Intelligent Satellite-based Visual Communication over Wireless ATM

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ABSTRACT

This paper focuses on satellite visual (image/video) communications over wireless ATM. When compared to computer data, remote sensed imagery requires huge volumes of information to be transmitted in a timely manner. On the other hand, error-free transmission is not strictly necessary at lower layer protocols. This is because more efficient error protection can be designed at the application layer and non-correctable transmission errors may be rendered imperceptible. In the proposed system, compression, transmission error protection, and packetization are jointly implemented as part of the application. For source coding, we propose to use our high performance significance-linked connected component analysis (SLCCA) wavelet codec. SLCCA provides multiresolution representation well suited for remote sensing data. We also propose error protection strategies to ensure reliable transmission of satellite data.

1. INTRODUCTION

Over the years, we have seen significant progress in multimedia information access over reliable wireline networks using Asynchronous Transfer Mode (ATM) protocol, which is now being extended to wireless ATM. Wireless ATM in combination with satellites holds the promise of delivering the "Internet in the sky" concept.

In the paper, an adaptive and integrated system is developed supporting satellite video communications by using wireless ATM. Applying the application level framing (ALF) [1] concept for the wireless connection, most of the system functionalities are implemented as an integral part of the application but not the networking infrastructure. More specifically, the source codec, channel codec, and packetizer are jointly implemented as part of the application. For source coding, we propose to use our significance-linked connected component analysis (SLCCA) [2, 3] image codec. For channel coding, interlaced unequal error protection [4] is applied. The significance information of the bitstream provided by the source codec is used in both channel coding and packetization for allocation of parity bit budget among ATM cells according to their importance. The channel state information is used to allocate the total bit budget between source coding and channel coding. Performance evaluation, which is carried out by using both Landsat TM imagery and land cover and land use classified data demonstrates the effectiveness of the proposed system.

2. SIGNIFICANCE-LINKED CONNECTED COMPONENT ANALYSIS

This section briefly describes the significance-linked connected component analysis technique. For more details, interested readers are referred to [2, 3]. The main components of SLCCA include:

- wavelet decomposition and uniform quantization;
- within-subband clustering of significant wavelet coefficients;
- cross-scale significance-link registration;

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- bit-plane-wise adaptive arithmetic coding based on higher order Markov source modeling.

After dyadic wavelet decomposition, all the coefficients are quantized with a uniform scalar quantizer. Wavelet coefficients quantized to nonzero are termed *significant* coefficients and zero coefficients are referred as *insignificant* coefficients.

The within-subband clustering property of significant wavelet coefficients [2, 5] is exploited by using conditioned dilation operation. In SLCCA, the conditioned dilation operation is used to recursively construct the *significance map.* Naturally the seed position of each cluster must be available at both the encoder and decoder.

In SLCCA, the cross-scale correlation between *significant* wavelet coefficients is exploited. Due to the magnitude decay property of wavelet coefficients [2], the parent coefficient of a significant coefficient is likely to be significant. This can be used to register the parent coefficient as having a *significance-linkage* and thus explicit seed positioning information of the child cluster can be avoided.

Finally, both the significance map and magnitude of significant wavelet coefficients are encoded by using adaptive arithmetic coding. Magnitudes of significant coefficients are transmitted in *global bit-plane* order.

3. TRANSMISSION ERROR PROTECTION

Several wireless extensions of the ATM protocol were proposed. Most of the techniques employ header compression and sequence numbering [6]. Header compression is used to reduce the relatively large header overhead of the wireline ATM protocol. Sequence numbering is used to detect lost ATM cells due to corrupted header.

To further increase error resilience over unreliable wireless satellite links, we propose to add *overhead* to the payload of each ATM cell. This overhead includes cyclic redundancy check (CRC) code and intracell forward error correction (FEC) code. Two byte CRC is used to detect transmission errors in the payload of each ATM cell. Intracell FEC is used to correct few symbol errors in the payload of each ATM cell.

The packetized bitstream is divided into interleaved blocks as shown in Fig. 1. Each block is protected by an interlaced (intercell) FEC code, implemented by Reed-Solomon code over GF(256). As shown in Fig. 1, each block is protected by a *different* interlaced Reed-Solomon code. The code is determined by the importance of ATM cells. Since the source bitstream is ordered in decreasing importance by SLCCA, ATM cells in the beginning of the bitstream are always more important than ATM cells at the end of the bitstream.

As usual, cell interleaving is applied to spread the effects of burst errors most common in the wireless scenario.

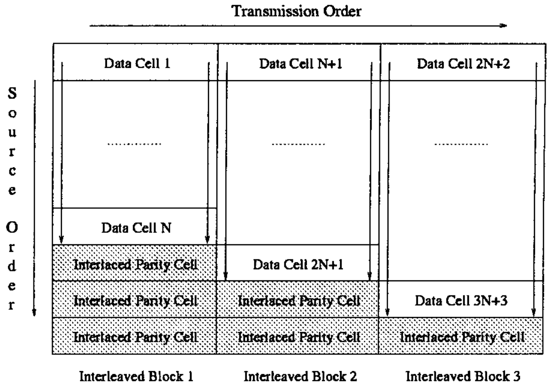


Figure 1: Source packetization with block interleaving and interlaced error protection.

ATM cells are organized in a 2-D matrix as shown in Fig. 1. The source bitstream produced by SLCCA is packetized into ATM cells in column major order. After interlaced unequal FEC, ATM cells are directly sent to the WATM layer (bypassing the ATM adaptation layer) in row major order.

4. PERFORMANCE EVALUATION

Performance evaluation is carried out on 1024 x 1024 pixels Landsat TM-3 data of St. Louis region taken in Fall 1991. The scene has 30 meter resolution, 7.5' quadrangle, and elevation corrected.

The performance is measured by root mean-squared error (RMSE), defined as

$$\mathrm{RMSE} = \sqrt{\frac{1}{N^2}\sum_{i=0}^{N-1}\sum_{j=0}^{N-1}\left(f(i,j)-\hat{f}(i,j)\right)^2}, \quad (1)$$

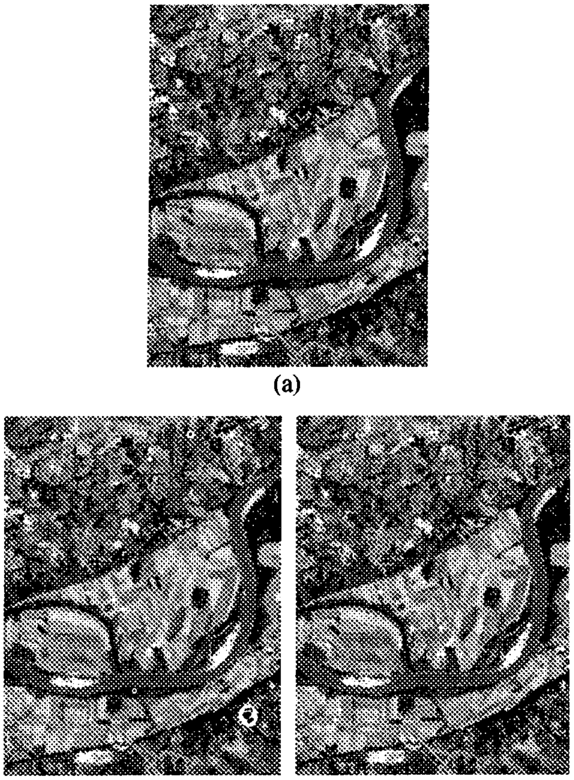
where the image is of size $N \times N$, and $f(i,j)$ and $\hat{f}(i,j)$ represent the original and reconstructed images, respectively.

Table 1 shows the performance comparison with the still image compression standard JPEG (Joint Photographic Experts Group) at compression ratios of 32:1, 16:1, and 6:1. As seen, SLCCA provides lower RMSE at each compression ratio.

Visual performance evaluation is carried out in Fig. 2 by showing the original image along with the reconstructed im-

Table 1: Performance comparison (RMSE) of SLCCA with JPEG on Landsat TM-3 data.

Compression ratio	SLCCA	JPEG
32:1	19.03	23.88
16:1	14.71	17.46
6:1	8.12	10.81



(a)

(b) (c)

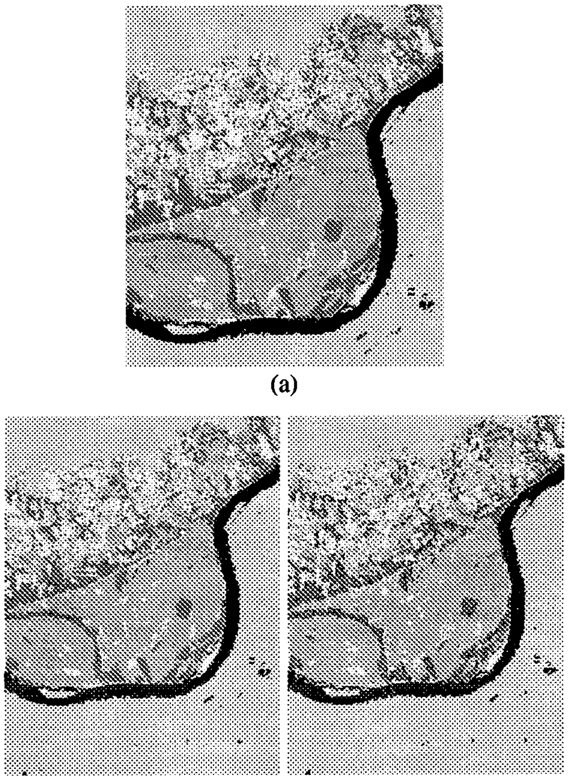
Figure 2: Comparison of SLCCA and JPEG for Landsat TM-3 scene. (a) Original scene. Compression result by (b) SLCCA and (c) JPEG.

ages by both SLCCA (Fig. 2b) and JPEG (Fig. 2c) as well. As seen, JPEG introduces blocking artifacts which significant reduces the utility of the Landsat data. On the other hand, SLCCA introduces some smoothing effect, which may not be objectionable.

Finally, compression results are also shown for the classified data. The land cover and land use classification is obtained by semi-automatic classification based on two Landsat TM images taken in Fall 1991 and Spring 1992 [7]. Fig. 3 shows the original classified scene, and the compression results by SLCCA and JPEG. As seen, SLCCA provides much better performance than JPEG.

5. CONCLUSIONS

In the paper, a novel framework including highly efficient and robust source coding, channel coding, and packetization schemes is developed for supporting wireless ATM information access over satellite links.



(a)

(b) (c)

Figure 3: Comparison of SLCCA and JPEG for the classified scene. (a) Original scene. Compression result by (b) SLCCA and (c) JPEG.

6. REFERENCES

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