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A modified listless strip based SPIHT for wireless multimedia sensor networks☆

Hanaa ZainEldin*, Mostafa A. Elhosseini, Hesham A. Ali

Faculty of Engineering, Computer Engineering and Control Systems Department, Mansoura University, PO Box 35516, Egypt

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A B S T R A C T

Set Partitioning In Hierarchical Tree (SPIHT) is considered one of the most important algorithms for reducing the size of the vision data collected by the sensor node within wireless multimedia sensor network (WMSN). The traditional SPIHT algorithm suffers from image coders complexity due to large memory requirement. This is an essential problem for the implementation on limited resource environments such as WMSN. The main objective of this paper is to introduce a listless pipelined strip based SPIHT for WMSN to reduce system complexity and minimize processing time and memory usage. The proposed algorithm is implemented using discrete wavelet transform (DWT) lifting-based instead of DWT convolution-based filter. The experimental results show the superiority of the proposed algorithm in terms of peak signal-to-noise ratio (PSNR) which reaches 1 dB for all bit rates. In addition, the memory requirement is reduced to 71% with 27% of energy saving.

1. Introduction

Wireless sensor networks (WSN) are networks that have small devices with collecting information capabilities from the physical environment. The main function of WSN is to process extracted data and transmit it to remote locations. Recently, many new applications are needed to capture multimedia content from the environment. Therefore, the development of wireless multimedia sensor network (WMSN) becomes mandatory. Unlike classical wired networks and WSN, the WMSN differs from its predecessor scalar network in the following points: the nature and size of data being transmitted, the important memory resources, as well as the power consumed per each node for processing and transmission [1]. Table 1 shows the differences between scalar WSN and WMSN.

Recently, WMSN has gained a wide attention and has been used for many applications such as military, traffic surveillance, security monitoring, health care, machine failure diagnoses, chemical and biological detection, plant monitoring, agriculture, binary document image compression [2] and transportation [3].

The layout of a typical WMSN consists of a large number of sensor nodes deployed in a region of interest and one or more base station or sink. Typically, each node in the WMSN has the ability to acquire process, compress and transmit captured frames to the base station which acts as the main network controller or coordinator. In this situation, its primary function is to coordinate the functions of the nodes. This coordinator also collects information gathered by the nodes to be stored or further processed. In fact, the most popular media considered in the WMSN are audio [4], video and image. Further, images and different frames contain large amount of redundancy that occupies a massive storage space and minimizes transmission bandwidth. Consequently, the

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* Corresponding author. Tel. +20 1017284935.
E-mail address: eng.hanaa2011@gmail.com (H. ZainEldin).

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Table 1
Comparison between scalar WSN, and WMSN.

Features	Scalar WSN	WMSN
Memory	Limited	Limited
Processing capability	Low	Low
Complexity	Low	High
Power consumption	High	Highest
Speed	Low	Lowest

most effective solution to minimize memory storage, and reduce power consumption due to processing and transmission via WMSN is image compression [5,6].

Due to having compact output bit stream, low bit rate with higher compression ratio, and using a subset partitioning scheme in the sorting pass, Set Partitioning in Hierarchical Tree (SPIHT) [7] is the most effective compression technique for limited resources environment. On the other hand, SPIHT has several coding drawbacks [8] as follows: (1) The use of three lists to store coordinates of individual coefficients will increase amount of storage, (2) The complexity and the implementation cost of the coder due to memory management required for adding or removing nodes from lists during sorting pass, significantly increases along with the processing time. (3) A full wavelet transformed image needs to be stored in memory as all zero trees are scanned in each pass, which will increase memory required with image resolution. (4) A Large memory is needed especially for the on-board image coders due to the increased hardware cost and complexity of image coders. (5) SPIHT applies the Mallat algorithm to realize fast wavelet transform, which causes bad real time performance [9].

In order to overcome these drawbacks, this paper presents an energy efficient compression scheme for WMSN by combining improved listless SPIHT with a pipelined strip based concept. This scheme minimizes processing time, memory usage and system complexity reduction. The modified algorithm uses:

1. A modified listless zero tree structure (LZT) based on SPIHT [10] with modified coding process.
2. A strip based image compression concept with the presented listless SPIHT.
3. A discrete wavelet transform (DWT) lifting based (Cohen-Daubechies-Feauveau wavelet (CDF) 9/7 [11]) instead of DWT convolution based filter [9,10].

All these features contribute in resolving some of previously mentioned SPIHT problems for WMSN. The listless SPIHT eliminates the use of lists that minimizes memory storage. Additionally, it requires a few bits to encode the same set of wavelet coefficients compared with classical SPIHT. Moreover, merging a sorting and refinement pass into only one single pass simplifies the coding algorithm. Also, there is no need for arithmetic coding with large memory requirement. Furthermore, there is no need to wait for full wavelet transform of the image using strip based concept. This is due to the ability to carry the coding out once a strip is fully buffered. Consequently, the processing time is reduced as a result of using the pipeline strip-based concept. The pipelined mode helps remote sensing images that are acquired continuously from sensors to be compressed. This will help efficient utilization of B.W in real time without full image buffering.

The implementation is conducted using a Raspberry Pi board with a Raspberry Pi hardware package in MATLAB 2014. Finally, comparative results confirm the supremacy of our approach over competing schemes in terms of power consumption, memory usage and system complexity.

The paper is organized as follows: Section 2 surveys image compression algorithms for WMSN and related work. The proposed work is discussed in Section 3 in detail. The results, discussion and analysis are covered in Section 4. Finally, conclusion will be drawn in section 5.

2. Background and related work

The compression techniques as shown in Fig. 1 can be classified into two main categories, namely; lossy and lossless compression techniques [12]. The choice of compression technique depends on the operating platform. However, limited platform resources such as WMSN requires compression techniques with less computation complexity, lower power consumption and acceptable image quality. The lossless compression method is not preferred for image transfer over WMSN. Therefore, lossy compression techniques are highly encouraged for WMSN [6,8].

2.1. Lifting based DWT

The convolution DWT based on Mallat filter requires a large memory requirement with a large number of arithmetic operations which increase the computational complexity. To overcome these problems, the lifting based DWT can be used, it has the following advantages over convolution DWT: (1) faster wavelet transform implementation, this is due to the use of half number of computations compared to traditional convolution based DWT, (2) the lifting based DWT allows a fully in-place calculation of wavelet transform with no extra memory requirement, (3) the computation complexity is reduced because it implements reversible integer wavelet transforms and, (4) the lifting scheme (L.S) provides inverse transform from the same forward structure.