Moving Object Tracking in Video Sequences based on Energy of Daubechies Complex Wavelet Transform

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ABSTRACT
Object tracking in the video sequence is a challenging task because of its various applications in video compression, video surveillance, robot technology etc. Several object tracking methods exist in spatial and wavelet domain, to work with rigid and non-rigid object boundaries. Spatial domain tracking techniques are not accurate as well as they are slow and this is a major reason why wavelet domain tracking methods are getting popular. Real-valued wavelet transform suffers from shift sensitivity producing inaccurate object tracking. In this paper, we proposed a novel object tracking method using Daubechies Complex Wavelet transform (DaubCxWT). Use of this transform is suitable to track the object from video sequences because of its approximate shift-invariance nature. Tracking of object in the first frame is done by computing the Daubechies complex wavelet coefficients corresponding to the object of interest and then matching energy of these coefficients to the object neighborhood, in Daubechies complex wavelet domain, to perform the tracking in the next consecutive frames. The proposed method needs only complex wavelet coefficients for tracking and hence it is simple in implementation and tracks object efficiently.

Keywords:
Object tracking, Daubechies Complex wavelet transform, Shift-invariance.

1. INTRODUCTION
The object tracking in video sequences is a problem of estimating the position and other relevant information of moving object. The main difficulties in reliable tracking of moving object include: rapid appearance changes caused by image noise, illumination changes, size and shape changes, occlusion cluttered background and interaction between multiple objects. In computer vision applications [1,2] object tracking is one of the challenging problem which receive the considerable attention by the research community in the past decade due to its wide range of potential applications in medical imaging [3], recognition and interpretation of objects in a scene [4], video surveillance [5-8], target detection and identification [9] etc.

Several algorithms had been proposed to solve the problem of tracking [10,11]. Every tracking method requires an object detection mechanism either in every frame or when the object first appears in the video sequence. A common approach for object detection is to use information of single frame. However, some object detection methods make the use of temporal information captured from sequence of frames [10, 12] to reduce number of false detections. This temporal information is usually in the form of frame differencing which highlights changing regions in the consecutive frames. Given the object regions in the image, it is the task of tracker to perform correspondence from one frame to the next, to generate the tracks. This type of tracking is known as region based tracking [7] and it requires number of parameters such as object size, color, shape, velocity, etc. which involves an increased computational cost. Use of feature based tracking techniques is the solution to avoid or at least minimize the computation of these many parameters. In this paper, we present a feature based object tracking mechanism which requires some heuristic to select the object feature. Various spatial and frequency domain techniques are used for this purpose, but the recent trend is to use wavelet transform.

Although, the discrete wavelet transform (DWT) provides a fast, local, sparse and decorrelated multiresolution analysis of images but it suffers from several serious disadvantages like shift-sensitivity [13, 14] and poor directionality [15]. Several researchers have provided solutions to minimize these disadvantages. The use of complex wavelet transform is one of the solutions to overcome these shortcomings. Several complex wavelet transforms like dual tree complex wavelet transform (DTCxWT) [16, 17], projection-based complex wavelet transform [18], steerable pyramid complex wavelet transform [19], etc. have been proposed to reduce effect of shortcomings of DWT. However, these transforms are approximate shift-invariant but all of them use real filters, making them not a true complex transform. These transforms are also computationally costly because of their redundancy. In this paper, we tried to minimize computational cost by using the Daubechies complex wavelet transform [20, 21] which also preserves the approximate shift-invariance property and is true complex wavelet transform as it uses complex valued filters in place of real valued filters.

In the proposed tracking algorithm, we have used the Daubechies complex wavelet coefficients as feature of object and only this feature has been used to track the object in video sequences. The proposed method of tracking does not require any other parameter except complex wavelet coefficients. The use of single parameter makes the tracking accurate and efficient.

The rest of paper is organized as follows: section 2 introduces the Daubechies complex wavelet transform, the usefulness of Daubechies complex wavelet transform in tracking is described in section 3, and the proposed algorithm is given in section 4.

The section 5 focuses on the experimental results and finally, the conclusions are given in section 6.

2. DAUBECHIES COMPLEX WAVELET TRANSFORM (DaubCxWT)

The scaling equation of multiresolution theory is given by:

$$\phi(x) = 2\sum_k a_k \phi(2x-k) \quad (1)$$

where ak are the coefficients. The ak can be real as well as complex valued and $\sum a_k = 1$. Daubechies's wavelet bases {ψj,k(t)} in one dimension are defined through the above scaling function and multiresolution analysis of L2(R). To provide general solution, Daubechies considered ak to be real valued only. If we consider ak and ϕ both to be complex valued as well, we will get Daubechies complex wavelet transform. The construction details of Daubechies complex wavelet are given in [21].

The generating wavelet $\psi(t)$ is given by:

$$\psi(t) = 2\sum_n (-1)^n \overline{a_{1-n}} \phi(2t-n) \quad (2)$$

Here ψ(t) and $\phi(t)$ share the same compact support *[−N, N + 1]*.

Any function f(t) can be decomposed into complex scaling function and mother wavelet as:

$$f(t) = \sum_k c_k^{j_0} \phi_{j_0,k}(t) + \sum_{j=j_0}^{j_{\max}-1} d_k^j \psi_{j,k}(t) \quad (3)$$

where j0 is a given resolution level, $\{c_k^{j_0}\}$ and $\{d_k^j\}$ are known as approximation and detailed coefficients.

Daubechies Complex Wavelet Transform (DaubCxWT) has reduced shift-sensitivity. The reduced Shift-sensitivity of DaubCxWT in shown is Fig. 1. Fig. 1(a) shows the input signal and its shifted form by one sample, Fig. 1(b) shows high pass wavelet coefficients of the original signal and the shifted-signals using DWT and Fig. 1(c) shows the magnitudes of the corresponding high-pass wavelet coefficients. Fig. 1 clearly illustrates that the real valued wavelet transform is highly shift-sensitive whereas CxWT has approximate shift-invariant nature. Our observation on DaubCxWT coefficient reveals that the magnitudes of the wavelet coefficients vary slightly with input shift while the phase vary rapidly. That is, there is an unpredictable change in the phase of wavelet coefficients with input shift. This is illustrated in Fig. 1(d).

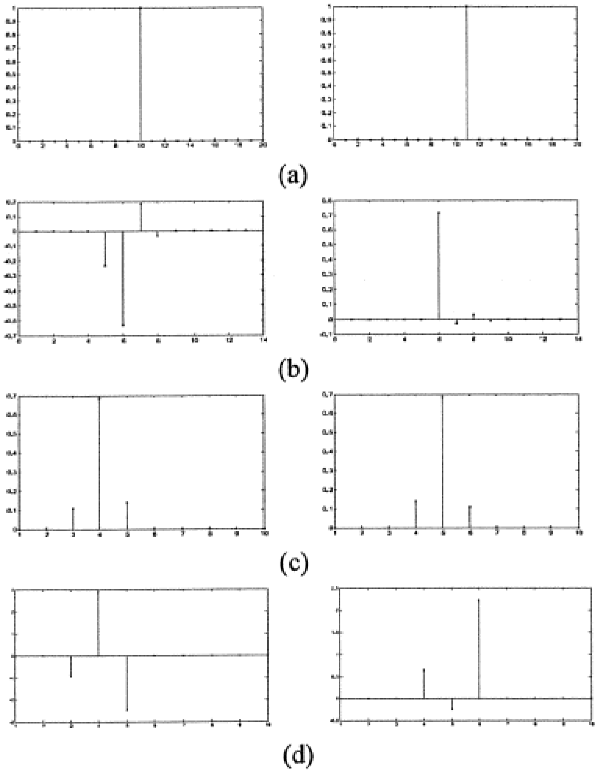


Fig. 1: (a) Original signal and the shifted signal by one sample, (b) High-pass wavelet coefficients of the original and the shifted signal using db4 wavelet, (c) High-pass wavelet coefficient magnitude and (d) Phase of the original and shifted signal using SDW6 complex wavelet

3. USEFULNESS OF DAUBECHIES COMPLEX WAVELET TRANSFORM IN OBJECT TRACKING

On the basis of properties of Daubechies Complex Wavelet transform (DaubCxWT), we observed following advantages of Daubechies Complex Wavelet transform (DaubCxWT) for object tracking in video sequences:

i.) The linear phase property of Daubechies Complex Wavelet transform (DaubCxWT) keeps the shape of the signal which is very important in object tracking applications and therefore it reduces the false tracks of the object.

ii) The symmetric property of complex-valued filter [22] makes it easy to handle the boundary problems for the finite length signals.

iii) Daubechies Complex Wavelet transform (DaubCxWT) can act as local edge detector. The imaginary part of the complex wavelet coefficients represents strong edges whereas the real components represent only some of the stronger edges. This helps in preserving the edges and implementation of edge sensitive tracking models.

iv) Daubechies Complex Wavelet Transform (DaubCxWT) has reduced shift-sensitivity. A transform is shift-sensitive if an input signal shift causes an unpredictable change in the transform coefficients. As the tracker moves through the frames of the video, the reconstruction using real valued Discrete Wavelet transform (DWT) coefficients changes drastically, while the complex wavelet transform reconstructs all local shifts and orientation in the same manner. Therefore, use of Daubechies Complex Wavelet transform (DaubCxWT) quickly and accurately finds boundaries of object in next frames.

4. THE PROPOSED OBJECT TRACKING ALGORITHM

A video sequence contains a series of frames. Each frame can be considered as an image. If the algorithm can track moving object between two frames then it will be able to track object in video sequence. In the proposed algorithm it is assumed that the frame rate is adequate and the size of the object should not change between adjacent frames. Complete algorithm is given as below -

Step 1: If frame_number = 1;

We draw a square bounding_box around the object with centroid (c1, c2) and compute the energy of Daubechies Complex Wavelet coefficients corresponding to the object, say Energy as

$$\text{Energy} = \sum_{(i,j)\in \text{bounding\_box}} \left|\text{wcoeff}_{i,j}\right|^2$$

where wcoeffi,j are the Daubechies complex wavelet coefficients at (i, j)th point.

Step 2: for frame_number = 2 to end_frame do
Search_region=64 (in pixels)
for i = -search_region to + search_region do
for j = -search_region to + search_region do
c1_new = c1+i; c2_new = c2+j;
make a bounding_box with centroid (c1_new, c2_new)
compute the difference of energy of the wavelet coefficients of bounding_box, with Energy, say $D_{i,j}$
end
end
find minimum of $\{D_{i,j}\}$ and its index, say (index_x, index_y)
c1 = c1+index_x; c2 = c2+index_y
update the bounding_box in the current frame with centroid (c1,c2)and energy of bounding_box, Energy as

$$\text{Energy} = \sum_{(i,j)\in bounding\_box} \left|wcoeff_{i,j}\right|^2$$

end

5. EXPERIMENTS AND RESULTS

In this section we show the experimental results of the proposed algorithm. We implemented tracking algorithm described in section 4 on various video clips. For two representative video clips of frame size 288 by 352 and 240 by 360 respectively, the results are shown:

Experiment#1:

The tracking algorithm is applied in the 'stuart.avi' video clip of frame size 288 by 352 and the tracking results are observed on various consecutive frames. The centroid of the object window at each frame is computed and recorded which is shown in the corresponding frames. The tracking results for this clip are shown in Fig. 2.

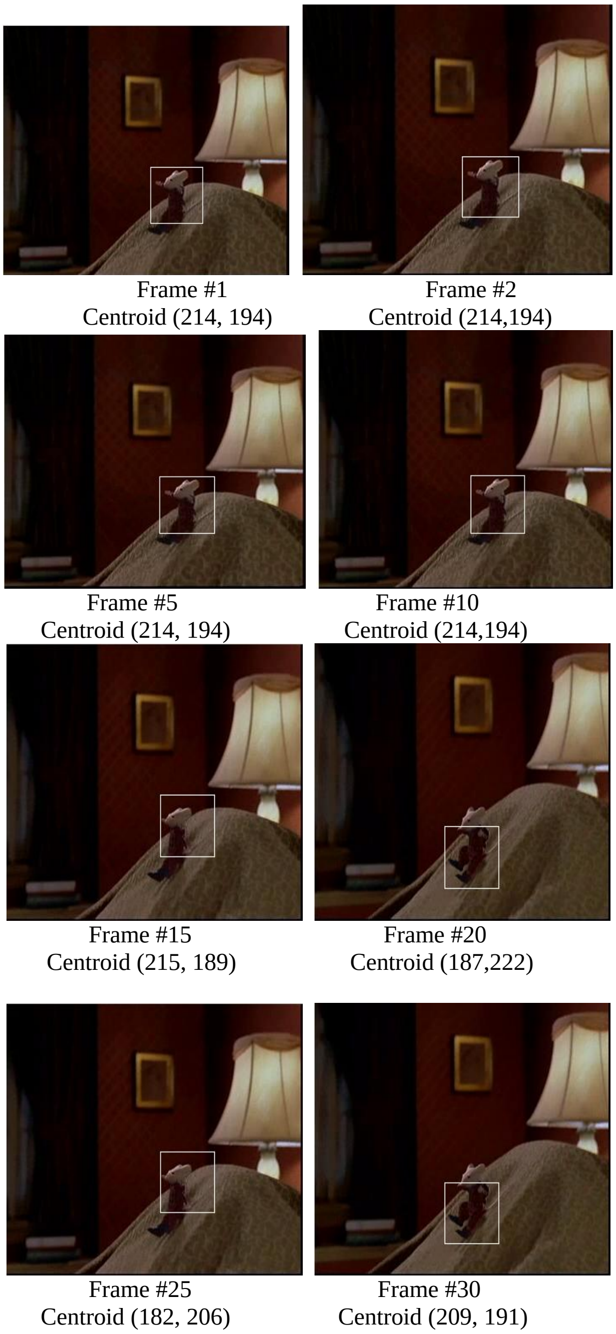


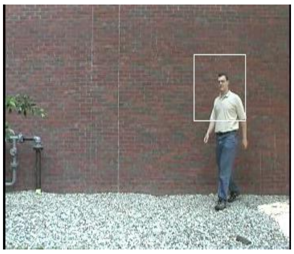
Fig. 2: Tracking of Object in the stuart video clip

Experiment#2

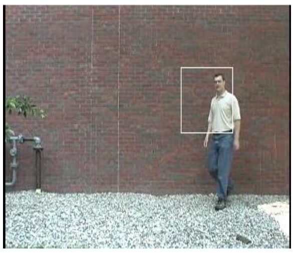
The proposed tracking algorithm is applied in the 'Sample.avi' video clip of frame size 240 by 360 and the tracking results are observed on various consecutive frames. The centroid of the object window at each frame is computed and recorded which is shown in the corresponding frames. The tracking results for this clip are shown in Fig. 3.

Frame #1
Centroid (280, 100)

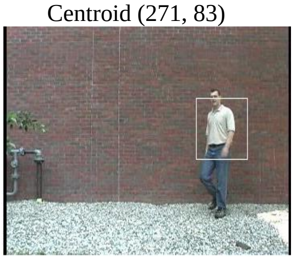
Frame #2
Centroid (275,87)



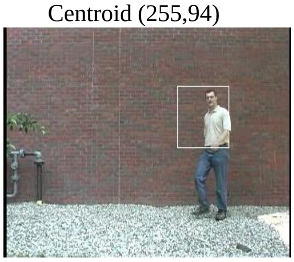
Frame #5
Centroid (271, 83)



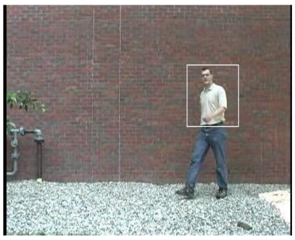
Frame #10
Centroid (255,94)



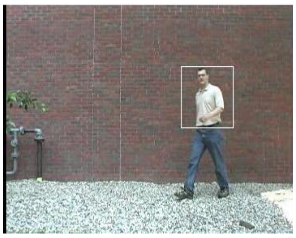
Frame #15
Centroid (274, 108)



Frame #20
Centroid (250,94)



Frame #25
Centroid (261, 95)



Frame #30
Centroid (252, 97)

Fig. 3: Tracking of Object in the Sample video clip

6. CONCLUSIONS

Moving object tracking is a key task in video monitoring applications. In this paper, we have presented a Daubechies Complex Wavelet transform (DaubCxWT) based tracking algorithm. The proposed algorithm is simple to implement. The preliminary experimental results demonstrate the effectiveness of the algorithm even in some complicated situations, such as ceased track etc. The approximate shift-invariance nature of the DaubCxWT helps in accurate tracking of object. Also, in the proposed method no other parameter except DaubCxWT is required makes the tracking efficient. The limitation of the algorithm is that the object size, shape should not change much between successive frames and object should move with approximate constant velocity between successive frames. The experimental results show that the proposed algorithm is capable to track the moving object in video sequences with stationary and varying background.

7. ACKNOWLEDGMENTS

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8. REFERENCES

[1] M. Sonka, V. Hlavac, and R. Boyle, *Image Processing, Analysis and Machine Vision*, Thomson Asia Pvt. Ltd., Singapore, 2001.

[2] A. K. Jain, *Fundamentals of Digital Image Processing*; Prentice Hall of India Pvt. Ltd., New Delhi, 2001.

[3] A. Yilmaz, K. Shafique, and M. Shah, "Tracking tracking in airbone forward looking imagery", Image and Vision Computing, vol. 21, no. 7, 2003, pp. 623-635.

[4] I W Selesnick, R G Baraniuk and N G Kingsbury: "The Dual-Tree Complex Wavelet Transform", IEEE Signal Processing Magazine, vol 22, no ,6 pp 123-151, Nov.2005.

[5] T. B. Moeslund, and E. Granum, "A survey of computer vision based human motion capture", Computer Vision and Image Understanding, vol. 81, no. 3, 2001, pp. 231-268.

[6] I. Haritaoglu, D. Harwood, and L. Davis, "W4: real-time surveillance of people and their activities", IEEE Transactions on Pattern Analysis and Machine Intelligence, vol. 22, no. 8, 2000, pp. 809-830.

[7] O. Masoud and N. P. Papanikolopoulos, " A novel method for tracking and counting pedestrians in real-time using a single camera", IEEE Transactions on Vehicular Technology, vol. 50, no. 5, 2001, pp. 1267-1278.

[8] Om Prakash and Ashish Khare, "Tracking of Non-Rigid Object in Complex Wavelet Domain", Journal of Signal and Information Processing, vol. 2, 2011, pp. 105-111.

[9] M Aksela. Handwritten Character Recognition: A Palmtop Implementation and Adaptive Committee Experiments. Master's Thesis, Helsinki University of Technology, 2000.

[10] D. Wang, "Unsupervised Video segmentation based Watersheds and Temporal Tracking", IEEE Transactions on Circuits and Systems for Video Technology, vol. 8, no. 5, 1998, pp. 539-546.

[11] A. J. Lipton, H. Fujiyoshi, R. S. Patil, "Moving Target Classification and Tracking from Real-time Video", WACV '98. Proceedings, Fourth IEEE Workshop on applications of computer vision, 1998, pp. 8-14.

[12] D. Comaniciu, V. Ramesh and P. Meer, "Kernel-based object tracking", IEEE Transactions on Pattern Analysis and Machine Intelligence, vol. 25, no. 5, 2003, pp. 564-575.

[13] G. Strang, "Wavelets and dilations equations: A brief introduction", SIAM Review, vol. 31, no. 4, 1989, pp. 614-627.

[14] I. W. Selesnick, R. G. Baraniuk and N. Kingsbury, "The Dual-Tree Complex Wavelet Transform", IEEE Signal Processing Magazine, vol. 22, no.6, pp. 123-151, Nov.2005.

[15] R. A. Gopinath, "The Phaselet Transform – An Integral Redundancy Nearly Shift-invariant Wavelet Transform",

IEEE Trans. On Signal Processing, vol. 51, no. 7, 2003, pp. 1792-1805.

[16] N. Kingsbury, “Complex Wavelet for Shift Invariant Analysis and Filtering of Signals”, Journal of applied and Computational Harmonic Analysis, 10(3), pp.234-253, 2001

[17] M. Khare, T. Patnaik and A. Khare, "Dual tree complex wavelet transform based video object tracking", in proc. of International Conference ICT 2010, in LNCS (Communications in Computer and Information Science), vol. 101, no. 2, pp. 281-286, 2010

[18] F. C. A. Fernandes, R. L. C. Spaendonck, and C. S. Burrus, “A new framework for complex wavelet transform”, IEEE Transactions on Signal Processing, vol. 51, no. 7, pp. 1825-1837, 2003.

[19] A.A. Bharath and J.Ng, “ A Steerable complex wavelet construction and its applications to image denoising”, IEEE Transactions on Image Processing, vol.14, no.7, pp.948-959, 2005.

[20] J. M. Lina and M. Mayrand, “Complex Daubechies Wavelets”, Applied and Computational Harmonic Analysis, vol. 2, pp. 219-229, 1995.

[21] I. Daubechies, “Ten Lectures on wavelets”, SIAM, 1992.

[22] A. Khare and U. S. Tiwary, “Symmetric Daubechies Complex Wavelet Transform and its applications to Denoising and Deblurring”, WSEAS, Transactions on Signal Processing , vol. 2, no. 5, pp. 738-745, May 2006.