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A low-overhead adaptive image compression technique for energy-constrained WMSN☆

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ABSTRACT

Advancement of low-cost hardware capable of processing multimedia data coupled with efficient short range radio communication has led to the development of Wireless multimedia sensor network (WMSN). We consider post-disaster situation analysis application where the nodes in a WMSN capture disaster images from the affected area. Energy is one of the scarcest resources for such a network especially for disaster application where power supply for charging the battery of a node is nearly impossible. In this paper we exploit such facts and propose an energy saving multimedia (image) data processing scheme for its subsequent transmission over energy-constrained WMSN. Unlike conventional image processing, it saves energy by reducing the data to be transmitted at the cost of segmentation-less adaptive compression. Finally, the comparative performance of the scheme shows its dominance over all the competing schemes. Precisely, our scheme saves on an average 34% energy over all the competing schemes.

1. Introduction

The Wireless multimedia sensor network [1] are capable of processing multimedia data like image, video and audio streams. A wide range of applications has come up exploiting the multimedia capabilities of the nodes. The applications vary from continuous monitoring application (e.g. post-disaster situation analysis) to event driven application (e.g. forest fire detection). In this work we consider the application post-disaster situation analysis through capturing images of the affected area. In such an application, it is essential to collect visual information of the affected areas through the capturing of images of the same by the nodes of the network and transmitting the data wirelessly through multiple hops towards high end receiving node (e.g. sink) that reconstructs the captured images. With the help of such visual information severity of destruction may be assessed and accordingly rescue and relief operation may be planned.

Energy is one of the scarcest resources in such networks, especially it is scarce in transmitting multimedia data. For a sensor node, energy consumption during communication [2] is much more than that of data processing inside it. Moreover, in a disaster affected area due to unavailability of power supply, battery replacement of nodes is nearly impossible. Therefore, it is essential to save energy during transmission. Reducing the size of the images to be transmitted is one of the solutions for the same. If data can be minimized using a lightweight compression technique before transmission, then overall energy consumption can be reduced. Moreover, from viewers' perspective entire image may not be equally important. If the degree of compression is applied adaptively on a region of an image based on its importance within the image,

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then for a less important region higher compression ratio may be applied and that reduces the volume of transmitted data thereby ensures further energy saving. This approach requires dividing the image into several regions by appropriate image segmentation algorithm. However, applying segmentation algorithm directly in tiny mote incurs too much computational overhead that in turn draws energy of the battery of the mote. Therefore, alternative mechanisms for segmentation need to be devised to implement the said adaptive compression technique.

1.1. Motivation

Many works have been done so far in this area. Most of these works require either additional hardware or incur intensive computation or significant amount of memory. Neither of these solutions is affordable for the energy-starved, resource-constrained nodes in WMSN. Further, in some of the WMSN based applications (e.g. post disaster situation analysis) it is rather important to save energy of the nodes as much as possible while reconstruction quality may be compromised to a certain extent. This motivates us to explore a solution towards the development of such low-overhead, energy-saving image processing scheme without requiring additional hardware or memory for the said application while keeping reconstruction quality within an acceptable limit.

1.2. Contributions and organization

The main contributions of this paper are as follows:

- We introduce a new concept of rough segment based on conventional image segmentation and set theory. Based on the proposed rough segment, application oriented template with multilayered segment is generated off-line.
- Based on the above template image segmentation is performed.
- We propose an energy saving image compression approach where columns of the image pixel array are dropped adaptively for different segments of an image.
- The performance of the scheme is evaluated both through qualitative and quantitative analyses. A comprehensive comparative performance in terms of different overheads including energy overhead is also provided.

The paper is organized as follows. Literature survey is provided in Section 2. In Section 3, we introduce a new concept, rough segment along with its features and characteristics. Section 4 presents the rough segment based proposed offline template generation scheme for segmentation. A template based adaptive image compression scheme is presented in Section 5. In Section 6, the performance of the scheme is evaluated based on qualitative analysis and quantitative results. Finally, in Section 7, the paper is concluded with some mention about the future scope of the present work.

2. Literature review

Many works on multimedia (e.g. image) data processing have been reported so far that deal with a goal to reduce the energy for prolonging the lifetime of mote in WMSN. All these works have been conducted through different approaches for achieving this goal. Each type of the above schemes has their own strengths and limitations. Applying low-overhead image compression technique is one such type to achieve the said goal. As our proposed work is on image processing, in this section we review some of the existing works on image compression and segmentation techniques.

2.1. Compression

Image data compression techniques in digital cameras are broadly categorized into two, namely interpolation-first and compression-first. In interpolation-first method raw image data are interpolated into an RGB colour image followed by compression. A technique [3] of interpolation first method separates the “raw” sensor data into the three colour groups. Then the compression is performed on each group. Carrying-out interpolation before compression forces compression method to operate on a large number of pixels which increases transmission overhead also. On the other hand, in compression-first scheme, compression is done before interpolation. Two compression-first methods, ‘structure conversion’ and ‘structure separation’ methods are proposed in [4] based on the Bayer pattern and human visual system. The first step is to convert the CFA data from the RGB colour space to the YCbCr colour space. The next step is to separate the luminance and chrominance components. The chrominance component is then compressed with JPEG.

The above compression techniques used in digital camera may not be suitable for the camera equipped tiny wireless sensor node because the techniques are too computation-intensive for such a node with limited memory and processing ability. A work [5] presents a low-complexity hardware implementation of JPEG-like encoder for still image compression. The designed circuit is planned to place inside camera equipped sensor node to separate out the data processing task of the main processor. A Low energy image compression algorithm (LEICA) is proposed in [6] where the whole image is divided into Regions of interest (ROI) and tiles. ROI on which monitored objects appear are compressed at a low compression ratio, and then tiles with background regions are compressed at a high compression ratio. In another work [7] fractional wavelet filter in conjunction with a low-memory wavelet-based image coding system is employed. The fractional wavelet filter is a low-overhead computational method for the image wavelet transform. Further, a scheme [8] is proposed where the image

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