame 4



Frame 5



Frame 6



Frame 7



Frame 8



Frame 9



Frame 10

Conclusion

Due to lack of shift invariance and directional selectivity real wavelet transform was not suitable for the tracking purpose. Proposed algorithm uses dual tree complex wavelet transform which do not suffers from shift variance and directional selectivity

problem. Optical flow based segmentation method is used for determining the moving object which is intelligent enough for finding the object boundaries. Thus this method is much efficient, accurate and simple to implement. For tracking multiple objects or non rigid objects some changes in this algorithm may be needed.

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