Chapter 4

Wavelet Filters Evaluation in Power Constrained Visual Sensor Networks

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ABSTRACT

While designing a wavelet-based coder (WBC) in the context of Visual Sensor Network (VSN), engineers and designers must respect their strict constraint on power consumption. This makes the selection of the appropriate wavelet, among many existing competitors, not an easy task. A set of wavelet filters are evaluated and the best of them are selected. The comparison is performed in terms of the quality of the reconstructed image at the base station and the power consumption of a visual sensor (VS) processing the wavelet. Image quality is measured objectively using PSNR and SSIM, and subjectively using the mean opinion score of many viewers. For power consumption, we have developed a power model based on the number of times basic operations are performed by the filters. Moreover, we show and discuss some factors, such as decomposition level and filter length, influencing the power dissipation of a given VS while executing a given wavelet under evaluation. Our results provide a good reference for designers of WBC for power-constrained applications such as VSN.

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INTRODUCTION

Visual Sensor networks (VSNs) are gaining attention from researchers and engineers as they can be used efficiently in many domains. VSN is a distributed ad hoc network made up of small sensing devices equipped with low-power miniature cameras, called visual sensors. VSN are deployed around strategic areas of interest to collect and reconstruct, in multi-hop fashion, a monitored scene. Inside a VSN, each visual sensor (VS) takes, processes, and transmits wirelessly images to the base station (also called sink) through its neighbors located in its range of transmission. VSN can be used in a wide range of applications such as video-surveillance, environmental monitoring, and object detection/tracking. Unfortunately, VSN faces some challenges such as the limitation of their resources in battery and memory, and they handle a plethora of visual redundant flows, which may cause several problems.

One of the challenging problems facing VSN is the huge amount of visual information processed and sent by each power-limited VS. The processing and communication of such information shorten the lifetime of the visual sensors and shrink the connectivity of the whole VSN. This is due to the limited resources of small VS. This problem also concerns mobile devices such as PDA, cell phones, and laptop computers.

The crucial solution to manipulate these visual flows is through image compression, which by definition might reduce significantly an image’s file size using lossy or lossless coding scheme. Very attractive and popular standards to achieve image compression are based on discrete cosine transform (DCT), such that JPEG, and discrete wavelet transform (DWT), such that JPEG2000. In past works, such as in (Mammeri et al., 2008a) or (Mammeri et al., 2008b), we have exploited the DCT in VSN, and have adapted JPEG to the requirements of such power-constrained networks. In this chapter, the DWT transforms evaluation is investigated in the context of VSN for the following reasons. DWT is a non-block-based transform, and thus, it allows to avoid the annoying blocking artifacts introduced by the DCT transform within the reconstructed image. Moreover, it has a good localization both in time and frequency domains. Furthermore, because of their inherent multiresolution nature, wavelet-based coders (WBCs) are especially suitable for applications where scalability and tolerable degradation are important (Mallat, 1989).

It is well known that the computational complexity of DWT is relatively higher than the DCT one. See (Grgic et al., 2001) for more details about the comparison between DCT and DWT. It is naturally that one could ask why DWT is preferred over DCT in VSN context. We believe that there exist at least two main reasons justifying this observation. Firstly, in VSN, it is highly recommended to reduce the size of the sent image for energy minimization purpose, thus the compression ratio CR should be high. In this case, DWT is favored over DCT (Grgic et al., 2001). Secondly, there exist a relatively new version of DWT implementation of low complexity (i.e., lifting scheme) than DCT (twice more efficient than convolutional-based wavelets). On the other it is reported in (Adams & Kossentini, 2000), that there is some correlation between the lifting version and the convolution version of the same wavelet filter.

A number of studies and reviews have evaluated the wavelet transforms in diverse domains, namely: medical image compression (Yao-Tien et al., 2005), audio compression (Srinivasan & Jamieson, 1999) and data compression (Grgic et al., 2001). While the aforementioned studies have considered the effectiveness of these transforms in terms of the perceived quality (in a non power-constrained application), none of them have focused on their use on special applications like VSN. Moreover, some research works in VSN have used some known wavelets within the compression stage of their WBC without any analysis or arguments, for instance the use of...