ADAPTIVE LIFTING SCHEME-BASED METHOD FOR JOINT CODING 3D-STEREO IMAGES WITH LUMINANCE CORRECTION AND OPTIMIZED PREDICTION

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ABSTRACT

This paper proposes a new adaptive scheme for stereo image coding. The original left and right images are jointly coded in order to exploit the high correlation between the two images for a lossless coding. Our goal is to design an efficient transform that reduces the existing redundancy in the stereo pair. This approach is inspired by the Lifting Scheme (LS). First, illumination change compensation has been made. Secondly, the prediction filtering is locally adapted and is based on local horizontal and vertical gradient information. In the sense that small gradient evokes predictability in the same direction. The coefficients of the predictor are then optimized. Experimental results show improvement in term of performance and complexity compared to other proposed methods.

Index Terms— Stereovision, Lifting Scheme, Disparity Compensation, Adaptive and Optimized Prediction

1. INTRODUCTION

The use of stereoscopic imaging has a wide range of applications such as digital cinema, medical surgical environments, telepresence in videoconferences, geographical information systems and video games. All these applications require large amounts of storage, consequently compression has become necessary. Stereo images are associated with the same scene observed from two viewpoints. The left and right views represent the stereo pair. Providing a distinct image for each eve makes the scene perceived in three dimensions by the human brain. Since these two images are slightly different, estimating one from the other enables high efficiency in compression of stereo image pairs. Traditional methods estimate first the disparity between the reference image and the other image, then the residual image which is the difference between the reference image and the compensated image is computed. So the reference image, the residual image and the disparity map are coded [1]. In 2D compression, especially with high resolution images, DWT has shown better performance and

flexibility than DCT [2]. The proposed structure is based on the LS which correspond to classical wavelet transform (WT). The implementation of lifting scheme is simple, fast and efficient, and easily invertible. More recent work has tried to extend the LS. Hybrid prediction was made in [3]. This method proposes to code the left image separately, and then introduces the disparity compensation of the left image details to compute the right image details. Besides, these methods do not fully exploit the existing redundancy in the stereo pair. In this paper, our objective is to improve the exploitation of the high redundancy in the stereo pair. We extend the scheme recently proposed in [4], so it can use directional adaptive filtering. In this way we can capture the geometrical nature of the image and consequently better prediction can be done. This scheme can be used for digital cinema where we can tolerate lossy coding, or it can be adopted in medical imaging with lossless coding where the reconstruction of minor information is required.

This paper is organized as follows. In section 2, we present a short background on LS. Then the proposed scheme is presented in section 3. In section 4, adaptive filtering is explained. Experimental results are shown in section 5. Finally, conclusion is made in section 6.

2. LIFTING SCHEME

The aim of this section is to make some necessary backgrounds on the lifting scheme. The fundamental principle of the lifting scheme is to exploit efficiently the correlation included in the signal, leading to a more compact information set. This scheme corresponds to classical WT. The implementation of LS is simple, efficient, and easily invertible. The canonical scheme consists of three main steps [5]:

- 1. The original signal, denoted x, is split into two disjoint subsets, x_e (the set of even samples of x), and x_0 (the set of odd samples of x).
- 2. A prediction operator, denoted P, is applied on the sub-

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set x_e , in order to predict the subset x_0 ,:

$$d = x_0 - P * x_e \tag{1}$$

where the prediction error d represents the details of x. This stage represents a lifting step.

3. An update operator, denoted U, is applied on d:

$$s = x_e + U * d \tag{2}$$

This stage represents a dual lifting step.

The lifting is build by alternating different prediction and update steps. The inverse lifting scheme consists of making the inverse operation and a merge (inverse of the split).

3. PROPOSED SCHEME

In order to optimally exploit the intra and inter image correlation, we jointly code the left and right images. In the basic LS [1], the two images are coded separately. Disparity in the stereo pair is not exploited. In the proposed method, the prediction step is only used. This step is adjusted to fit with the particularity of stereo images.

The proposed scheme is shown in figure 1 and is defined in four steps:

- The first step in the proposed structure is the disparity estimation and the compensation process.
- In step 2, a post-processing luminance correction step is done. This step is integrated in the disparity compensation process for better computational efficiency.
- In step 3, a directional adaptive filtering is performed using optimized predictors. The optimized operator P_{optz} is adaptively applied to the compensated image in order to compute the prediction error which represent the detail coefficients D.
- In step 4, the detail coefficients D and the left image I_L are decomposed through a 5/3 transform over three levels.

3.1. Disparity Estimation and Luminance Correction

Since the pixel intensities are used as matching cost, disparity estimation is not robust against illumination variation. To improve that, we used the (Zero Mean Normalized Cross Correlation) ZNCC criterion which takes into account the illumination difference between two block candidates. In the following, the left image I_L after disparity compensation is denoted as \tilde{I}_L where:

$$\tilde{I}_L(x,y) = I_L(x + DV_x(x,y), y + DV_y(x,y))$$
(3)



Fig. 1. Proposed Lifting Structure

Then, a post-processing step is performed. Since the illumination can vary significantly between the two images, luminance correction has been done for each block after the best matching. This highlights the existing spatial redundancy and consequently improves our results in the prediction step. We considered as in [6] that illumination variation in the stereo pair can be approximated to a luminance shift. For this end, only one additive block component needs to be sent. For each matching block, luminance correction is done as follows:

$$Block(\tilde{I}'_{L}) = Block(\tilde{I}_{L}) - Mean(Block(I_{R})) + Mean(Block(\tilde{I}_{L}))$$
(4)

Where I'_L is the left compensated image resulting of luminance correction.

3.2. Joint Lifting Structure

In the first step of the basic lifting scheme, the input image is split into two parts. Besides, in the proposed scheme, we omit this step and consider that the stereo pair represents those parts. In this way, joint information from the left and right image are involved to compute the detail coefficients D.

The second step corresponds to the prediction lifting step. It begins with the disparity and illumination compensation. After the computation of \tilde{I}'_L , the coefficients of the predictor P are applied to \tilde{I}'_L in order to predict I_R . The difference between the two represents the detail coefficients D. This can be written as follow:

$$D = I_R - P * \tilde{I}'_L \tag{5}$$

In the final step, D and I_L are decomposed separately using the 2D separable lifting structure. In our structure the well-known 5/3 scheme [7] is used to decompose the images and to generate the approximation coefficients S as well as D_h, D_v, D_d the detail coefficients respectively in the horizontal, vertical and diagonal direction. One can note that this scheme is totaly invertible. The reconstruction does not require sending I_R , since I_R can be computed using the disparity vectors and I_L .

4. ADAPTIVE PREDICTION

4.1. Directional adaptive filtering

The proposed lifting-based scheme adapts the signal by exploiting local orientation information. In order to discriminate between different geometrical information, the system makes use of a criteria, denoting to the optimal way of prediction [8] [9]. We set up the condition under which the decision can be recovered at the reconstruction, without the need to transmit any overhead information. The direction of prediction filtering is triggered by a decision obtained by computing the local gradient of each pixel in the horizontal and vertical directions.

$$\nabla_x \tilde{I}'_L(x,y) = \frac{\delta I'_L(x,y)}{\delta x} \tag{6}$$

$$\nabla_y \tilde{I}'_L(x,y) = \frac{\delta \tilde{I}'_L(x,y)}{\delta y} \tag{7}$$

The proposed scheme consists of a selection between two filtering directions among each pixel of \tilde{I}'_L . If the local gradient in the horizontal direction is lower than the local gradient in the vertical direction: the prediction filtering is applied in the horizontal direction and so on as shown in equation (8) and (9). At the reconstruction, the optimized prediction filter is applied in the same way, and this by inverting the operation.

If
$$\nabla_x \tilde{I}'_L(x,y) < \nabla_y \tilde{I}'_L(x,y)$$
 then:

$$D(x,y) = I_R(x,y) - \sum_{k \in \mathcal{P}} p_k \cdot \tilde{I}'_L(x-k,y)$$
(8)

else:

$$D(x,y) = I_R(x,y) - \sum_{k \in \mathcal{P}} p_k \cdot \tilde{I}'_L(x,y-k)$$
(9)

where \mathcal{P} is the support index of the filter.

4.2. Predictor Optimization

We optimize the predictor coefficients p_k as done in [10] [11]. For optimization, we consider that a good predictor P has to generate a signal of coefficients with suitable properties for compression. According to the coding theory, a signal with minimum variance is coded with the highest efficiency. Then, a reliable and adequate criterion is used to minimize the variance of the detail coefficients :

$$J(\{P_k\}) = \sigma_D^2 \tag{10}$$

The derivation of the optimization criterion J_P ,

$$\frac{\delta J(\{P_k\})}{\delta P_k} = 0, \qquad \forall k \in \mathcal{P}$$
(11)

generates an optimum predictor which minimizes the variance of the detail coefficients D as shown in equation (11). The derivation is done under the constraint of $\sum p_k = 1$. Then, the obtained predictor P_{Optz} is applied in equation (8) and (9).

5. SIMULATION AND RESULTS

We have implemented the proposed scheme and apply it to stereo pairs of size (512×512) . The disparity compensation is done using the Block Matching Algorithm (BMA). The retained criterion for block comparison was ZNCC criterion. In order to show the performance of the proposed scheme, the results were compared with wavelet-based coding methods. These methods use the 5/3 transform over 3 levels in order to code the original left image I_L and the residual image I_e . The disparity map and luminance correction map are lossless coded using the Differential Pulse Code Modulation (DPCM). As the disparity map is coded in the same way for all the tested methods, the computation of the average entropy of the images can be significant for the evaluation at a first time. The entropy is computed and is independent of the performance of any coder. For lossless coding we apply a rounding operator for the second term in equation (8) and (9).

Some brief results in terms of entropy are shown bellow in table 1. Where I_e is the residual image and I'_e is the modified residual image after luminance correction. PS is the proposed scheme, PS with LC is after luminance correction. Then we have PS (Adapt) with adaptive directional filtering, and finally PS (Adapt with P_{optz}) is the overall scheme with luminance correction, adaptive directional filtering and optimized predictor.

The proposed method generates in the transform domain lower entropy for all tested images. It is less complex compared to [3], and it is more robust against erroneous disparity compensation. The experimental results show successive improvements after luminance correction and adaptive filtering with optimized predictors. Future tests will be done on digital cinema stereo pairs.

6. CONCLUSION

In this paper, we have presented an adaptive scheme for joint coding 3D-Stereo Digital cinema. The proposed scheme better exploits the correlation in the stereo pair than methods applying simple prediction or using hybrid prediction. Illumination change compensation and optimized prediction have been implemented. We also adapt our scheme to local orientation information in order to have better prediction. The proposed method shows improved performance and efficiency compared to other methods.

	Original	$5/3$ for (I_L, I_e)	5/3 for (I_L, I'_e)	PS (without LC)	PS (with LC)	PS (Adapt)	PS (with LC, Adapt, P_{Optz})
Fruit	6.36	4.10	3.88	3.88	3.73	3.56	3.50
Pentagon	6.66	5.27	5.15	5.11	5.02	4.84	4.82
Houseof	6.75	5.37	5.24	5.27	5.17	4.96	4.93

Table 1. Results in terms of entropies (in bpp).

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Fig. 2. (a) left image, (b) right image, details coefficients D for: (c) PS without LC, (d) PS with LC, (e) PS Adapt, (f) PS with LC, Adapt, P_{Optz} .

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