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Resolution Increment & Quality Enhancement of Video Frame using Stationary and Discrete Wavelet Transform with Planar Histogram Equalization

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Abstract

Resolution increment is a technique of increasing the resolution of image and video frame to fit to the current requirement of high resolution appliances. The need for resolution increase arise because of transmission/capture of high resolution image and video is costlier along with a requirement high bandwidth in communication leading to higher storage space requirement. Many researchers are working in regenerating high resolution image and video frame from low resolution image and video frame to reduce cost of capturing devices, decreasing usage of bandwidth with reduction in storage space. In this article, we address generation of high/super resolution video frame from low resolution video frame through a combination of decomposing stationary wavelet transform and reconstructing discrete wavelet transform. When the resolution of video frame is increased the highest importance must be given to preserve the quality of video frame. For preserving the quality of video frame planar histogram equalization is applied along RGB color planes. The results of experimentation are measured in objective fidelity criteria through peak signal to noise ratio, mean square error and root mean square error. The comparative statistics of objective fidelity criteria reveal experimental results are competent and improved compared to state of art wavelet resolution enhancement technique wavelet zero padding.

Keywords: Stationary Wavelet Transform, Discrete Wavelet Transform, Complex 2D discrete wavelet transform, Planar Histogram Equalization.

1. INTRODUCTION

The resolution of displayed image/video frame (IM/VF) plays a prime role in assessing the standard of day to day multimedia appliances starting from television to mobile phone. The high resolution multimedia appliances need elevated cost imaging solutions, increased storage capacities along with increase in transmission cost with higher bandwidth. The latest research strategy of high resolution multimedia appliances is in resolution increase and quality enhancement (RIQE) of video frames. RIQE is a crucial topic of research for creating high resolution multimedia IM/VF, which starts with either capturing low resolution image/video frame (LR-IM/VF) or decreasing the resolution of high resolution image/video frame (HR-IM/VF) for reducing transmission cost and bandwidth then later increasing its resolution to fit to multimedia appliances by cutting the cost of imaging solutions, storage and transmission.

The projected architecture of RIQE begins first by creation of low resolution video frame (LR-VF) for experimentation from reference high resolution video frame (HR-VF). The reference HR-VF works as a indicator for comparing the quality of RIQE generated HR-VF. The created LR-VF is used in video transmission for reducing bandwidth, storage and cost of transmission. In the projected architecture LR-VF is created through applying decomposing dual tree complex 2D discrete wavelet transform (DTC2D-DWT). The LR-VF is subjected to decomposing stationary discrete wavelet transform (DSDWT). The advantage of DSDWT is decomposed four components are not down sampled[1] but it increases data redundancy[1]. In the next step decomposed four components of DSDWT are subjected to reconstructive discrete wavelet transform (RDWT). The RDWT has inherent up sampling filter[2][3] which leads to increase in resolution by a factor of 2.0. The major requirement in all multimedia appliances is visual appearance, for which planar histogram equalization(PHE)[3][4][5][6] is applied on resultant video frame(VF) of RDWT leading to generation of HR-VF. The generated HR-VF is compared in mean square error(MSE)[7][8][9], root mean squared error(RMSE)[8][9] and peak signal to noise ratio(PSNR)[7][8][9] with reference HR-VF. The comparison statics are significantly improved compared to state of art wavelet domain resolution increment technique wavelet zero padding(WZP)[10] results both in MSE, RMSE & PSNR and visual results shown in figure 5 and 6.

The remaining sections of this paper are organized as, the latest research in wavelet domain resolution increment technique are discussed in section 2. The projected experimentation design for creation of LR-VF through DTC2D-DWT and wavelet domain RIQE technique are shown in section 3. The objective fidelity comparison statistics with visual results are stated and discussed in section 4. The section 5 presents the summary of this article.

2. RELATED WORK

The resolution increment algorithms for IM/VF are mainly build under either spatial domain or frequency domain or the combination of both. These algorithms are primarily categorized based on either applying interpolation/zooming[3] [11][12] techniques directly or using interpolation/zooming techniques in their architecture or applying machine learning[13][14] techniques or using the analyzing and synthesis filter construction structure of wavelet transform technique.

The latest research in resolution increment techniques are focusing on wavelet transform. The wavelet domain resolution increment techniques are categorized based on either using only wavelet transform in resolution increment and other uses wavelet domain wherein wavelet characteristics are combined with interpolation algorithms for resolution increase.

The most familiar algorithm in wavelet transform which increase resolution of IM/VF only through up sampling filters present in wavelet design is WZP[10]. The architecture of WZP uses RDWT having LR-IM/VF as one component and other three components are taken as zero, When RDWT is applied on these four components the resolution of input IM/VF is increased by a factor of 2.0. The other category of resolution increment algorithms are explored under three variants of wavelet transform, they are discrete, stationary and complex. The resolution increment algorithms in discrete wavelet transform(DWT)[15][16] work on four different sub band components of IM/VF i.e. the first one is LR-IM/VF which is interpolated to the half of the required interpolation factor and to preserve sharpness the input IM/VF is correlated to interpolated IM/VF and the difference is added to other three high frequency IM/VF components which are interpolated by a factor 2. Then all four components are interpolated by half of required resolution and subjected to RDWT to have high resolution. Instead of adding difference to high frequency IM/VF components stationary wavelet transform(SWT)[17][18] is used in generating HR-IM/VF i.e. high frequency IM/VF components of SWT are added with high frequency IM/VF components of DWT which are interpolated by a factor 2. Then all four components are interpolated by half of required resolution and subjected to RDWT to have HR-IM/VF. The DWT provides multi resolution(MR) analysis but suffer from 2 major problems[19] i.e. crucial shift variance and poor direction selection. To address above problems complex wavelet transform(CWT) were developed and many researchers applied CWT in RIQE on different classes in IM/VF. The [20] focus on enhancing resolution of image using CWT, which decompose the input IM/VF into 6 high frequency components and 2 low frequency component. The 2 low frequency component are discarded and original input IM/VF interpolated by half of required interpolation factor are taken 2 low frequency component with 6 high frequency component are interpolated by required interpolation factor then all 8 components are subjected to inverse CWT to generate HR-IM/VF. The [21] in satellite input image resolution increment used nonlocal means along with Lanczos interpolation in CWT domain for generation of high resolution IM/VF.

The most resolution increment algorithms in wavelet domain other than WZP uses interpolation algorithms for their resolution increment and enhancement. This article explore the inbuilt up sampling filter design of RDWT for decomposed DSDWT components which increases the resolution of input LR-VF by factor of 2.0 the results are subjected to PHE for better visual appearance. The results are compared with statistics of WZP which reveal obtained results are competent and improved.

3. PROPOSED ARCHITECTURE

The projected architectural diagram of LR-VF creation is shown in figure 1. The reference HR-VF is subjected to decomposing DTC2D-DWT[22] resulting in two LR-VF and six distinct direction components each for real and imaginary wavelets. The decomposing DTC2D-DWT has inbuilt down sampling filter which reduce the reference HR-VF resolution by a factor of 2.0. The LR1-VF of figure 1 is taken as LR-VF for experimental construction of HR-VF shown in figure 2. The constructed HR-VF is compared in MSE, RMSE &PSNR with reference HR-VF. The resultant statics are tabulated in table II and compared with results WZP in figure 7,8 and 9.

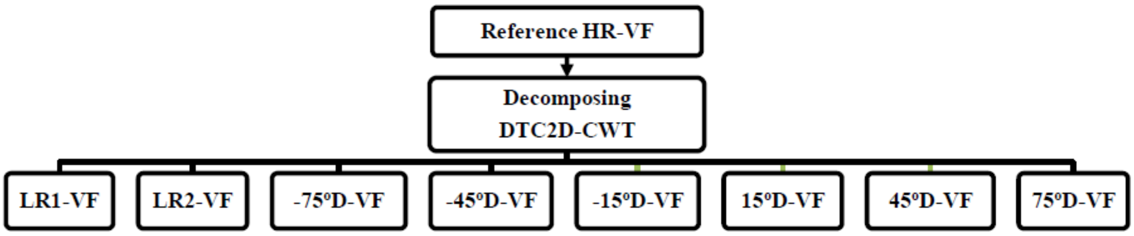

Fig. 1 Creation of LR-VF through decomposing DTC2D-DWT

3.1 Notations Used

The notations used in this article are listed in table I.

Table I: Notations Used

Notation	Description
IM/VF	Image/Video Frame
RIQE	Resolution Increase and Quality Enhancement
HR- IM/VF	High Resolution Image/Video Frame
LR-IM/VF	Low Resolution Image/Video Frame
LR-VF	Low Resolution Video Frame

HR-VF	High Resolution Video Frame
DTC2D-DWT	Dual Tree Complex 2D Discrete Wavelet Transform
DSDWT	Decomposing Stationary Discrete Wavelet Transform
RDWT	Reconstructive Discrete Wavelet Transform
PHE	Planar Histogram Equalization
VF	Video Frame
MSE	Mean Square Error
RMSE	Root Mean Squared Error
PSNR	Peak Signal to Noise Ratio
WZP	Wavelet Zero Padding
DWT	Discrete Wavelet Transform
SWT	Stationary Wavelet Transform
MR	Multi Resolution
CWT	Complex Wavelet Transform
LRLR-VF	Low Resolution LR-VF
HDLR-VF	Horizontal Detail LR-VF
VDLR-VF	Vertical Detail LR-VF
DDLR-VF	Diagonal Detail LR-VF
SR-VF	Super Resolution Video Frame

3.2 Proposed Architectural Design of RIQE

The architectural design diagram of RIQE for construction HR-VF is displayed in figure 2. The architecture starts with LR-VF as input and subjected to DSDWT leading to generation of four components low resolution LR-VF(LRLR-VF), horizontal detail LR-VF(HDLR-VF), vertical detail LR-VF(VDLR-VF) and diagonal detail LR-VF(DDLR-VF). The key aspect of DSDWT is all decomposed components LRLR-VF, HDLR-VF, VDLR-VF and DDLR-VF are not down sampled i.e. the resolution of these components are same as LR-VF. In the current research this feature of DSDWT is explored for resolution increase of LR-VF using RDWT. The decomposed components LRLR-VF, HDLR-VF, VDLR-VF and DDLR-VF are subjected to RDWT for creation of initial HR-VF. The RDWT has inbuilt up-sampling filter which increase the resolution of combined VF by a factor for 2.0 which increase the resolution of LR-VF by a factor of 2. The most inherent requirement of multimedia appliances is visual quality and resolution of video, Hence, the resultant initial HR-VF of RDWT is subjected to PHE along 3 color planes red, green & blue, the results are combined to form HR-VF taken as super resolution video frame(SR-VF). The generated HR-VF is contrasted with reference HR-VF and the objective fidelity results are tabulated in table II and visual results are shown in figure 6. The results are compared and contrasted with WZP results in table II and figure 7,8 and 9, which demonstrates the competency of obtained results over WZP.

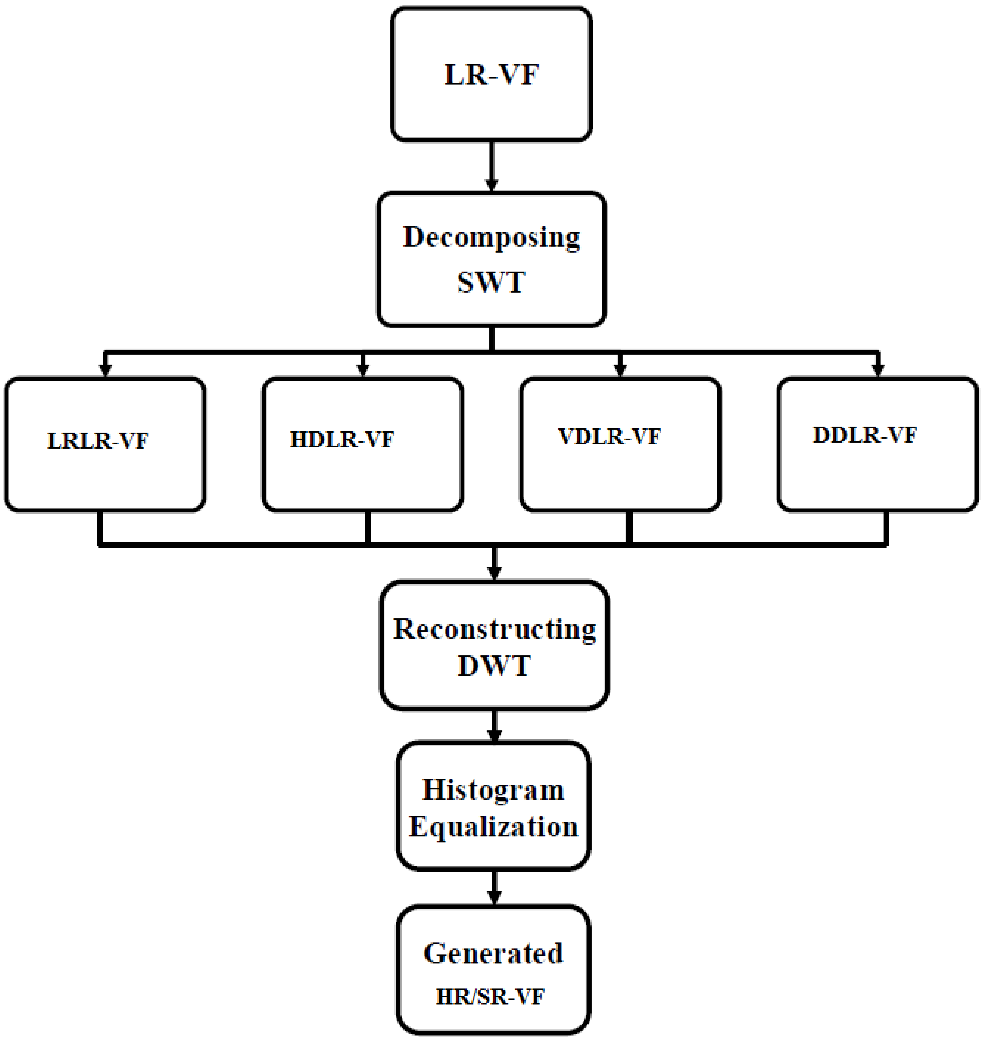

Fig.2. Proposed Architecture of RIQE

4. RESULTS WITH DISCUSSION

The experimentation is conducted on UT Interaction video dataset[23] of human interaction having 30fps. The video frames taken from video and used for experimentation are shown in figure 3, which serves as reference HR-VF.

Frame1	**Frame2**	**Frame3**	**Frame4**

Fig.3: Reference HR-VF of experimentation

The first phase of experimentation starts with creation LR-VF by applying decomposing DTC2D-DWT as shown in figure 1. The yielded results of experimentation are shown in figure 4, which serve as input for RIQE architecture in figure 2.

Frame1	**Frame2**	**Frame3**	**Frame4**

Fig: 4. LR-VF created through decomposing DTC2D-DWT

The LR-VF are subjected to WZP experimentation for resolution increase. The resultant HR-VF of WZP are increased in resolution by a factor of 2.0 and shown in figure 5. The results in figure 5 are contrasted with reference HR-VF of figure 3 and the resultant statistics are tabulated in table II.

Frame1	**Frame2**	**Frame3**	**Frame4**

Fig.5: Generated HR-VF through WZP

In projected experimentation conducted on LR-VF of figure 4 as per architectural layout of RIQE in figure 2 yields HR-VF shown in figure 6. The resultant HR-VF of figure 6 are increased in resolution twice the LR-VF because of up sampling filter present in RDWT. The results in figure 6 are contrasted with reference HR-VF of figure 3 and the resultant statistics are tabulated in table II.

Frame1	**Frame2**	**Frame3**	**Frame4**

Fig.6: Generated HR/SR-VF through proposed method

The corresponding statistics analysis of table II, WZP & projected architecture reveal RIQE yields lower comparison error rate with higher peak signal relation rate respectively. The insight reveals the projected RIQE results are competent and significantly improved both in objective statics comparison of table II and visual HR-VF result comparison of figure 5 & 6.

Table II: Calculated statistics of WZP and projected RIQE

Frames	WZP			Projected RIQE		
	MSE	RMSE	PSNR	MSE	RMSE	PSNR
Frame1	254.6089	15.9565	24.0721	119.4242	10.9281	27.3599
Frame2	254.2727	15.9459	24.0778	120.8897	10.9950	27.3069
Frame3	254.2493	15.9452	24.0782	118.6558	10.8929	27.3879
Frame4	254.2938	15.9466	24.0774	117.1741	10.8247	27.4425

The calculation data statistics of table II are plotted in figures 7-9 for RMSE, MSE and PSNR respectively. The RMSE & MSE performance comparison plot of Fig. 7&8 reveals error between reference HRVF and constructed HRVF is lower in projected RIQE than WZP, which ensures projected RIQE constructs HR-VF more accurately than WZP.

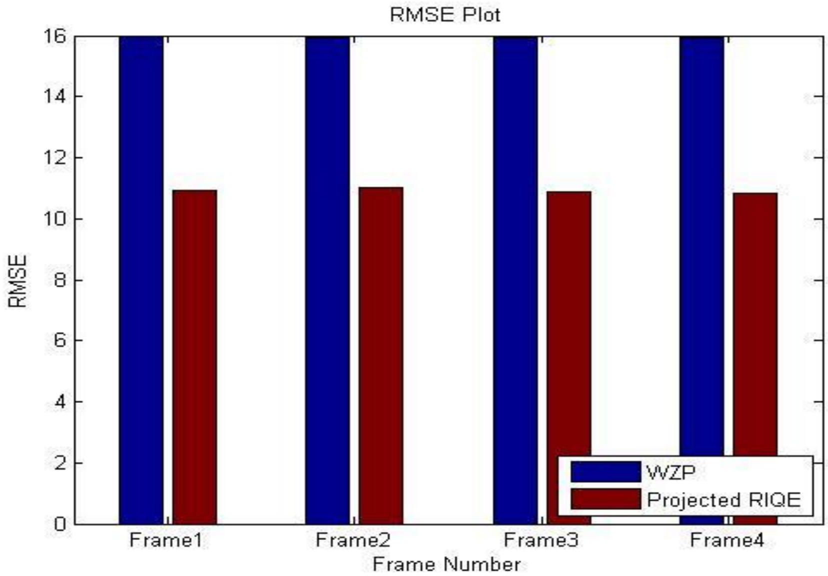

Fig.7: RMSE comparison plot

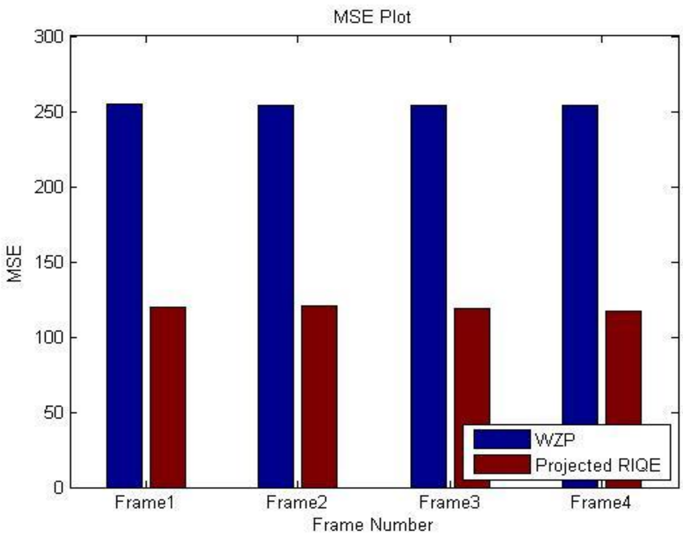

Fig. 8: MSE comparison plot

The PSNR performance comparison plot of figure 9 reveals maximum pixel value to mean error between reference HR-VF and constructed HR-VF is higher in projected RIQE than WZP, which ensures projected RIQE constructs HR-VF with more accurate pixel value than WZP.

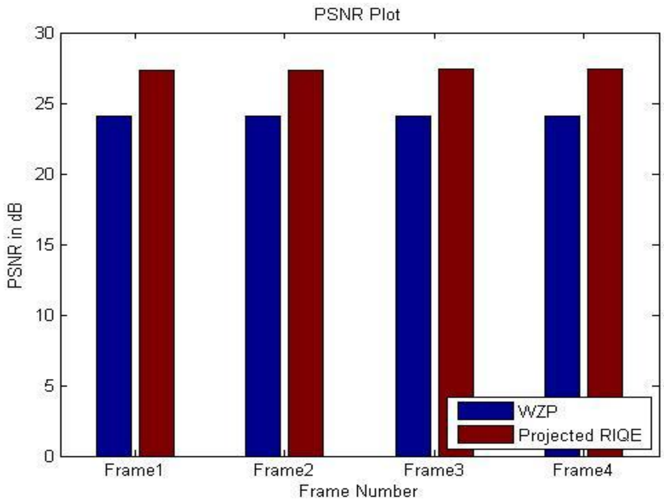

Fig. 9: PSNR comparison plot

CONCLUSION

This paper propose architectural design of RIQE for construction HR-VF from LR-VF created through decomposing DTC2D-DWT. In the beginning the decomposing DTC2D-DWT is applied on reference HR-VF for creation of LR-VF, since decomposing DTC2D-DWT has inbuilt down-sampling filter it reduce the resolution of reference HR-VF by factor of 2.0. Later the LR-VF is subjected to RIQE architecture which as DSDWT which will decompose the LR-VF into four components but it won't decrease resolution then the decomposed components are subjected to RDWT which has inbuilt up-sampling filter which increase the resolution of LR-VF by a factor of 2.0. At the end for better visual result and qualitative measure the results of RDWT are applied with PHE and the results are compared with reference HR-VF in MSE, RMSE & PSNR which reveal obtained results are better with competent algorithm in wavelet space.

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