Int. J. Electron. Commun. (AEÜ) 72 (2017) 216–224

Contents lists available at ScienceDirect

International Journal of Electronics and Communications (AEÜ)

journal homepage: www.elsevier.com/locate/aeue

Regular paper

Compressed sensing based foreground detection vector for object detection in Wireless Visual Sensor Networks

Aasha Nandhini Sukumaran *, Radha Sankararajan [1], Manimozhi Swaminathan

Department of ECE, SSN College of Engineering, Kalavakkam, India

ARTICLE INFO

Article history:
Received 23 December 2015
Accepted 24 December 2016

Keywords:
Compressive sensing
Background subtraction
Foreground detection vector
Transmission energy
WVSN

ABSTRACT

Compressed sensing based background subtraction (CS-BS) plays a significant role in video surveillance applications in Wireless Visual Sensor Networks. This paper implements a CS-BS framework with a novel thresholding strategy to detect the anomaly with fewer measurements in a secured indoor environment. In CS-BS, the CS is performed on the difference frame which is sparse, thereby reducing energy, memory and bandwidth. In this framework, a foreground threshold is proposed based on the measurement matrix to extract the moving object from a scene. The performance of the CS-BS framework with FDV is evaluated using metrics such as detection accuracy, energy complexity, percentage of reduction in samples and measurements. The proposed CS-BS framework with hybrid matrix based FDV achieves around 95.8% reduction of measurements and 91% reduction of samples.

1. Introduction

Wireless visual Sensor Network (WVSN) consists of few camera motes and many relay nodes to be deployed in the area of interest to monitor the presence of an intruder and transmit the information to the monitoring site. Nowadays WVSN is used for variety of surveillance applications like traffic monitoring, monitoring of elderly people, detecting anomalies in highly secured area etc. In case of surveillance applications, the camera motes capture the video and transmit it via relay nodes to the monitoring site. When there is no scene change, it is unnecessary to transmit the entire video in a resource constraint environment like WVSN. Hence an efficient signal acquisition technique called as compressed sensing (CS) was adopted to acquire and transmit only necessary measurements ($M << N$) rather than N samples [1]. CS assures that the signal can be perfectly reconstructed with fewer measurements using a perfect recovery algorithm. The minimum number of measurements (M) relies on the sparsity level (K) of the signal (i.e. the number of non-zero elements in the signal) which is calculated to be $M \geqslant c\log(N/K)$ [1].

The source node with camera capability captures the video and processes it using CS to obtain the measurements. These measurements are transmitted to the receiver side where the video is reconstructed using the recovery algorithm. To reduce the transmission energy of the source node background subtraction technique can be adopted which extracts and transmits the foreground measurements. Traditional Background subtraction algorithm first computes the difference between the frames and then applies a threshold to extract the foreground [2].

CS based background subtraction (CS-BS) is carried out on the differenced frame of the video sequence [3]. Since static camera is considered in this work, the first frame is taken as the reference frame from which the current frames are subtracted to obtain the difference frames. The CS is applied to the difference frame which by itself is sparse and the resulting compressive measurements undergo a thresholding process to extract the foreground measurements. The background subtraction method along with an efficient thresholding process plays an important role in detecting the object accurately.

This paper mainly addresses the energy complexity incurred during the video transmission by proposing an efficient foreground detection vector (FDV) for CS-BS framework which will efficiently extract the moving objects in the video sequence with less energy. An indoor video sequence is captured in real time with a single moving object and multiple moving objects for implementation. Also, the proposed work is tested on videos taken from the database for both single and multiple object detection [17,18]. In this work the first frame is considered as the reference frame hence no background modeling techniques are required to obtain the background frame thereby reducing the computational complexity of the framework.

* Corresponding author.
E-mail addresses: aashanandhinis@ssn.edu.in (A.N. Sukumaran), radhas@ssn.edu.in (R. Sankararajan), manimozhi1313cs@ece.ssn.edu.in (M. Swaminathan).
[1] IEEE Member.

http://dx.doi.org/10.1016/j.aeue.2016.12.020
1434-8411/

The key idea in this work is to derive FDV based on the CS measurement matrix and design the threshold using FDV. This threshold is called as foreground threshold which will be applied to the differenced measurements to extract the foreground measurements. These foreground measurements will be transmitted for reconstruction and orthogonal matching pursuit (OMP) algorithm is used to reconstruct the moving object. The proposed CS-BS algorithm is implemented for both single object and multiple objects scenarios. The CS-BS framework with FDV was evaluated in terms of detection accuracy, transmission energy, percentage of reduction in samples and measurements. The FDV was derived based on a simple, memory and energy efficient hybrid matrix and the performance was compared with the well-known Gaussian matrix.

The rest of the paper is organized as follows. Section 2 provides a brief survey of related works. Section 3 provides in detail about the proposed work. This section also explains in detail about the designing of threshold using FDV whereas Section 4 discusses the simulation results and performance evaluation in detail; finally, Section 5 gives the conclusions and proposed future work.

2. Related works

A brief survey related to CS process and CS-BS framework for different applications is provided in this section.

Cevher et al. [3] adopted CS to directly recover the background subtracted images for applications in communication constrained computer vision problems. CS is applied to recover object silhouettes when the subtracted images are sparse in spatial domain. The performance of the proposed algorithm is tested on videos captured using single-pixel camera. This approach can also be used for 2D tracking and 3D shape reconstruction application using the compressive measurements obtained from the data captured by multiple conventional cameras.

Yi and Liang [4], proposed an algorithm based on running average background modeling and temporal difference method. Foreground image was extracted with the help of running average method that dynamically updates the background image. The temporal difference method was used to obtain the difference image. The common information was obtained by combing the foreground image and the difference image. The proposed algorithm was tested experimentally and the results were compared with the traditional method. It is observed that the proposed technique outperforms the traditional technique.

Manimozhi et al. [5] has adopted CS based background subtraction for object detection in Wireless sensor networks (WSN). Binary Permuted Block Diagonal matrix was used as the measurement matrix to reduce the complexity and for easier hardware implementation. Discrete wavelet transforms (DWT) and discrete cosine transform (DCT) based object detection framework was implemented using fixed and variable threshold. The object detection framework was evaluated using metrics such as precision, recall, accuracy and F-Score. From the results it is observed that DWT based object detection framework with variable threshold yields an accuracy of 99% and precision of 0.9. However, the impact of the framework on WSN was not evaluated.

Cao et al. [6], proposed a real time vehicle detection system using CS based background subtraction technique. The authors present an algorithm to model and update the background depending on the scene changes. A differential threshold was used to extract the foreground objects from the video sequence. OMP algorithm was used to reconstruct the object from the foreground measurements. The experimental results show that the proposed system yields higher precision detection with less complexity compared to traditional systems.

In [7], the authors present the binDCT algorithm, which is a fast approximation of the Discrete Cosine Transform, and its efficient VLSI architectures for hardware implementations. BinDCT is efficient to meet the real time constraints in the embedded system. The authors have also proposed two architectures based on real time embedded system. These architectures address both high performance and low complexity applications for which the algorithm is decomposed into simple matrices and then map them into multi-stage pipeline architecture.

Hong et al. [8] proposed a method to extract moving objects from the background in a surveillance video. Low rank and sparse decomposition of the matrix was used to reconstruct the video acquired by compressive measurements. The low rank matrix was used to identify the background, and the sparse matrix represents any moving objects present in the video. The method was experimentally validated and the results showed that very few measurements were needed to extract moving objects in the surveillance video. Hence the method performs well with less complexity.

Cai and Lie [9], introduces the OMP algorithm for recovery of a high-dimensional sparse signal based on a small number of noisy linear measurements. OMP is an iterative greedy algorithm that selects at each step the column that is most correlated with the current residual. From the implementation, it is observed that OMP is a fast and less expensive algorithm.

Zhang et al. [10], proposed a three frame subtraction process in which the target is extracted first and then processed using mathematical morphology method. Three frame subtraction methods are efficient as it can effectively detect the moving object as well as reduce noise significantly. The experimental results show higher real-time performance and detection accuracy with less number of computations.

Radhe et.al [11] proposed a three parameter based running average model for updating the changes in the scene. Background subtraction with a differential threshold operation was carried out for detecting the moving objects in the video. Detection of the moving objects completely depends on the background model and hence the proposed model proves to be efficient. The authors have also compared the proposed method with the state of the art techniques and from the results it is proved that the proposed method achieves better detection accuracy.

Monnet et al. [12], proposed an on-line auto-regressive method to capture and predict the behavior of dynamic scenes. The authors have addressed the problem of dynamic scenes and have introduced a new metric for performance analysis based on state driven comparison between the predicted and actual frame. The proposed method could adapt with global and local illumination changes, weather changes, changes of the natural scene, etc. The proposed on-line adaptation of the prediction method proves to be efficient as it reduces the complexity.

Matsuyama et al. [13] proposed an efficient background subtraction method for non-stationary video sequence. The proposed background subtraction addresses the illumination changes and local image fluctuations. To address the illumination changes and local image fluctuations they have proposed a correlation measure (SMNVD) and a two dimensional histogram (TNVDCM). They have tested the algorithm in real time and the results demonstrate the robustness and effectiveness of the algorithm.

From the literature, CS-BS framework was adopted for object detection method to detect objects with less energy complexity in WSN without compromising the detection accuracy. Moreover, OMP was used for reconstructing the object as it is fast and less complex algorithm.

3. Proposed FDV based thresholding strategy

A novel FDV based thresholding strategy for CS-BS framework is proposed to detect the moving objects from a stationary background indoor video sequence. The key idea in this framework is