Target Tracking System based on Block Compressive Sensing

Divya R. Bora
Department of Information Technology
VES Institute of Technology
Chembur, Mumbai

Smita Jangale
Associate Professor
Department of Information Technology
VES Institute of Technology
Chembur, Mumbai

Abstract:- The aim of the surveillance system is to detect and track the target object. For surveillance application in sensitive areas, there is need to have an unmanned tracking system by using wireless visual sensor network. This paper proposes a target tracking system based on block compressive sensing that utilizes minimum amount of data for processing. It also aims at improving quality of frame reconstruction and tracking of the moving object by minimizing the computational complexities in real time scenario. The use of Kalman filter technique for tracking improves the performance of the system.

Keywords:- *Block Compressive Sensing, Target Tracking, Kalman Filter.*

I. INTRODUCTION

In this paper, the detailed methodology of target tracking using Kalman Filter Technique is presented. The objective of the paper is to track a target or an object effectively even if less details of the object are available for tracking. This is achieved by the application of the method of block compressive sensing [1][8][9] technique for compression and decompression of video frames.

Object detection and pattern recognition are important topics in the field of automatic analysis of images and videos. Video surveillance systems are under rapid development due to their application in safety and security, traffic monitoring, surveilling public premises etc. The challenges in designing these systems are tracking the target with the minimal signal with higher accuracy and even predict the location of interested object in absence of object in few video frames [2][3][4].

The goal of this paper is to formulate a target tracking system using compressed signals. Block compressive sensing technique is used in this paper in order to compress the video frames. This system is simulated using MATLAB and required input videos are retrieved from the standard video database CAVIAR [5]. The tracking results and results after application of digital communication modulation technique are presented.

II. TARGET TRACKING SYSTEM

The system of target tracking using Kalman Filter adopted in this paper is presented in Fig. 1. The background subtraction step involves subtraction of background frame from the given input frame. Before the step of block compressive sensing, the object detected frame is divided into blocks. In the step of block compressive sensing, every block with the assigned index of detected object frame is compressed so that it can be transferred over communication media. For communication between transmitter node and receiver node, different types of shift keying techniques like BPSK, QPSK, DPSK etc. are employed. At the receiver side, the received compressed blocks are reconstructed to form frames and fed to the Kalman filter. The Kalman filter predicts the location of object if not present in consecutive frames and updates the location of the object if object is present in the input reconstructed frame.

A part of the system, Background Subtraction and Block compressive sensing, has already been explained and respective results are published in literature [10]. For sake of completion, these parts are described in this paper briefly.

A. Background Subtraction

The foreground of an image is extracted in background subtraction for further processing. It aims at catching changes in image sequences. The principle is that if a reference background image is known, the image can be compared with the frame in which objects are to be detected [2]. In the adopted system, Background subtraction is carried out using Gaussian Mixture Model.

B. Block Compressive Sensing (BCS)

Compressive Sensing (CS) captures and represents compressible signals at a rate remarkably below the Nyquist rate. This eliminates the demand of acquiring a large number of samples. This method uses non-adaptive linear projections which preserve the structure of the signal. The signal is then reconstructed from these non-adaptive linear projections using an optimization process [3]. Block compressing sensing technique is employed in this system. The detailed algorithm is illustrated in the literature [10].

C. Digital Communication System

The circulation of information from the sender to the recipient through some medium is called as communication. It helps us to share information with receiver. Communication occurs through various routes and channels and with the help of a medium. Digital communication is one of the medium. At first, the source output is converted into a binary sequence and then that binary sequence is converted into a form acceptable for transmission over particular physical media such as cable, twisted wire pair, electromagnetic radiation through space or optical fiber.

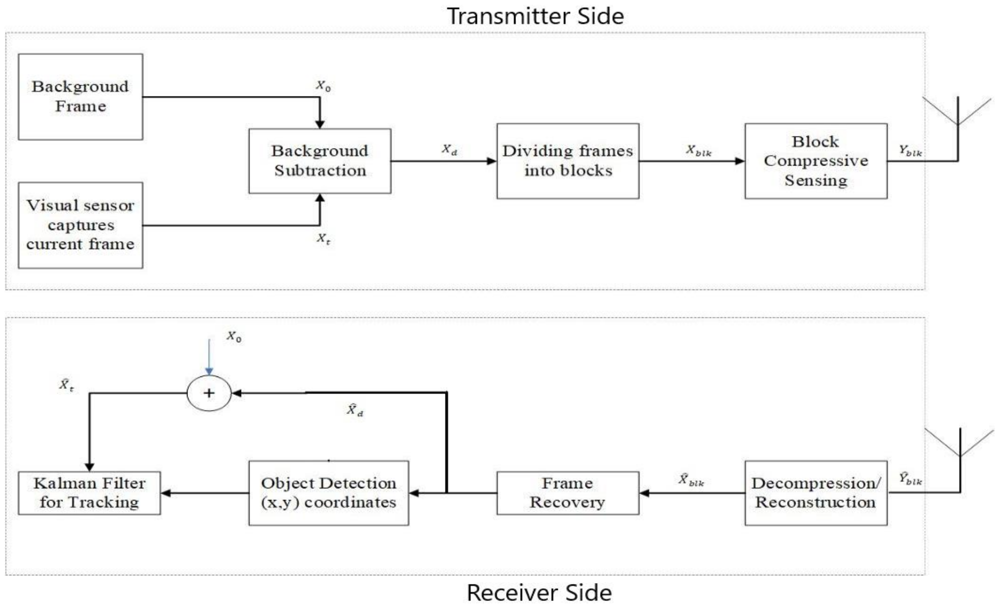


Fig 1:- Block Diagram of proposed target tracking system

The information to be transmitted is modulated to a higher frequency, called as the carrier frequency. The data to be sent is transformed to an electromagnetic wave which will propagate through space to its destination. This type of modulation is carried out using the techniques Amplitude Shift Keying (ASK), Frequency Shift Keying (FSK) and Phase Shift Keying (PSK).

D. Phase Shift Keying

In phase shift keying (PSK) the phase of the carrier sinewave at the transmitter's output is switched between 0° and 180° as per the data to be transmitted. The modulator uses sinewave carrier as its carrier input. The digital signal is applied to the modulation input for PSK generation which is bipolar in nature, that is it has equal positive and negative voltage levels.

When the modulation input is positive, the modulator multiplies the carrier input by this constant level, so that the output signal of modulator becomes a sinewave which is in phase with the carrier input.

When the input for modulation is negative, the modulator multiplies the carrier input by this constant level, so that the output signal of modulator becomes a sinewave of 180º out of phase with the carrier input.

At the Receiver, the PSK demodulator decodes the frequency shift-keyed signal by means of a squaring loop detector.

Different types of PSK techniques are as follows:

- Binary Phase-Shift Keying (BPSK)
- Quadrature Phase Shift Keying (QPSK)
- Differential Phase Shift Keying (DPSK)

A. Target Tracking using Kalman Filter

Kalman filter is used where the uncertain information about some dynamic system is available, and there is need to make a speculation about what the system is going to do next. Kalman filters are most suitable for systems which are changing repeatedly. They have an upper hand as they are light on memory and they are very speedy, making them ideal for real time problems and embedded systems.

The algorithm is iterative. It can run in real time. It uses only the present input measurements and the previously calculated state and its uncertainty matrix. There is no need of additional past information.

The Kalman filter operates by propagating the mean and covariance of the state through time. The mean of the state is Kalman filter estimate of the state while the covariance of the state is covariance of Kalman filter state estimate [6].

Consider a linear discrete-time system as follows [12]

$$x_k = F_{K-1}X_{K-1} + G_{k-1}u_{k-1} + w_{k-1} \quad (1)$$

$$y_k = H_k x_k + v_k \quad (2)$$

$$w_k \sim (0, Q_k) \quad (3)$$

$$v_k \sim (0, R_k) \quad (4)$$

$$E(v_k w_k^T) = 0 \quad (5)$$

The aim is to estimate the state x_k based on system dynamics and noisy measurement y_k.

To start estimation process with x_0^+, the best estimate of initial state x_0. We have from system dynamics how mean propagates with time.

$$\hat{x}_k = F_{k-1}\hat{x}_{k-1} + G_{k-1}u_{k-1} \quad (6)$$

To compute the time update equation for P, covariance of state estimation error, we start with P_0^+ which is covariance of initial estimate x_0. If initial state is known perfectly, $P_0^+ = 0$ and if there is no idea $P_0^+ = \infty$.

Using error propagation, the time update equation for P can be written as

$$P_k = F_{k-1} P_{k-1}^+ F_{k-1}^T + Q_{k-1} \quad (7)$$

After time update equation for x and P, we require measurement update equations for the same i.e., how estimate changes after measurement is made. From recursive Bayesian state estimation, we have the following available equations.

$$K_k = P_k^- H_k^T (H_k P_k^- H_k^T + R_k)^{-1} \quad (8)$$
$$\hat{x}_k^+ = \hat{x}_k^- + K_k (y_k - H_k \hat{x}_k^-) \quad (9)$$
$$P_k^+ = (I - K_k H_k) P_k^- (I - K_k H_k)^T + K_k R_k K_k^T \quad (10)$$

Where K_k is the Kalman gain, $\hat{x}_k^+$ is the estimated state and P_k^+ are corresponding covariances.

The reconstructed frame whose coordinates are obtained is the measurement input y_k to the Kalman filter. As, the reconstructed frame contains only the object, the background frame is later attached to the reconstructed frame to get the complete frame. This complete frame serves as prior input x_k for Kalman filter. Then the approximation of the location of the target using the coordinates of the reconstructed frame is done by Kalman Filter.

III. RESULTS

The system is simulated using MATLAB 2018a on a laptop with i3 processor CPU 2.10GHz and 4 GB memory. The videos used for simulating the system are retrieved from the standard video database CAVIAR [5] and are listed in Table I.

Sr. No.	Video Name	Video Description
1	sv1	Walk By Shop 1 front
2	sv2	Meet Walk Together 1
3	sv3	Two Leave Shop 2 front

Table 1:- List of videos retrieved from video database CAVIAR [5] with description

All the videos are converted in .avi format. To evaluate the system's performance parameters like Peak-signal-to-noise ratio (PSNR), Weighted-signal-to-noise ratio (WSNR), Mean square error (MSE) and Structural Similarity Index (SSIM) are measured after reconstruction of video frames. To analyze the performance of the system in real time scenario, the results of performance parameters are measured for different modulation techniques like BPSK, QPSK and DPSK. MSE is error between original and reconstructed frame while SSIM shows the similarity between the real and reconstructed frame. PSNR and WSNR values are calculated after reconstruction of frame. More importance is given to quality of the reconstructed image as quality of image after reconstruction will improve the reliability of target tracking.

The reconstruction of compressed frames are carried out using Smooth projected landweber with contourlet transform (SPLCT) [7][11]. Channel modelling is done using QPSK modulation technique and additive white Gaussian noise (AWGN) channel. The energy per bit to noise power spectral density ratio (Eb/No) is considered as 40. The presented work aims at reconstruction of frames from reduced number of measurements (M) with acceptable image quality. The main objective of using CS is to minimize the amount of measurements required for reconstructing the image. As published in the literature [10],

Video Name	PSNR (in dB)	WSNR (in dB)	MSE	SSIM
sv1	41.96854	84.76556	4.10963	0.96921
sv2	50.87166	75.59371	0.45751	0.99329
sv3	40.38206	71.57096	5.95082	0.99292

Table 2:- Performance parameters of reconstructed videos subject to QPSK channel modelling and block size N=64

The MSE is nearly equal to 1 and PSNR is above 40 for block size 64. Thus, the results of PSNR, WSNR, MSE and SSIM with subject to QPSK modulation technique are presented in the Table II by using block size N=64.

a. Original Feed

b. Tracking of Object

Fig 2:- Detection and Tracking of video sv1

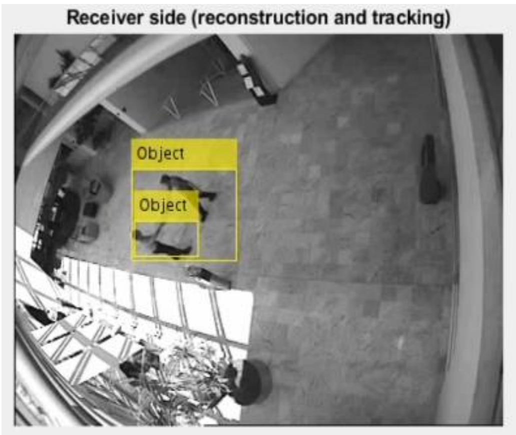
The PSNR and WSNR values for every video are above 40dB and 70dB respectively which confirms the better image quality. SSIM values are nearly equal to 1 which implies that similarity between the original image and reconstructed image is more than 99%. As presented results of MSE are subject to QPSK channel modelling, MSE is not nearer to 1 but are acceptable as other performance parameters ensures the better image quality.

To measure the efficiency of tracking, video frames' MSE is used as performance parameter. Fig. 2 to Fig. 4 represents the random time snapshots of original feed and tracking of detected object for all the videos listed in Table I. From Fig. 3, it can be deduced that the system is capable of tracking more than one object. After, channel modelling, the results of MSE of tracking are presented in Table III. These MSE values indicates that the tracking of object closely matches with the original feed. Hence, the MSE results justify that the Kalman filter accurately tracks the object's location.

Video Name	MSE
sv1	3.933536
sv2	3.903977
sv3	1.889715

Table 3:- MSE of target tracking system

a. Original Feed



b. Tracking of Object
Fig 3:- Detection and Tracking of video sv2

a. Original Feed

b. Tracking of Object
Fig 4:- Detection and Tracking of video sv3

The results presented above demonstrates the reliability of the system in terms of requirement of amount of data for processing. It also reflects the reliability on the quality of image after reconstruction and object tracking.

IV. CONCLUSION AND FUTURE WORK

A target tracking system based on block compressive sensing has been presented in this paper. The focus is mainly to propose a system which requires minimum amount of measurements for processing. After channel modulation, the results that have been presented in this paper proves that the target tracking system works best in noisy environment and also produces reconstructed frames of better quality. For tracking the target, the Kalman filter provides good results. These results show that the error between the original video at the transmitter side and the reconstructed and tracked video at the receiver side is within the acceptable range. In future work, for the tracking of multiple objects effectively, the target tracking system needs to be improved. As this system has been implemented on the videos captured using stationary camera, it can be implemented using moving cameras as well.

REFERENCES

[1]. D. Donoho, "Compressed sensing," IEEE Transactions on Information Theory, vol. 52, no. 4, pp. 1289–1306, 2006.
[2]. Md. Zakir Hussain Mrs. Ayesha Naaz and Mohd Nayeem Uddin. "Moving Object Detection Based on Background Subtraction Frame Differencing Technique". International Journal of Advanced Research in Computer and Communication Engineering Vol. 5 (May 2016). doi:10.17148/IJARCCE.2016.55200
[3]. S. Fayed, S. M.youssef, A. El-Helw, M. Patwary, and M. Moniri, "Adaptive compressive sensing for target tracking within wireless visual sensor networks-based surveillance applications," Multimedia Tools and Applications, vol. 75, no. 11, pp. 6347–6371, 2015.
[4]. S. Nandhini and S. Radha, "Compressed sensing based object detection and tracking system using measurement selection process for wireless visual sensor networks," 2016 International Conference on Wireless Communications, Signal Processing and Networking (WiSPNET), 2016.
[5]. Caviar datasets (2001) Dataset: EC Funded CAVIAR project/IST 200137540, http://homepages.inf.ed.ac.uk/rbf/CAVIAR/
[6]. R. E. Kalman. "A New Approach to Linear Filtering and Prediction Problems". Journal of Basic Engineering 82.1 (1960), p. 35. doi:10.1115/1.36625520.
[7]. R. Shoitan, Z. Nossair, I. Isamil, and A. Tobal, "Hybrid wavelet measurement matrxices for improving compressive imaging," Signal, Image and Video Processing, vol. 11, no. 1, pp. 65–72, 2016.
[8]. V. Cevher, A. Sankaranarayanan, M. F. Duarte, D. Reddy, R. G. Baraniuk, and R. Chellappa, "Compressive Sensing for Background Subtraction," Lecture Notes in Computer Science Computer Vision – ECCV 2008, pp. 155–168, 2008.
[9]. M. S. Asif, F. Fernandes, and J. Romberg, "Low-complexity video compression and compressive sensing," 2013 Asilomar Conference on Signals, Systems and Computers, 2013.
[10]. Divya R. Bora, Mrs. Smita Jangale, "Block Compressed Sensing of Videos: A Case Study", IOSR Journal of Computer Engineering (IOSR-JCE), Volume 20, Issue 3, Ver. IV (May. - June. 2018), PP 49-53
[11]. Hanxu YOU, Jie ZHU, "Image Reconstruction based on Block- based Compressive Sensing," Australasian Computer Science Conference (ACSC), 2015.
[12]. D. Simon. "Optimal State Estimation: Kalman, H infinity and nonlinear approaches", John Wiley & Sons, Inc., 2006