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ROBUST MATCHING PURSUITS VIDEO TRANSMISSION USING THE HIPERLAN/1 AIR INTERFACE STANDARD

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ABSTRACT

Matching pursuits over a basis of separable Gabor functions has recently been demonstrated to outperform DCT methods for low bit rate video coding. This paper introduces an error resilient implementation of the matching pursuits algorithm, based on the Error Resilient Positional Code. Coded video is transmitted using the simulated HIPERLAN/1 air interface standard, which recommends ARQ as a means of overcoming channel errors. This may be unsuitable for real time and broadcast applications. Therefore, a modified HIPERLAN/1 receiver is proposed in this paper, which does not use ARQ to retransmit erroneous packets but instead passes them to the video decoder to exploit error resilience. This strategy provides an acceptable reconstruction quality for average bit error rates equal to 1 in 1000 and is superior to a standard compliant system in the absence of ARQ. This confirms that wireless LAN standards should support a transparent mode for video applications.

1. INTRODUCTION

With low bit rate video coding algorithms reaching maturity, the next challenge facing the digital video community is to develop error resilient and scalable codecs, which facilitate video transmission over heterogeneous networks. Since many advanced video coding algorithms, such as the standards described in [1][2], employ a combination of predictive and variable length coding (VLC) they are known to fail catastrophically in the presence of channel errors. Techniques such as forward error correction (FEC) and retransmission (ARQ) are often employed to overcome this problem. However, the former can compromise the compression performance, especially if transmission across a time varying channel is required, while the latter is usually unsuitable for real time or broadcast applications. Error resilient techniques [3][4] are attractive bearers of multimedia information across noisy environments as they tolerate a certain level of transmission error and provide acceptable quality of reconstruction without resorting to FEC or ARQ.

The contribution of this paper is twofold: Firstly, to introduce an error resilient implementation of a state-of-the art video codec, known as the *matching pursuits* algorithm. Secondly, to investigate the transmission of the video bitstream over a wireless local area network, using the ETSI HIPERLAN/1 standard [5]. The standard recommends a low-level rejection of erroneous data packets. In this paper, a modification is considered to make such packets available to the error resilient video decoder. This strategy is demonstrated to provide a better quality of service, compared to mandatory rejection of corrupted packets.

The paper is structured as follows: section 2 provides a description of the proposed video codec, section 3 characterizes the simulated HIPERLAN/1 implementation, section 4 presents the results and conclusions are drawn in section 5.

2. THE VIDEO CODEC

The video codec employed in this paper is based on matching pursuits. Matching pursuits is a method for decomposing a signal over an overcomplete basis set. The matching pursuits codec developed by Neff *et al.*, which decomposes the *displaced frame difference* (DFD) signal over a basis of Gabor functions, was reported consistently to outperform standard discrete cosine transform (DCT) methods for low bit rate video coding [6][7]. The codec employed in this paper shares a lot of similarity with the codec described in [6], however, the basis functions are factorized into short-kernel convolutions. This enables a considerable reduction in the computational cost [8][9].

A DCT expansion is described by two parameters per coefficient: (1) coefficient position, which also identifies the basis function and (2) coefficient magnitude. By contrast, a matching pursuits expansion requires three parameters per coefficient: (1) coefficient position, (2) an index into the basis set and (3) coefficient magnitude. A position-index-magnitude triplet is referred to as an *atom*. For best coding results, atoms and the motion field are normally variable-length coded. The codecs presented in this paper are designed for error resilience. Therefore, alternative methods to VLC are employed, which do not fail catastrophically in the presence of channel errors. In particular, the performances of the following two methods are investigated:

- fixed length code (FLC);
- error resilient positional code (ERPC).

It should be noted that, in both above cases, a small portion of the data, such as the frame type, the temporal reference, the quantization parameters and the count of coefficients encoded per image plane is highly protected against channel errors by means of forward error correction. These data fields are crucial for any meaningful decoding and constitute a small enough fraction of the bitstream to not compromise the compression performance.

2.1 The FLC Algorithm

FLC represents the simplest and the least compact form of coding. However, it is naturally resilient, with a single bit error affecting only a single codeword. The following bit allocation was in place for coding atom parameters: 17 position bits (for SIF resolution sequences), 7 basis function index bits and 5 magnitude bits. FLC offers the benefits of simplicity and resilience, however, as can be verified from Figure 1, for the two example test sequences considered here, it involves a coding performance penalty of 1–2 dB, compared to the VLC algorithm.

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2.2 The ERPC Algorithm

The ERPC was developed by Cheng and Kingsbury [10] as an efficient, yet resilient method for positional coding of sparse data. A description of the algorithm falls beyond the scope of this paper; it is shown in [10] that the compression performance of ERPC is close to the first order source entropy, while a single error in the coded positional information affects an average of 2.7 coefficients. As can be verified from Figure 1, the ERPC matches the performance of the VLC algorithm in the case of 'Silent Voice'. In the case of 'Akiyo', it is inferior by approximately 1 dB, mainly due to the fact that the VLC algorithm codes the motion field much more compactly.

2.3 Motion Field Coding

Since the FLC version of the motion field takes up a relatively large portion of the bitstream, it was found to be more vulnerable to channel errors compared to the ERPC version. Therefore, both coder configurations described above employ the same, ERPC based algorithm for motion field coding.

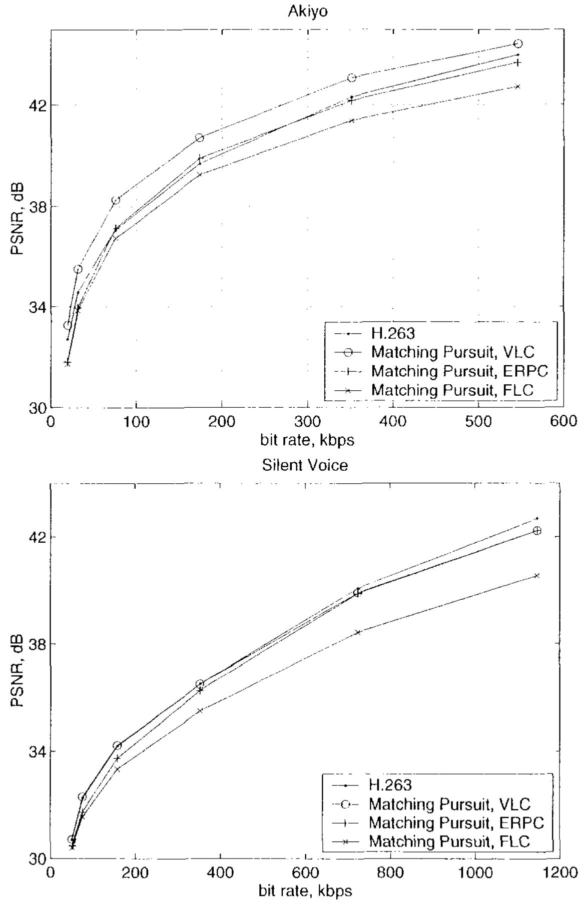

Figure 1. Clean channel performances of different entropy coding strategies in the context of matching pursuits video coding. VLC–variable length coding, FLC–fixed length coding, ERPC–error resilient positional coding. The performance of H.263 is also included for comparison.

3. THE HIPERLAN/1 MODEL

HIPERLAN/1 (HIgh PErformance Radio Local Area Network) is a first generation European wireless LAN standard defined by ETSI [5]. The system uses Gaussian Minimum Shift Keying (GMSK) with BT = 0.3 to transmit 23.529 Mbps at carrier frequencies around 5.2 GHz. The HIPERLAN reference model is composed of a Medium Access Control (MAC) sublayer, a Channel Access Control (CAC) sublayer and a Physical layer. As shown in Figure 2, the MAC and CAC overheads allow the user to send a maximum of 2383 bytes in a single packet.

A 450 bit synchronization sequence is added to each Physical layer packet to synchronize and train an optional equalizer in the receiver. The 2444 bytes received from the CAC sublayer are divided into 47 blocks of 416 bits each. A block is split into 16 segments of 26 bits, which in turn are FEC coded with the BCH(31,26) code, to produce a data block of 496 bits. The CAC sublayer always provides the Physical layer with an integer multiple of 416 bits, using stuffing bits if necessary.

In this paper, the HIPERLAN/1 Physical layer was simulated at baseband by transmitting 2383 bytes in each packet. The MAC and CAC protocols were ignored by filling the protocol-specific fields with zeros. The block diagram of the HIPERLAN transmitter and receiver is shown in Figure 3.

The transmitter blocks were implemented following the HIPERLAN/1 recommendations. As shown in Figure 4, a 25 tap T/4 spaced exponential channel was simulated with rms delay spread of 50 ns. The excess delay spread is 250 ns. The fading was generated using Rayleigh statistics since this represents a worst case scenario in radio channels. After the channel filter, Additive White Gaussian Noise (AWGN) was added.

At the receiver, a lowpass FIR filter with a noise equivalent bandwidth of 13.56 MHz was used to limit the out of band noise. A T-spaced optimum sampler followed this. To combat Inter-Symbol Interference (ISI), a combination of a Channel Matched Filter (CMF) and a hard Decision Feedback Equalizer (DFE) was deployed [11]. The channel estimation was performed over a 5-symbol window by correlating the first 62 symbols of the synchronization sequence with the received signal. The DFE had 5 feedforward and 4 feedback taps. The DFE coefficients were calculated by solving a 9x9 linear system using Gauss elimination. After the CMF-DFE, the received bits were passed through a deinterleaver and a BCH decoder to recover the data.

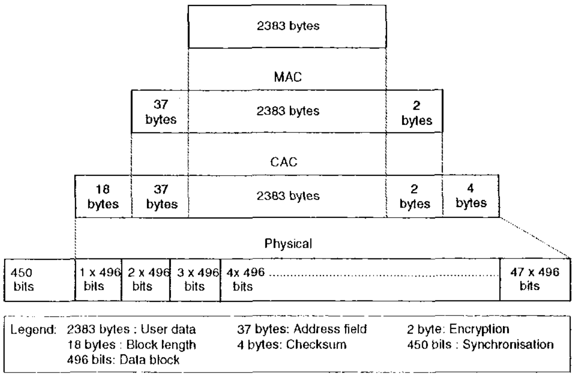

Figure 2. HIPERLAN/1 reference model.

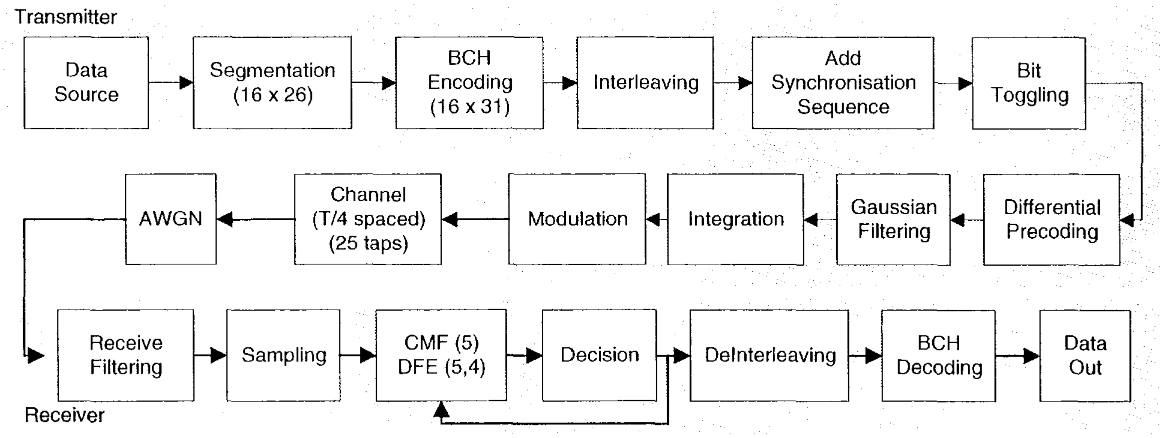

Figure 3. Block diagram of the HIPERLAN/1 system.

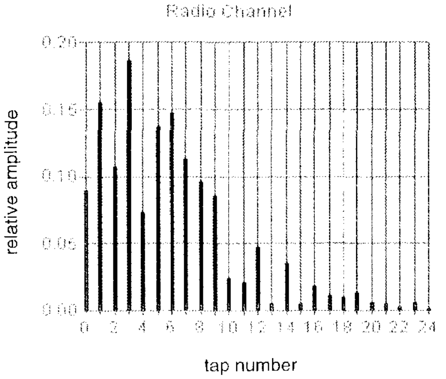

Figure 4. Snap shot of a 25-tap Rayleigh channel with an exponential power profile (tap spacing = 10.6 ns).

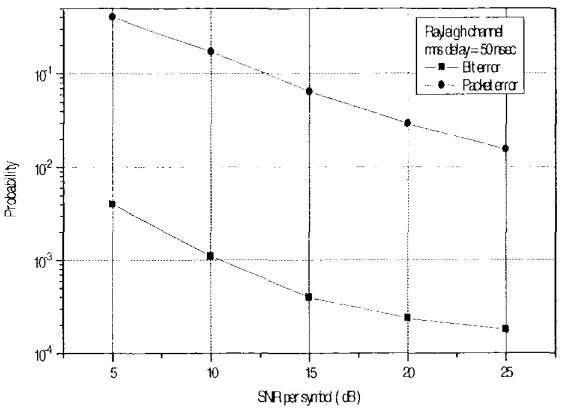

Figure 5. Bit error and packet error probability of HIPERLAN/1.

Unlike the HIPERLAN/1 compliant receiver, the packets received in error were not requested to be retransmitted but passed over to the video codec for further processing.

The performance of HIPERLAN/1 deploying a CMF-DFE is plotted in Figure 5. It shows the average Bit Error Rate (BER) and Packet Error Rate (PER) for different values of Signal to Noise Ratio (SNR) per symbol. Due to the use of the CMF and BCH encoding, the BER remains around 1 in 1000 even though the PER rises to 17 % at SNR of 10 dB. However an error floor appears at around 20 dB which limits the BER to approximately 2 in 10,000. The source of this error floor is the sub-optimal channel estimation used by the CMF-DFE procedures in certain channels. The sub-optimal channel estimation is caused due to unacceptable levels of unwanted quadrature interference generated in certain channels while receiving GMSK as Offset Quadrature Phase Shift Keying (OQPSK).

4. CODING RESULTS

The performance of the FLC and ERPC algorithms, as described in section 2, was tested in the presence of channel errors. An example bitstream, corresponding to the sequence 'Silent Voice' coded at 350 kbps was transmitted over the simulated HIPERLAN/1 system. Average PSNR results for this experiment are shown in Figure 6 and an example reconstructed frame is shown in Figure 7. For comparison, a HIPERLAN/1 system that rejects corrupted packets in the absence of ARQ was also simulated. Firstly, it can be verified from Figure 6 that the ERPC strategy remains superior to the FLC strategy under the tested channel conditions. Secondly, the proposed system, which permits the decoder to use all data packets is clearly superior to the HIPERLAN/1 compliant system. Therefore, it is postulated that the packet acceptance/rejection decision should rest with the video decoder application, rather than the low-level HIPERLAN/1 protocol.

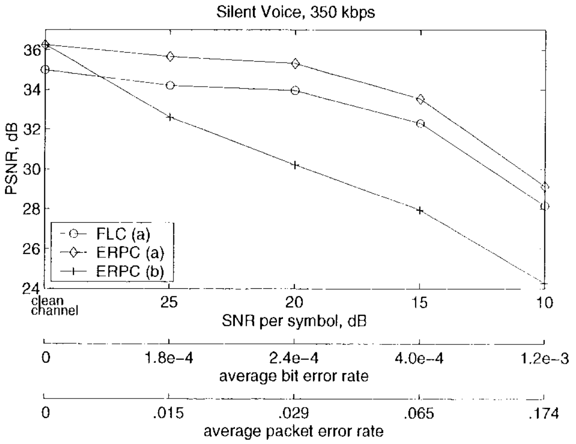

Figure 6. Matching pursuits video coding: the PSNR performances of the FLC and ERPC in a noisy HIPERLAN/1 environment. (a) all packets are passed to the decoder; (b) corrupted packets are rejected by HIPERLAN/1 CAC layer.

5. CONCLUSIONS

This paper reports an error-resilient implementation of the matching pursuits video codec. This implementation uses the Error Resilient Positional Code to encode the motion field and the atoms. The clean channel performance of the ERPC is close to an implementation which employs variable length coding. However, the ERPC has the added capability to cope with channel errors and was demonstrated to provide acceptable reconstruction quality for bit error rates up to 1 in 1000.

The acceptable reconstruction quality, which was achieved by using all (including corrupted) data packets is a strong case for the HIPERLAN/1 and other wireless LAN standards to support a transparent mode for video applications

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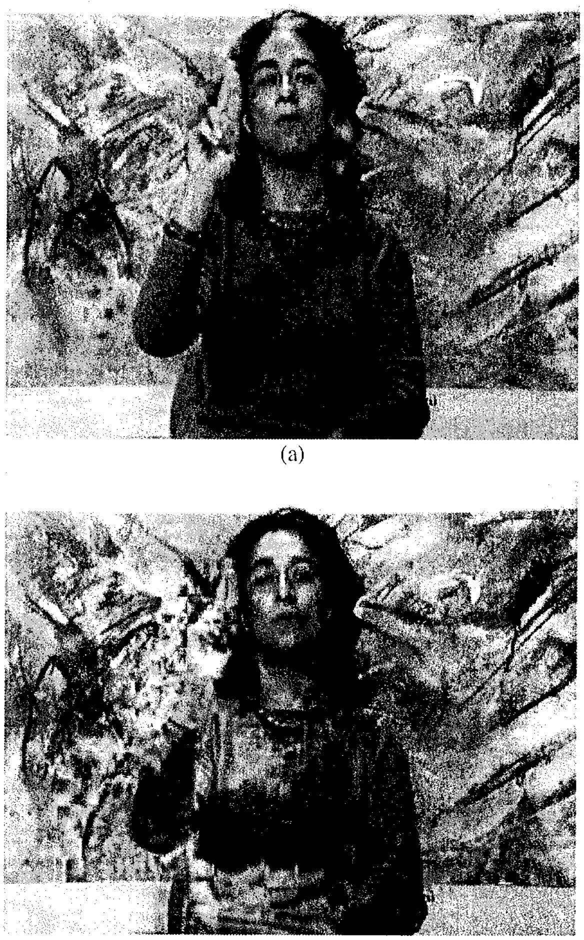
(a)

(b)

Figure 7. Example luminance plane of reconstructed frame 298, BER=8.7e-4, PER=7.3e-2. (a) utilizing corrupted packets–ERPC algorithm; (b) discarding corrupted packets.

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