RESEARCH ARTICLE   OPEN ACCESS

Image Reconstruction Using Dual Tree Complex Wavelet Transform For Mosaic Video Sequences

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Abstract

Most of the commercial digital cameras have three type of color sensors such as Red,Green and Blue for capturing the image scene. Sensor is the most expensive part of digital camera which costs 10% to 25 % of the total cost of the device.To reduce the cost and complexity a single sensor with a Color Filter Array is used. These color channels are placed on the detector surface according to a specific pattern,where the commonly used pattern is Bayer pattern.Such an image is called a mosaic image. At the location of each pixel only one color sample is taken ,and the other color samples are obtained by interpolating the neighbouringsamples.This color plane interpolation is called demosaicing.If this is not performed correctly images suffer from highly visible color artifacts.

Index Terms—Demosaicing, Bayer pattern,alternating projections, dual tree complex wavelet, waveletdenoising.

I. INTRODUCTION

A demosaicing algorithm is a digital image process which is used to reconstruct a full color image from the incomplete color samples output obtained from an image sensor which is overlaid with a color filter array(CFA).The reconstructed image is typically accurate in uniform colored areas, but loss of color resolution and image artifacts exists.Thedemosaicing algorithms can be grouped into two classes. In the first class interpolation techniques are applied to each color channel separately.Nearestnneighbourinterpolation,bilinear interpolation, cubic spline interpolation comes under this class.

The second class of algorithms uses interchannel correlation between the color samples.Smooth hue transitions and edge directed interpolation are examples for this class.Two algorithms which effectively uses inter channel correlation for demosaicing.

The first algorithm is demosaicing using alternate projections[3].It considers the correlation between the color channels that exist in natural images and the arrangement of sensors in CFA.This algorithm defines two constraint sets which are based on the observed color samples and the knowledge about the correlation between the channels. The first constraint set comes from the observed color samples .The interpolated color channels must be consistent with the color samples captured by the digital camera. We denote $O(n_1,n_2)$ as this observed data ,which has red,green,and blue samples placed according to the CFA used.(n_1,n_2) are integers denoting the pixel co-ordinates.

The second constrained set is a result of the interchannel correlation. The color channels are very similar to each other, and similarity increases when high frequency components such as edges are concerned. This information would not be enough to define constraint sets if all channels loss the same amount of information in sampling.

But the red and blue channels lose more information than the green channel when captured with the CFA .Therefore the constraint sets are defined on the R,B channels which force the high frequency components to be similar to the high frequency components of the green channel.Inorderto decompose the channels into the frequency subbandsfilterbank structures are used. The filter bank performs an undecimated wavelet transform , with $H_0(z)$ and $H_1(z)$ respectively denoting high pass and low pass filters. This analysis filters $H_0(z)$ and $H_1(z)$ constitute a perfect reconstruction filter bank with the synthesis filters $G_0(z)$ and $G_1(z)$.

The perfect reconstruction equation can be written as

$$H_0(z) \, G_0(z) + \, H_1(z) \, G_1(z).=1$$

The detailed constrained set C_d forces the details of the R,B, channels to the similar to the details of the green channel which is based on the threshold $T(n_1,n_2)$.It is a positive threshold that quantifies the closeness of the detail subbands to each other. If the color channels are highly correlated then the threshold should be small.If the correlation is not high then the threshold should be large.

This algorithm first interpolates the R,G,B channels to obtain initial estimates.Bilinear or edge directed interpolation algorithms can be used for this initial interpolation.Then it decomposes all three channels

with a filter bank.At each level of decomposition there will be four subbands.This process is called as detail projection. Then compare the samples of the reconstructed R,B channels with the original samples.This process is called as observation projection.This process is repeated until a stopping criterion is achieved.

The second algorithm uses data adaptive filtering concept for demosaicing[2].In this method ,using the data adaptive filtering concept, the sample values for the vectors are found out.then the weights of the vector are normalized to ensure that the filter output is an unbiased estimator and the samples obtained are present within a given intensity range.The weights obtained describes the contribution of the input vectors to the output of the filter.The weights of the filter are obtained using the functions of the distance or similarity criterion between the vectorialinputs.Using this the aggregated statistics is obtained.These aggregated statistics are mapped into the weighting coefficients.The missing components are found out making use of the spectral models and edge sensing mechanism.

In edge sensing mechanism the aggregated statistics are mapped into the weighting coefficients which are used to track the changes in the structural content of the image.

These weighting coefficients are inversely proportional to the gradients.The spectral problems present in the image are reduced by the use of spectral models. Finally the demosaiced image is post processed. The commonly used techniques for post processing are local color ratio based and median filtering. In local color ratio postprocessing mean values are used in order to correct unnatural changes in hue values by smoothing the color ratio planes. Testing shows that this method performs well when removing falsecolors, which occur mainly along edges. The median filtering method is introduced by gathering all the color difference values over a square neighborhood around a pixel. Once the differences are gathered, their median is calculated, and then used as an approximation of what the current pixels color difference should be. It is best used when performed on edge pixels.

II. PROPOSED METHOD

The alternating projections algorithm explained above establishing a first estimate of the three channels by two-dimensional interpolation. Then, R and B estimates are projected onto two constraint sets in an iterative manner. The first constraint is a detail constraint which forces similarity -within a specific tolerance- between R-G and B-G HF wavelet subbands. Themotivation behind this constraint originated from the strong

correlation between the HF subbands of the three color channels, which is due to the fact that they share many of image features such as edges and texture being characterized by the HF subbands. This correlation is stronger in HF subbands of a natural image. Via this constraint, a natural image feature is exploited in the demosaicing problem. The second constraint is the observation constraint which guarantees consistency be- tween the demosaicing outcomes and the sampled (measured) color samples..The basic block diagram of enhanced AP is shown below.
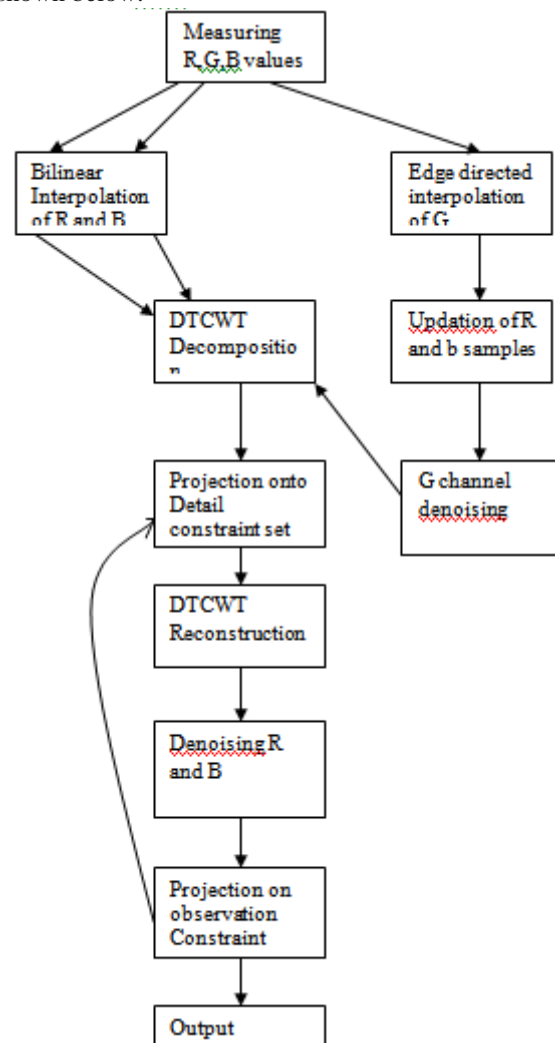

Fig.Block diagram of enhanced AP algorithm

Now enhancements are made on the baseline AP algorithm which is explained above. First, the dual-tree complex wavelet transform (DTCWT) is proposed as a framework for the AP stage. The main reason for it is that it is more direction- ally selective and thus inter-channel correlation between the respective DTCWT subbands of the three color channels is stronger. Secondly, G channel reconstruction is enhanced with wavelet-based

denoising to refine the reconstruction. Another enhancement is developing R and B denoising stage to be embedded in the AP loop. This modification allows the AP algorithm to exploit the edge persistence property as a natural image feature. Experimentations also verify a superior or at leat comparable performance of the proposed algorithm as compared to the leading demosaicing approaches

The enhancements made on the above AP algorithm is explained below.

A. Using DTCWT for Alternate Projections

The primary enhancement is the use of the DTCWT as a framework for the AP algorithm.This idea comes from the fact that the DTCWT is more directionally selective than the standard discrete wavelet transform (DWT). Since the inter-channel similarity is basically in the detail content characterized by edges and texture, having a more directionally selective transform means more accurate description of image details in a directional manner. The result is better extraction of those details which leads to forcing more accurate similarity between R and G and B and G channels during the detail projection.

The standard (separable) DWT resolves an image into four subbands; the approximation, the horizontal detail, the vertical detail and the diagonal detail subbands. Notably, image directionality is described only with three orientations characterized by three wavelets. Besides, DWT does not make any distinction between the diagonal (45°) and the anti-diagonal (135°) orientations, and gets their information mixed together. On the other hand, the DTCWT uses a dual tree of DWT transforms to decompose an image into twelve HF subbands,and some LF subbands . The analysis filters are specially designed so that the first (second) DWT tree will yield the real (imaginary) parts of the resultant complex-valued coefficients. The result is having six complex valued coefficients. Therefore, the DTCWT resolves image HF content into subbands with six distinct orientations instead of three for the DWT. Because of the improved directional selectivity, it is expected that the detail projection stage of the AP algorithm will be further improved. Furthermore, due to the directional selectivity of the DTCWT, an improved inter-channel subband correlation is expected which will make the detail projection more effective..

For natural Images, The R, G and B channels are highly correlated in the HF subbands, so it is expected that the R-G and B-G relationships are very similar. Therefore, the R-G correlation only is provided herein to avoid repetition.

B. G channel denoising

In [3], G channel is reconstructed by edge-directed inter- polation followed by updating G with the HF subbands of the sampled R and B color values at their locations. However, this reconstruction can be further improved by refining this channel with a DTCWT-based denoising. Due to the down sampling of G channel invoked with CFA usage, its HF content exhibits less loss as compared to the other channel information.

Denoising can help in better G channel reconstruction, this is done by decomposing G channel into several decomposition levels and tracing the wavelet amplitudes throughout all levels, when an abrupt reduction in wavelet amplitude is invoked, this means that it was lost during downsampling, and so it needs correction to become near to its values in the other levels. In fact, natural images have the feature of edge persistence, i.e. edges persist to appear with decomposition levels. It has been shown that because of the shift-invariance nature of DTCWT, the persistence of wavelet magnitudes over scales becomes a more valid assumption with this transform [5]. This assumption presents a rationale for image denoising. The advent of denoising herein exploits this feature to contribute to the demosaicing process. Improving G channel at this stage is promising since G is of crucial importance as it plays a dominant role in reconstructing R and B HF content during the AP process. Therefore, G improvement contributes to better reconstruction of the other two channels.

C. R , B channel denoising

The work conducted in [3] considered two constraints for the AP stage, and left the addition of other constraints as an open-ended area. Besides, it has been reported in the literature that natural image properties can be effectively used as demosaicing hints. The AP algorithm starts with a first estimate of the solution and alternately projects it onto some constraint sets which are desirable features that restrict the solution space [4].

The third enhancement presented in this work, is adopting a DTCWT-based Rand B denoising stage as a third constraint to the AP stage. This constraint set exploits the edge persistence principle as a natural image feature, very similarly to utilizing the detail and observation constraints proposed in [3]. The denoising constraint is suggested to be applied just after the detail projection in sequence. Applying this constraint means decomposing R and B channels into several wavelet levels via DTCWT, and then the

HF wavelet amplitudes are corrected by tracing their values throughout all decomposition levels, and reducing sharp jumps in those values.

III. CONCLUSION

Three demosaicing frameworks operating on Bayer CFA data are dicussesd. The first framework alternative projections exploits inter channel correlation.Here two constraint sets are defined based on the observed data and the prior knowledge about the correlation of channels and the initial estimates are projected onto this constraints to reconstruct the color channels.The second framework utilizes an efficient data adaptive filtering concept, a generalized spectral model, and a correction step to produce restored color images. At the same time it yields excellent results in terms of commonly used objective image quality criteria.This paper proposes enhancements to the AP algorithm proposed in [3]. The first one is adopting the DTCWT as framework for the AP algorithm. The motivation behind this idea is the improved directional selectivity attained by this transform, which results in stronger inter-channel HF sub- band correlation. Therefore, G channel information is more accurately extracted and used to reconstruct R and B. The raise in correlation is empirically verified by studying it on a representative image set.The second enhancement is G channel refinement aided with DTCWT denoising, which is shown to contribute to better color reconstruction, not only on for this channel, but also for R and B channels.The third enhancement uses a denoising stage for the R and B channels into the AP loop to assist in better R and B reconstruction.

IV. ACKNOWLEDGEMENT

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