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Image Resolution Enhancement by Using Different Wavelet Image Decompositions

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Abstract—Resolution has been frequently referred as an important aspect of an image. Images are being processed in order to obtain more enhanced resolution. This project propose an image resolution enhancement technique based on interpolation of the high frequency sub band images obtained by discrete wavelet transform (DWT) and the input image. The edges are enhanced by introducing an intermediate stage by using stationary wavelet transform (SWT). DWT is applied in order to decompose an input image into different sub bands. Then the high frequency subbands as well as the input image are interpolated. The estimated high frequency sub bands are being modified by using high frequency subband obtained through SWT. Then all these sub bands are combined to generate a new high resolution image by using inverse DWT

Index Terms— Decomposition, Discrete Wavelet Transform (DWT), Intermediate stage, Interpolation, Resolution, Stationary Wavelet transform (SWT), Sub band Images.

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1 Introduction

Resolution has been frequently referred as an important aspect of an image. Images are being processed in order to obtain more enhanced resolution. One of the commonly used techniques for image resolution enhancement is Interpolation. Interpolation has been widely used in many image processing applications such as facial reconstruction multiple description coding, and super resolution. There are three well known interpolation techniques, namely nearest neighbor interpolation, bilinear interpolation, and bicubic interpolation. Image resolution enhancement in the wavelet domain is a relatively new research topic and recently many new algorithms have been proposed. Discrete wavelet transform (DWT) is one of the recent wavelet transforms used in image processing. DWT decomposes an image into different subband images, namely low-low (LL), low high (LH), high-low (HL), and high-high (HH). Another recent wavelet transform which has been used in several image processing applications is stationary wavelet transform (SWT). In short, SWT is similar to DWT but it does not use down-sampling, hence the sub bands will have the same size as the input image. In this work, we are proposing an image resolution enhancement technique which generates sharper high resolution image. The proposed technique uses DWT to decompose a low resolution image into different sub bands. Then the three high frequency subband images have been interpolated using bicubic interpolation. The high frequency sub bands obtained by SWT of the input image are being incremented into the interpolated high frequency sub bands in order to correct the estimated coefficients. In parallel, the input image is also interpolated separately. Finally, corrected interpolated high frequency sub bands and interpolated input image are combined by using inverse DWT (IDWT) to achieve a high resolution output image. The proposed technique has been compared with conventional and state-of-art image resolution enhancement techniques. The conventional techniques used are the following: Interpolation techniques: bilinear interpolation and bicubic interpolation; wavelet zero padding (WZP). The state-of-art techniques used for comparison purposes are the following: regularity- preserving image interpolation. NEDI-new edge- directed interpolation HMM-hidden Markov model HMM-based image super resolution (HMM SR). WZP and cycle-spinning (WZP-CS). WZP, CS, and edge rectification (WZP-CS-ER). DWT based super resolution (DWT SR). Complex wavelet transform based super resolution (CWT SR). According to the quantitative and qualitative experimental results, the proposed technique over performs the aforementioned conventional and state-of-art techniques for image resolution enhancement.

2 Existing Methods

Image resolution enhancement is the process of improving the clarity of the image. Most of the techniques are based on interpolation. Interpolation has been widely used in many image processing applications such as facial reconstruction, multiple description coding, and super resolution. There are three well known interpolation techniques, namely nearest neighbor interpolation, bilinear interpolation, and bicubic interpolation.

3 Proposed method

Here it is proposed an image resolution enhancement technique which generates sharper high resolution image. The proposed technique uses DWT to decompose a low resolution image into different sub bands. Then the three high frequency subband images have been interpolated using bicubic interpolation. The high frequency sub bands obtained by SWT of the input image are being incremented into the interpolated high frequency sub bands in order to correct the estimated coefficients.

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In parallel, the input image is also interpolated separately. Finally, corrected interpolated high frequency sub bands and interpolated input image are combined by using inverse DWT (IDWT) to achieve a high resolution output image A.

Down sampling-based multiple description image coding using optimal filtering By Y. Rener, J. Wei, and C. Ken, "Down sample-based multiple description coding and post-processing of decoding," in Proc. 27th Chinese Control Conf., Jul. 16–18, 2008, pp. 253–256 In this paper, a multiple description image coding scheme is proposed to facilitate the transmission of images over media with possible packet loss. The proposed method is based on finding the optimal reconstruction filter coefficients that will be used to reconstruct lost descriptions. For this purpose initially, the original image is down sampled and each sub image is coded using standard JPEG. These decoded images are then mapped to the original image size using the optimal filters. Multiple descriptions consist of coded down-sampled images and the corresponding optimal reconstruction filter coefficients. It is shown that the proposed method provided better results compared to standard interpolation filters (i.e., bicubic and bilinear)

The multiple description coding (MDC) approach is used for data transfer over packet networks, which are nowadays widespread. This approach fundamentally provides efficient transmission of multimedia data through these kinds of error-prone networks. MDC carries out this operation by coding and transmitting the original data using more than one bit stream and therefore reduces the influence of possible packet loss.

Various multimedia applications require data transmission over error-prone networks in which part of the data might not arrive at the receiver. Automatic repeat requests executed by the receiver are not possible for real-time data, such as voice and video, because these will cause long delays. The MDC approach enables reconstruction of data at an acceptable quality level in the case of possible packet losses. Original data are coded at the encoder into more than one packet _i.e. multiple descriptions_ such that each one is self-decodable. When all descriptions reach the receiver, data are reconstructed at high quality; otherwise, acceptable quality data are still obtained. Nevertheless, coding efficiency is degraded due to redundancy introduced into descriptions MDC schemes can be grouped according to their computational complexity and redundancy insertion approaches. One of the first MDC methods makes use of multiple description scalar quantizations MDSQ which uses overlapping quantization steps to enable redundancy.

At the decoder the intersection of received quantization steps are used for inverse quantization. These methods transform two input variables into two output variables and then encode the transformed variables. If one of the transformed variables is not received, then it can be estimated at a certain accuracy using the other variable. Polyphone down sampling (PD) based MDC approaches have been proposed. The first type of PD- based MDC approaches quantizes input data at two different quantization levels after down sampling.

The second type of PD-based MDC approaches perform oversampling, by making use of zero padding in the discrete cosine transform (DCT) domain in one or twodimensions.Respectively, before the descriptions are generated. In PD-based MDC approaches, if one of the descriptions is lost at the receiver, then the other samples are used to reconstruct the lost data. MDC redundancy is introduced using frame expansion.

Recently, wavelet based MDC approaches have become popular. The MDSQ approach is applied in the wavelet domain and it is shown that MDC performance is increased

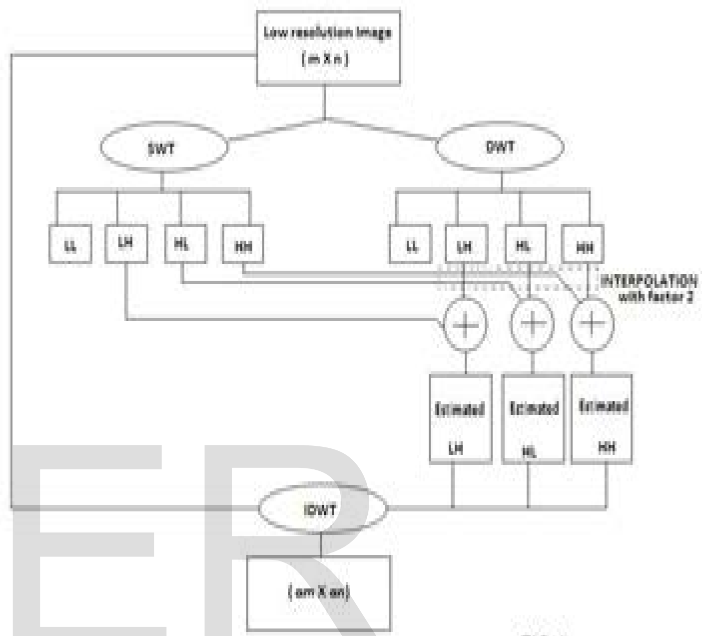

FIG.1

4 Related Works

4.1 PD based MDC Approach

A PD-based MDC approach is used in the wavelet domain, and it is shown that the performance of this method is better than the MDSQ approach. MDC is directly used with a JPEG2000 coder in, where rate distortion characteristic of the input data is examined to introduce an adjustable level of redundancy. PCT is combined with wavelet transform- based image coding, and it is shown that this outperforms MDC in the DCT domain. Down sampling-based image coding has recently been proposed for low bit-rate image coding. In this approach, images are down sampled prior to coding and up sampled at the receiver to reconstruct the full resolution original image. Optimal filtering approach issued to reconstruct the full-resolution image. It is shown that this approach improves the performance significantly in JPEG coding.

A similar approach is also applied to warped cosine transform-based image coding .In this paper, an optimal filtering-based MDC image coding approach that can improve the MDC performance is proposed. This method basically obtains filter coefficients by a least-squares approach, minimizing the difference between encoded and original data, for each description. A higher quality image can be reconstructed at the decoder, performing a filtering operation using the optimal filter coefficients that are included in the descriptions.

4.2 Poly phase Down Sampling

Based Multiple Description Image Coding using Optimal Filtering with Flexible Redundancy Insertion By G. Anbarjafari and H. Demirel, "Image super resolution based on interpolation of wavelet domain high frequency sub bands and the spatial domain input image," ETRI J., vol. 32, no. 3, pp. 390–394,Jun. 2010. In this paper, a novel multiple description image coding scheme is proposed to facilitate the transmission of images over unreliable networks. The target is to minimize the received image distortion over error prone channels. The proposed method is based on adding redundancy to multiple descriptions coding structure to increase correlation between descriptions.

The novelty of the paper is that optimal reconstruction filter coefficients are obtained, that will be used to combine the multiple descriptions in an optimal way, based on least squares minimization of the reconstruction error. It is shown that the proposed method provides better results compared to existing approaches in the literature. Nowadays wired and especially wireless networks are widespread, and therefore transmitting data packets over error-prone networks is very important. Moreover many multimedia applications such as video conferencing, digital video broadcast require large bandwidth and limited delay time. These constraints may cause important problems in some applications that require real time data transmission. Multiple descriptions coding (MDC) approaches provide a reasonable solution for such mediums. MDC creates self decodable data packets, so called descriptions, to transfer data over unreliable networks . In the case of packet loss some of the descriptions might not reach the decoder. In such cases, the decoder utilizes only the received descriptions to reconstruct the original data as good as possible. If all descriptions are received, a higher quality signal can be reconstructed. However, since certain level of redundancy to is introduced to recover lost data, the overall coding efficiency may be degraded.

The purpose of MDC is to effectively transmit data such as voice, image and video, over error-prone networks. Multiple description scalar quantization is presented in to provide rate distortion bounds. It is proposed to use MDC for voice communication in creating two descriptions using odd and even samples of the speech signal. These descriptions are encoded using two separate differential pulse code modulation (DPCM) encoders. The method in , which is referred to as Pair wise Correlating Transform (PCT) performs encoding on the transformed variables. Typically if one of the two transformed input variables is not received, the original signal is estimated making use of the other received variable.

The lapped orthogonal transform is used for multiple description images coding in. Some poly phase down-sampling (PD) based approaches are also presented in the literature. PD based MDC approaches can be grouped into two main categories. The first one introduces the redundancy by employing different quantization levels for each description as described in. The second approach is to insert the redundancy using a zero padding approach in the DCT (Discrete Cosine Transform) domain, as in. Then, multiple descriptions are generated by simply sub-sampling the oversampled image data. MDC can also be used for 3-D model coding. The method in employs a wavelet subdivision surfaces strategy for 3-D model coding and introduces 3-D multiple description capabilities.

In the literature, it is shown that down-sampling prior to image coding at the encoder, and succeeding up-sampling after decoding at the decoder provides better results.Compared to conventional image coding at low bit- rates. In, an optimal filtering approach is investigated for the minimization of the difference, introduced by decimation and encoding, between the original and decoded image. Hence, it is shown that the performance of standard JPEG coding can be improved in this way. In, the optimal filtering concept presented in is applied for MDC, employing a PD framework. Four sub-images are created by simply down sampling the original image. Next, each sub-image is encoded using standard baseline JPEG and using the optimal filtering concept a total of sixteen optimal filters are obtained. The sub-images and related filter coefficients are combined to create equally important and independent multiple descriptions. It is shown that such a scheme can provide better performance with respect to standard schemes. In this paper it is proposed to combine the zero padding based PD approach in with the optimal filtering based MDC approach in to enable even better performance for multiple description coding. Following this idea we present a MDC approach that is superior compared to the methods presented.

4.3 Improved Motion-Based Localized Super Resolution Technique Using DWT

Improved Motion-Based Localized Super Resolution Technique Using Discrete Wavelet Transform For Low Resolution Video Enhancement By H. Demirel, G. Anbarjafari, and S. Izadpanahi, Improved motion based localized super resolution technique using discrete wavelet transform for low resolution video enhancement," in Proc. 17 th Eur. Signal Process. Conf., Glasgow, Scotland, Aug. 2009, pp. 1097–1101. Super resolution is used for resolution enhancement of images or video sequences. Instead of super resolving frames globally, using localized motion based super resolution increases the quality of the enhanced frames. In this paper, we propose to use the super resolution on different sub bands of localized moving regions extracted from discrete wavelet transform (DWT) and composing the super resolved sub bands using inverse DWT (IDWT) to generate the respective enhanced high resolution frame. The results based on PSNR values, in comparison with he global super resolution method, show improvement in quality. The improvement is achieved by isolating different frequencies in different sub bands extracted from DWT and super resolving them separately. There are several ways of performing super resolution algorithms, but most of them are variations on two main approaches. The first approach is multi-frame super resolution which is based on the combination of image information from several similar images taken from a video sequence. This method consists of two main stages, firstly estimating motion parameters between two images referred as registration, and secondly projecting the low resolution image into the high resolution lattice referred as reconstruction.

The second approach is called single-frame super resolution, which uses prior training data to enforce super resolution over a single low resolution input image. In this paper we are using multi frame super resolution taken from low resolution video sequences.

Tsai and Huang are the pioneers of super resolution idea, who used the frequency domain approach. Further work has been done by Keren, et al. who described a spatial domain procedure to perform image registration using a global translation and rotation model. Lucchese and Lucchese presented a method for estimating planar roto-translations that operates in the frequency domain and hence is not based on features. Another frequency domain approach was introduced by Reddy et al.

Their method utilizes separately rotational and translational components of the Fourier transform similar to . Irani et al. has developed a motion estimation algorithm, which considers translations and rotations in spatial domain. Demirel et al. introduced a method which reduced the computational cost of the multi-frame super resolution by utilizing motion based localization and also improved the quality of the enhanced super resolved frames. In the moving region has been separately super resolved by using the state- of-art methods such as the method of Irani et al. and the static region has been simply interpolated using bicubic interpolation. Image and video resolution enhancement in the wavelet domain is a relatively new research area and recently new algorithms have been proposed. In this work, we propose to use the super resolution on different wavelet sub bands of localized moving regions and composing the super resolved sub bands using inverse DWT (IDWT) to generate the respective enhanced high resolution frame. Localized moving region registration is more precise than global registration of the entire frame, due to the fact that local alignment of the changes in the local neighborhood is more efficient. The proposed super resolution method is tested using different super resolution methods described in as reported in the previous work to achieve enhanced high resolution video sequences.

4.4 Image Resolution Enhancement using Inter-Subband Correlation in Wavelet Domain

Image Resolution Enhancement using Inter- Subband Correlation in Wavelet Domain By Y. Piao, I. Shin, and H. W. Park, “Image resolution enhancement using inter-subband correlation in wavelet domain,” in Proc. Int. Conf. Image Process., 2007, vol. 1, pp. I-445–448. Wavelet-based resolution enhancement methods improve the image resolution by estimating the high-frequency band information. In this paper, we propose a new resolution enhancement method using inter-subband correlation in which the sampling phase in DWT is considered. Interpolation filters are designed by analyzing correlations between sub bands having different sampling phases in the lower level, and applied to the correlated sub bands in the higher level. The filters are estimated under the assumption that correlations between two sub bands in the higher level are similar to that in the lower level in DWT. The experimental results show that our proposed method outperforms the conventional interpolation methods including the other wavelet-based methods with respect to peak signal-to-noise-ratio (PSNR) as well as the subjective quality. Conventional image resolution enhancement methods, such as bilinear and bicubic interpolation methods may generate false information and blurred images because they do not utilize any information relevant to edges in the original image. They were based on the assumption that the image to be enhanced was the low frequency sub band among wavelet-transformed sub bands of the original one and the target is to estimate the high frequency sub bands of wavelet transform, so that a resolution-enhanced image can be obtained. Because the analysis filter bank used in the wavelet transform has a poor frequency characteristic such as wide transition region, some information of high-frequency band is remained in the low frequency band.

The resolution enhancement methods in wavelet domain are very significant not only for enlarging the image size but also for in-band scalable video coder. In in-band scalable video coding, because the motion estimation is performed in wavelet domain, over- complete form of reference bands is usually used to solve the shift-variance problem in wavelet domain. However, it rings serious drifting errors in decoder since the high frequency bands are not available to construct the over complete form of reference band and the drifting error propagates along the lifting structure of temporal filtering. If the unavailable high-frequency bands are estimated from the only available low- frequency band in the decoder, the drifting error will be reduced dramatically.

5 IMAGE RESOLUTION ENHANCEMENT

In image resolution enhancement by using interpolation the main loss is on its high frequency components (i.e., edges), which is due to the smoothing caused by interpolation. In order to increase the quality of the super resolved image, preserving the edges is essential. In this work, DWT has been employed in order to preserve the high frequency components of the image. The redundancy and shift invariance of the DWT mean that DWT coefficients are inherently interposable [9]. In this correspondence, one level DWT (with Daubechies 9/7 as wavelet function) is used to decompose an input image into different subband images. Three high frequency sub bands (LH, HL, and HH) contain the high frequency components of the input image. In the proposed technique, bicubic interpolation with enlargement factor of 2 is applied to high frequency subband images. Down sampling in each of the DWT sub bands causes information loss in the respective sub bands. That is why SWT is employed to minimize this loss. The interpolated high frequency sub bands and the SWT high frequency sub bands have the same size which means they can be added with each other. The new corrected high frequency sub bands can be interpolated further for higher enlargement. Also it is known that in the wavelet domain, the low resolution im-

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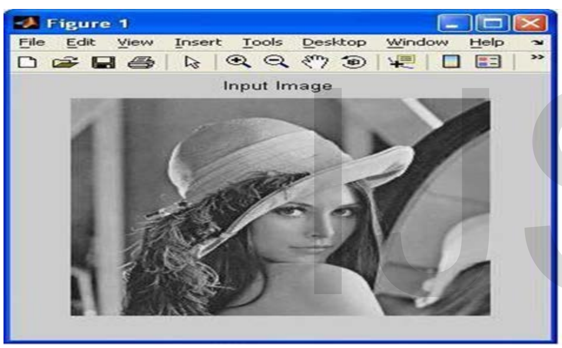
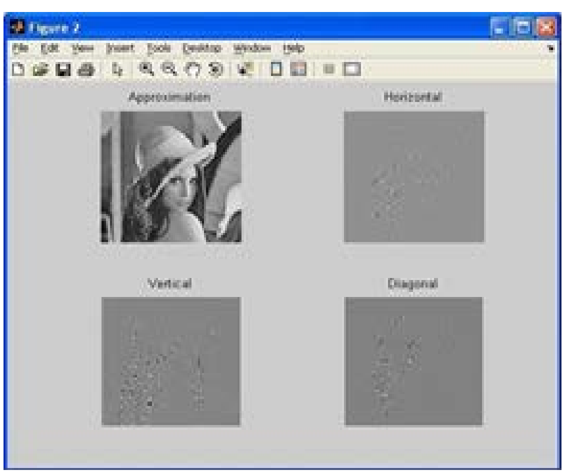
age is obtained by low pass filtering of the high resolution image .In other words, low frequency subband is the low resolution of the original image. Therefore, instead of using low frequency subband, which contains less information than the original high resolution image, we are using the input image for the interpolation of low frequency subband image.

Using input image instead of low frequency subband increases the quality of the super resolved image. Fig. 1 illustrates the block diagram of the proposed image resolution enhancement technique. By interpolating input image and high frequency sub bands by 2 and in the intermediate and final interpolation stages respectively, and then by applying IDWT, as illustrated in Fig. 1, the output image will contain sharper edges than the interpolated image obtained by interpolation of the input image directly.

This is due to the act that, the interpolation of isolated high frequency components in high frequency sub bands and using the corrections obtained by adding high frequency sub bands of SWT of the input image will preserve more high frequency components after the Interpolation than interpolating input image directly.





6 Conclusion

This work proposed an image resolution enhancement technique based on the interpolation of the high frequency sub bands obtained by DWT, correcting the high frequency subband estimation by using SWT high frequency sub bands, and the input image. The proposed technique uses DWT to decompose an image into different sub bands, and then the high frequency subband images have been interpolated. The interpolated high frequency subband coefficients have been corrected by using the high frequency sub bands achieved by SWT of the input image. An original image is interpolated with half of the interpolation factor used for interpolation the high frequency sub bands. Afterwards all these images have been combined using IDWT to generate a super resolved imaged. The proposed technique has been tested on well-known benchmark images, where their PSNR and visual results show the superiority of proposed technique over the conventional and state-of- art image resolution enhancement techniques.

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