SCALABLE LOW COMPLEXITY CODER FOR HIGH RESOLUTION AIRBORNE VIDEO

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Abstract

Real time transmission of spaceborne and airborne images to the ground station is highly desirable in many telemetering applications. They also need to be sent through an error prone, time varying, wireless channel possibly under jamming conditions. Hence, a fast, efficient, scalable, error resilient image compression scheme is vital to realize the full potential of airborne reconnaisance. JPEG2000, the current international standard for image compression offers most of these features. However, the computational complexity of JPEG2000 limits its use in real time applications. Thus, in this work a scalable low complexity coder (SLCC) is designed that possess many desirable features of JPEG2000, yet having high throughput.

Index Terms

JPEG2000, airborne reconnaisance, low complexity, scalable compression.

I. INTRODUCTION

With technological advances in image acquisition systems, use of high resolution videos are common in many telemetering applications. High speed, high resolution video cameras [1], [2] have been developed for airborne applications [3] such as reconnaissance, earth survey [4], RDT&E [5] etc. These specialized video cameras [3] can typically record images at 200-400 frames per second (fps). For real time transmission of these images, the encoder needs to compress each image within 5ms. Some sophisticated systems also use dual band imagery (visible and IR). Thus a fast and efficient image compression scheme is vital to realize the full potential of airborne reconnaisance [6].

In [7], features required in an image compression algorithm for airborne reconnaissance is considered. The paper also studies the compression performance of two international image compression standard- JPEG and JPEG2000. JPEG2000 [8] is the current standard and offers rich scalability features that are beneficial for wide variety of applications. It is used for archiving and disseminating images within united states imagery and geospatial system (USIGS) and distributed common ground system architectures (DCGS) [9]. The only disadvantage with JPEG2000 is its high encoding and decoding complexity, which limits its use in real time applications. This disadvantage can also make it impractical for power constrained remote sensing applications, as highlighted in [10]. Other standards such as MPEG-4 and H.264 have low decoding complexity. However their encoding complexity is much higher even when compared to JPEG2000 [11] and hence will not be suitable for airborne video transmission. Thus, in this work a scalable low complexity coder (SLCC) is designed that possess many desirable features of JPEG2000, yet having high encoding and decoding throughput.

The paper is organized as follows. Section II gives an overview of scalable image compression methods and its use in airborne reconnaissance. Section III gives the algorithmic details of SLCC and describes its salient features that makes it well-suited for airborne video transmission. In Section IV, we present compression and throughput performance of SLCC and compare it with JPEG2000. Section V concludes the paper.

II. SCALABLE IMAGE COMPRESSION

Fig. 1 gives the architectural layout of an image compression scheme that possess four dimensions of scalability. The input image samples first pass through an optional color transform to exploit the redundancy between the RGB components (if any). The resulting luminance (Y) and chrominance (Cb and Cr) components are then compressed independently, thereby providing the component scalability. The components are then subjected to 2D dyadic discrete wavelet transform (DWT), enabling multi-resolution representation of the image [8]. This is illustrated in Fig. 2. Wavelet coefficients from LL_3 band can be transmitted to give a low resolution version (R_0) of the original image. Sending contributions from HL_3, LH_3 and HH_3 gives the next higher resolution and so on. Hence, in a resolution scalable scheme, portions of the compressed data corresponding to a resolution required at the receiver (ground station) can be transmitted.

Each wavelet subband is subdivided into codeblocks which are compressed independently by the block coder.

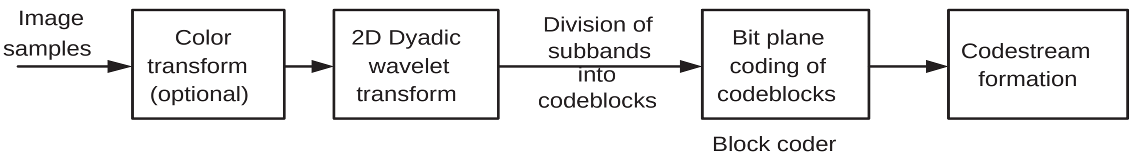

Fig. 1. Schematic of a scalable image compression system.

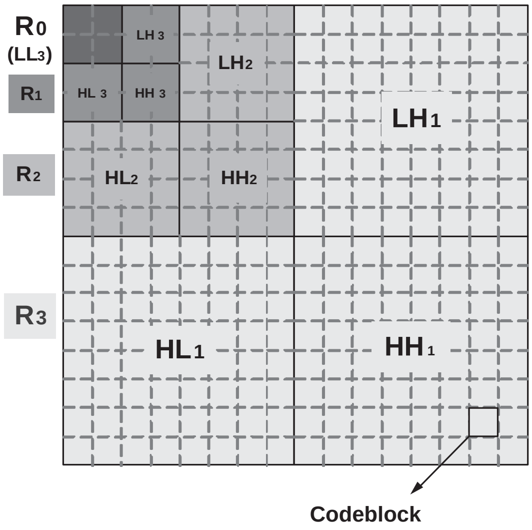

Fig. 2. Image samples subjected to three levels of wavelet transform. Each subband is divided into codeblocks.

Thus, portions in the compressed data that corresponds to a spatial region of interest (ROI) can be prioritized for transmission (Fig. 3). In remote surveillance applications, ample bandwidth savings can be acheived by utilizing the spatial scalability feature in conjunction with a object tracking scheme as shown in [12].

JPEG2000 has adopted the scalable compression scheme presented in Fig. 1 and thus possess all the three scalability features described above. In addition, a quality scalable codestream with high granularity is produced by encoding each bit plane in three passes (‘coding passes’) [8]. The ‘coding passes’ are compressed using MQ coder (a variant of context adaptive arithmetic coding) to provide superior compression performance. These steps demand high encoding and decoding complexity and hence limits the use of JPEG2000 for some real time applications such as airborne reconnaissance. The following section presents the SLCC algorithm that is more suited for real time applications.

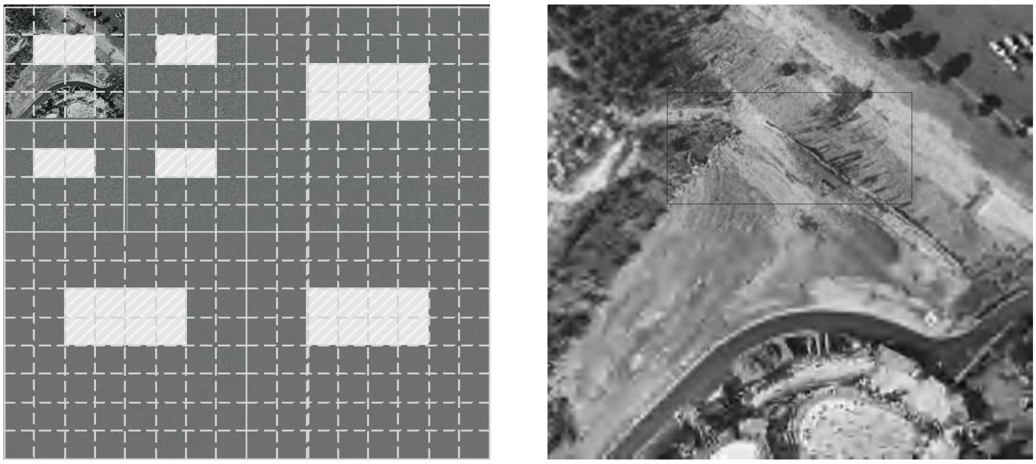

Fig. 3. Codeblocks from different subbands (left) that correspond to a region of interest in the original image (right).

III. SCALABLE LOW COMPLEXITY CODER

SLCC performs the color transform, 2D DWT and independent block coding (Fig. 1), thereby ensuring three dimensions of scalability (component, resolution and spatial). A limited amount of quality scalability is introduced by stacking bit planes into two layers starting from the Most Significant Bit-plane (MSB). The first layer can be used for real time transmission, while the second layer can be stored locally on the aircraft for later use. The 'thickness' (number of bit planes) of the first layer is adjusted based on the transmission bit rate, known apriori.

Fig. 4 illustrates the configuration of the two quality layers with an example. For the LL_2 subband shown in the figure, all bit planes above the 4th bit plane contribute to the first layer. The other subbands have fewer bit planes included in the first layer due to their lesser importance. The importance of each subband is measured from a MSE point of view, by the synthesis filter energy weights associated with the inverse wavelet transform. These energy weights are rounded to the nearest power of two and used to adjust the stack lengths. In the example of Fig. 4, codeblocks belonging to the HL_2 and LH_2 subbands will have one less bit plane in the first layer while the HH_2 and level-1 subbands have two less. All-zero bit planes in a codeblock are termed as missing MSBs and are indicated in the header information. The stack of bit-planes (discounting missing MSBs) from each codeblock contributing to a layer is coded in one single pass. The coding scheme employed depends on the stack length of the codeblock. Entropy coding is restricted to three (or less) MSBs in the first layer. When there is one bit-plane, the position indices of 'ones' in that bit-plane are coded. Run-value and Quad-Comma coding is used for stack lengths of 2 and 3 respectively. For codeblocks with more than 3 bit planes, Quad-Comma coding is used for the three MSBs and raw bits are coded for the remaining ones.

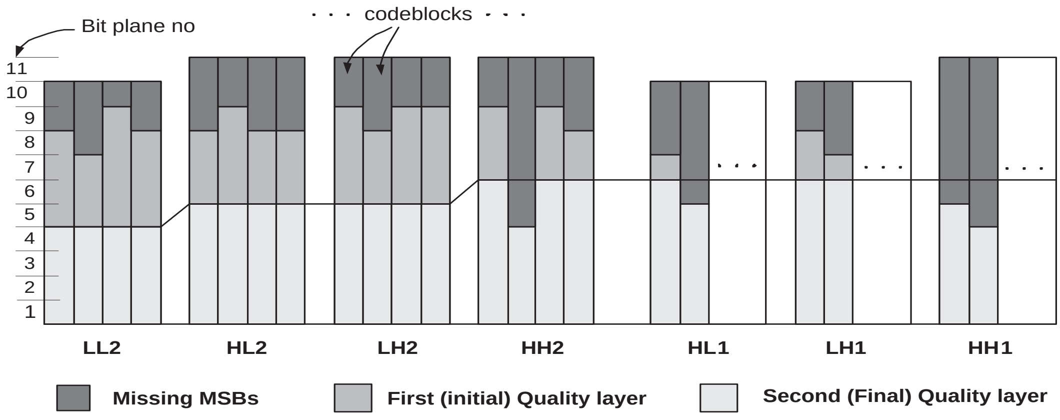

Fig. 4. Wavelet coefficient structure.

Since airborne video is transmitted through an error prone wireless channel, error-resilience of the image compression scheme is very important. By virtue of independent block coding, an error in the bit-stream error may not propagate beyond a codeblock in both SLCC and JPEG2000. Additionally, JPEG2000 supports error resilient modes [8] that enables an error resilient decoder to localize the corrupted bits. This again will demand higher compuatational time. With SLCC, error localization is more difficult. A single bit error would most likely lead to loss of the whole codeblock. However, smaller codeblock sizes can be used to limit the error propagation. This will incur little overhead from the header information when compared to JPEG2000. Thus, the error resilience of SLCC will be comparable to that of JPEG2000.

IV. RESULTS

The throughput performance of our coder is compared with kakadu V5.0 - an efficient JPEG2000 software [13]. Results are reported for a 720x576 grayscale aerial video with 100 frames. All the timing experiments were carried out on a PC with 2.8GHz P4 processor and 512MB RAM. Fig. 5 compares the end-to-end encoding time of JPEG2000 and SLCC at different bit-rates (bits/pixel). The end-to-end encoding time comprise of reading input image from memory, 2D DWT, block encoding and writing the compressed data to memory. As seen from the figure, SLCC is 3 to 4 times faster than JPEG2000. Fig. 6 shows the compression performance of the two coders averaged over 100 frames. Peak Signal to Noise Ratio (PSNR) is used as the quality metric. SLCC is worse than

JPEG2000 by 0.6 to 1 dB at low and moderate bit rates. Alternatively, for a given image quality, SLCC requires 12-15% higher bit-rate when compared to JPEG2000. However, by virtue of fast encoding, SLCC can deliver much higher temporal quality. This can be seen in Fig. 7 where the achievable frame rate (1/end-to-end encoding time) is plotted against the PSNR. In particular, at a PSNR of 30 dB, SLCC can deliver images at 98 fps while JPEG2000 can only deliver at 30 fps. The original image(1^{st} frame in the video) and the decompressed image with 30 dB PSNR are shown in Fig. 8 and Fig. 9 respectively. At high image quality ($\approx$ 45 dB), SLCC can perform at 70 fps while JPEG2000 can work only at 15 fps. Though the throughput performance of the decoders are not shown, similar gains are achieved when compared to JPEG2000.

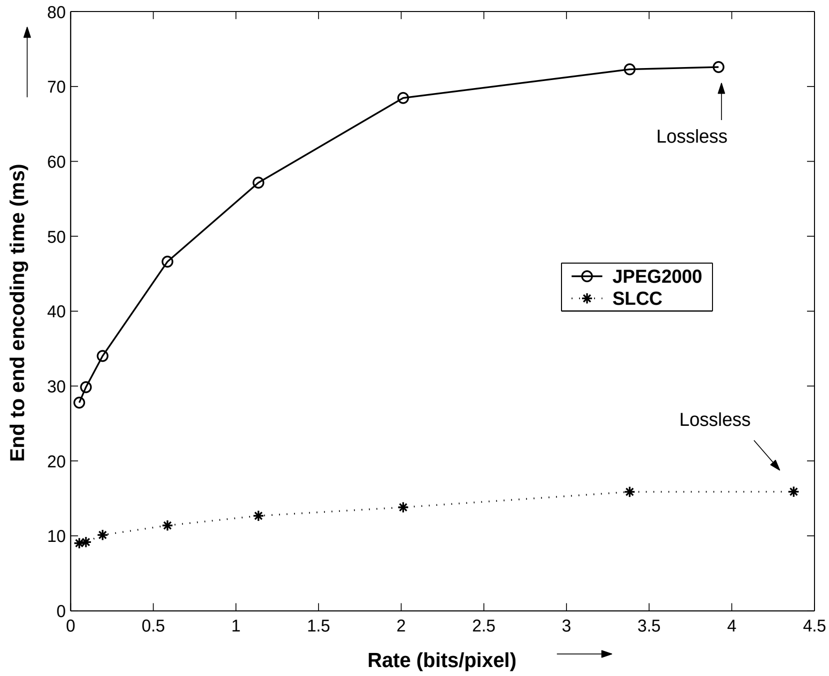

Fig. 5. Comparison of end-to-end encoding time.

V. CONCLUSION

In this work, a fast and scalable image coder is designed for airborne video transmission. Small amount of compression performance and granularity in quality layers of the codestream are traded to obtain the reduction in computational complexity. The throughput performance of SLCC has been compared to JPEG2000 and it is shown that much higher frame rates are achievable with small loss in bit-rate.

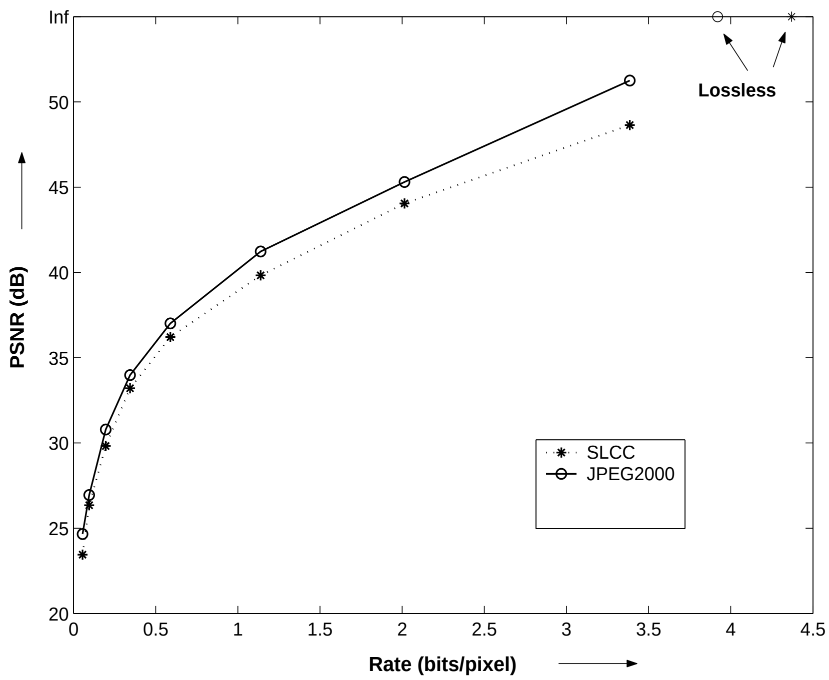

Fig. 6. Comparison of video quality without complexity constraint.

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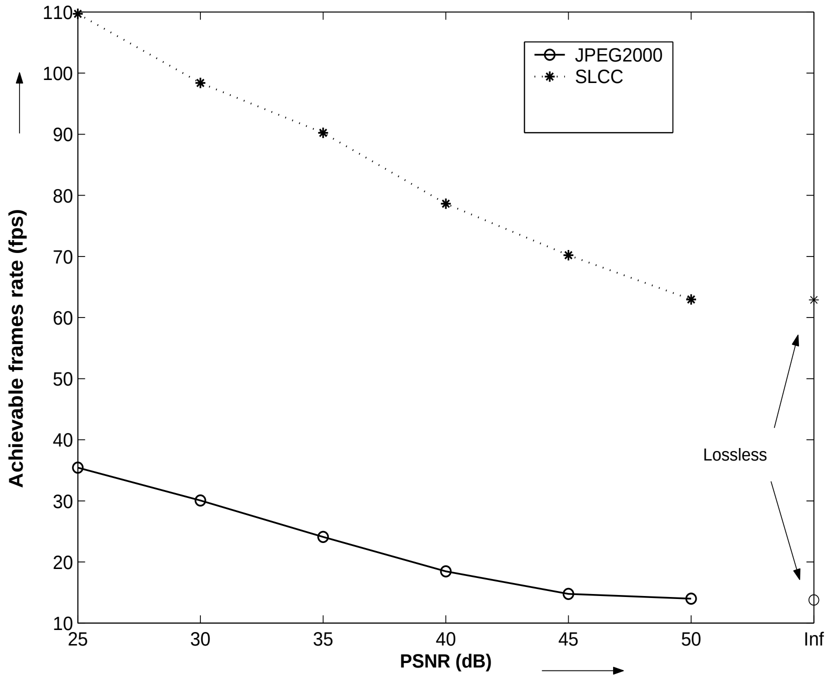

Fig. 7. Achievable frame rate at different quality.

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Fig. 8. Original image.

Fig. 9. Decompressed image with a PSNR of 30 dB.