A novel Super Resolution Algorithm Using Interpolation and LWT Based Denoising Method

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Abstract

Image capturing technique has some limitations and due to that we often get low resolution(LR) images. Super Resolution(SR) is a process by which we can generate High Resolution(HR) image from one or more LR images. Here we have proposed one SR algorithm which takes three shifted and noisy LR images and generate HR image using Lifting Wavelet Transform(LWT) based denoising method and Directional Filtering and Data Fusion based Edge-Guided Interpolation Algorithm.

Keywords: Super Resolution, Interpolation, Wavelet Lifting Scheme

1. INTRODUCTION

Processing power limitations and channel capabilities are some of the factors because of which images are transmitted at low bit rates and down sampled and due to this reason we get LR compressed images. Computational process known as super resolution(SR) image reconstruction is used to reconstruct HR image from one or more noisy, blurred and down sampled LR images.

For the same scene we can have different images with different looks. Due to capturing technique images are aliased as well as shifted with sub pixel precision[14]. The basic idea for increasing the spatial resolution in SR image reconstruction technique is the availability of several LR images captured from the same scene. Many different methods like nonuniform interpolation, frequency domain approach, regularization and projection onto convex set [13,16] are available for doing Super Resolution.

Related problem to SR called Image restoration is one of the famous area in image processing applications in which we recover degraded images(remove noise, blur etc. from source image)[2,3,15]. The main difference between SR technique and restoration is that restoration does not change size of the image while in SR we do restoration as well as increase the size of image. Super Resolution is very useful in many practical cases like video applications, medical imaging and satellite imaging. SR is also useful in Synthetic zooming of region of interest (ROI) which is used in surveillance, forensic, scientific, medical, and satellite imaging.

In this paper we have presented one SR algorithm in which we have taken three LR images which are shifted and noisy. First we estimate shift between images using shift estimation algorithm, using these information next we align all three images and fuse them so we get single image. On this image we have applied LWT based denoising method for removing noise. Finally using Directional Filtering and Data Fusion based Edge-Guided Interpolation Algorithm we can get SR image. We have used wavelet lifting based denoising algorithm because implementation of lifting scheme is easy. It is fast as it can be computed in linear time and requires less memory. We can improve image quality by adding detail information and achieve high compression ratio too.

Paper is organized as follows. In section II we have briefly described shift estimation and fusion method, Section III provides wavelet lifting scheme for HAAR wavelet and denoising algorithm based on HAAR LWT, in section IV we have presented interpolation algorithm. We have presented our proposed algorithm and experiment results in section V. Finally section VI contain conclusion.

2. SHIFT ESTIMATION AND FUSION METHOD

Here we have considered RGB images. It is stored as [m,n,1:3] array of class double. Each color component contains floating-point values in the range of 0 to 1. Each row contains the red, green, and blue components of a single color. Array of RGB image can be of class uint16, uint8 or double. Pixel with color component (1,1,1) is displayed as white while (0,0,0) is displayed as black. The third dimension of the data array contains three color components for each pixel. As shown in figure, the red, green, and blue color components of the pixel (9,7) are stored in RGB(9,7,1),RGB(9,7,2), and RGB(9,7,3) respectively[5].

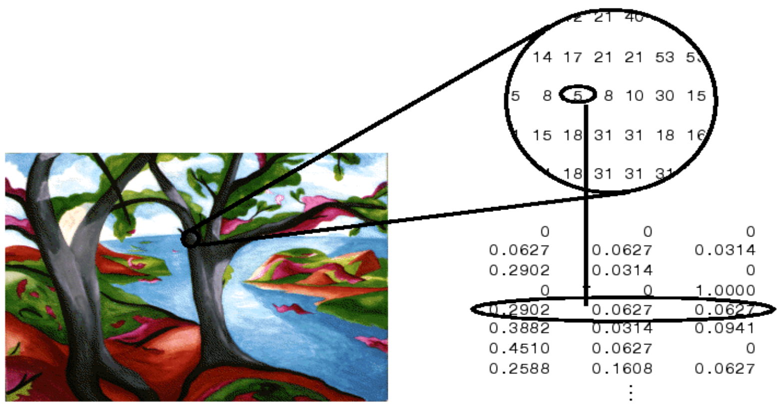

FIGURE 1 : RGB image[5]

2.1 Shift Estimation Method

For doing super resolution, first we need to align LR images and for that we have to do image registration. We can align two or more images of the same scene using registration (Images are taken from different viewpoints or taken at different times)[4,8]. From available LR images, we consider one image as reference image (base image) to which we can compare other input images. Main goal of registration is to do alignment of input images with the reference image by applying a spatial transformation.

We have considered three shifted images so our first task is to estimate shift between these images in both x and y coordinates. For shift estimation (here we have not consider rotation in images), we have used A Frequency Domain Approach to Registration presented in [9] by Patrick Vandewalle. In Fourier domain, shift between images can be expressed as

$$F_2(x) = e^{j2\Pi x^T \Delta s} F_1(x)$$

So we need to find out Δs only. Here we have briefly presented shift estimation algorithm.

Step 1 : Make input images circularly symmetric.
Step 2 : Compute Fourier transform of all LR images.
Step 3 : Consider one image as reference image.
Step 4 : Compute phase difference between reference image and other images.
Step 5 : For all frequencies, write linear equation with unknown slope Δs.
Step 6 : Find shift parameter Δs.

2.2 Fusion Method

For doing fusion of three images, we have consider each pixel of the images separately. We fetch R, G and B component of each pixel from all three images and fuse all R,G and B component separately. For example three images are i1, i2 and i3, then consider pixel (3,5) of all images. We find mean value of R component of i1(3,5),i2(3,5) and i3(3,5), Same way for G and B component. From all these three value we get single pixel (3,5) in fused image. Below we have shown the code for doing fusion of three images.

```
        for i=1:m
        for j=1:n

        R = [i1(i,j,1) i2(i,j,1) i3(i,j,1)];
        G = [i1(i,j,2) i2(i,j,2) i3(i,j,2)];
        B = [i1(i,j,3) i2(i,j,3) i3(i,j,3)];

        fused(i,j,1)= mean(R);
        fused(i,j,2)= mean(G);
        fused(i,j,3)= mean(B);
        end
end
```

we have used mean value for fusion as shown above(we can take median value also but it takes lot of time for computation) and we have taken care of shift between the images that we have found initially.

3. WAVELET LIFTING SCHEME

Next we have to apply denoising method on fused image. For that we have used HAAR lifting wavelet Transform. For signal decomposition, we can use analysis filter bank which consist of low pass and high pass filters at each decomposition stage and split signal into two bands. The low pass filter fetch the coarse information(corresponds to an averaging operation) while high pass filter fetch detail information(corresponds to a differencing operation) of the signal. Finally the filtering operation's output is decimated by two[6,11].

For two-dimensional transform, the image is filtered along the x-dimension using low pass and high pass analysis filters and decimated by two. Then it is followed by filtering the sub-image along the y-dimension and decimated by two. Finally, the image has been split into four bands denoted by LL, HL, LH, and HH, after one level of decomposition[12,17]. The LL band is again subject to the same procedure. This process of filtering the image is called pyramidal decomposition of image. This is depicted in Fig. 2. The reconstruction of the image can be carried out by reversing the above procedure and it is repeated until the image is fully reconstructed.

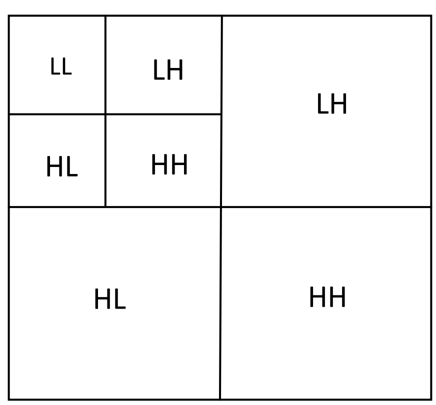

FIGURE 2 : One level Decomposition of image

3.1 Lifting Scheme Haar Transform[1]

The wavelet lifting scheme is a method for decomposing wavelet transforms into a set of stages. The forward lifting wavelet transforms has three steps, split step, predicate step and update step. Split step divides the data set into odd and even elements. The predict step uses a function that approximates the data set. The difference between the approximation and the actual data replaces the odd elements of the data set. The even elements are left unchanged and become the input for the next step in the transform. The update step replaces the even elements with an average. The simplest version of a forward wavelet transform expressed in the lifting scheme is shown in figure 3.

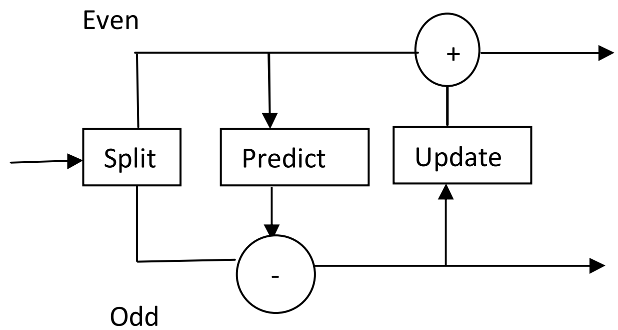

FIGURE 3 : Forward wavelet lifting Scheme[18]

In HAAR forward wavelet lifting Scheme, odd elements are equal to even elements in prediction step. The odd element are replaced by the difference of predicted value and actual value of odd element. For iteration y and element x, the new odd element, y+1,x would be

$$odd_{y+1, x} = odd_{y, x} - even_{y, x}$$

Even elements are replaced by average of even/odd pair in update step.

$$even_{y+1,x} = (even_{y,x} + odd_{x,y}) / 2$$

Value of $odd_{y,x}$ element has been changed by the difference between this element and its even predecessor.

$$odd_{y,x} = even_{y,x} + odd_{y+1,x}$$

We get average by substituting above,

$$even_{y+1,x} = (even_{y,x} + even_{y,x} + odd_{y+1,x}) / 2$$
$$even_{y+1,x} = even_{y,x} + (odd_{y+1,x} / 2)$$

As in shown in below figure, for the next recursive step averages become the input.

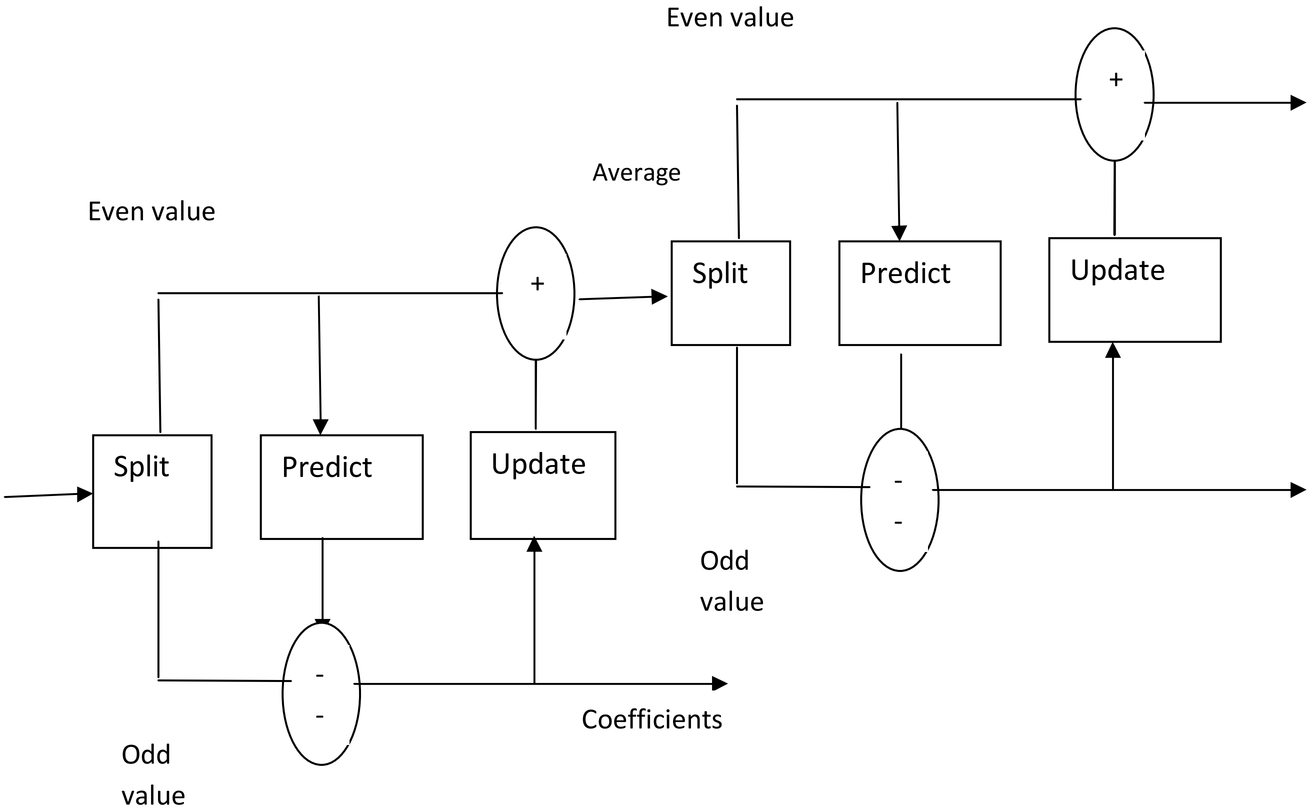

FIGURE 4 : Two steps in Forward wavelet lifting scheme[18]

Good thing in lifting scheme is that, inverse lifting is same as forward lifting. In HAAR wavelet lifting schemes what we have to do is, replace addition with substitution and visa versa and replace split step with merge step.

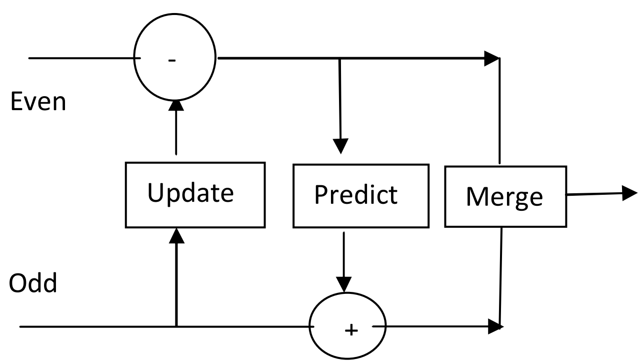

FIGURE 5 : Inverse lifting scheme [18]

3.2 Denoising Using Lifting Wavelet Transform (LWT)

Denoising techniques are necessary to remove additive noise at the same time maintain the important details of the image. LWT based denoising method gives good result as wavelet transform contain large coefficients of image which represent detail of image at different resolution. Two methods are available for denoising. i)Hard Thresolding ii) Soft Thresolding[1].

HARD THRESHOLDING : I(P,T) = P if |P| > T and I(P,T) = 0 if |P| < T
SOFT THRESHOLDING : I(P,T) = sign(P) * max(0, |P| - T)

Where T is the threshold level, P is the input subband and D is the denoised band.

In LWT image is decomposed into four bands(LL,LH,HL,HH). For our denoising algorithm we only consider LH,HL and HH subbands because LL subband contains main information about the image while main noise is present in other three subbands. we have used the Median Absolute Deviation (MAD) to calculate noise level.

$$\sigma = \text{median } |S_{i,j}| / 0.6745 \text{ where } S_{i,j} = LH, HL, HH$$

Threshold value is calculated by

$$T = \sigma - (|\text{Harmonic Mean} - \text{Geometric Mean}|)$$

$$\text{Where Harmonic Mean} = M2 / \sum_{i=1}^{M} \sum_{j=1}^{M} 1/g(i,j)$$

$$\text{And Geometric Mean} = \left[\prod_{i=1}^{M} \prod_{j=1}^{M} g(i,j) \right]^{(1/M2)}$$

So the procedure is, from LH subband calculate noise level(σ) than find threshold value(T) for that subband and finally apply soft thresolding method to get denoise LH subband. Apply same procedure for HL and HH subband.

4. INTERPOLATION ALGORITHM

In interpolation method main issue is to find out information of missing pixels from neighboring pixels as shown in figure.

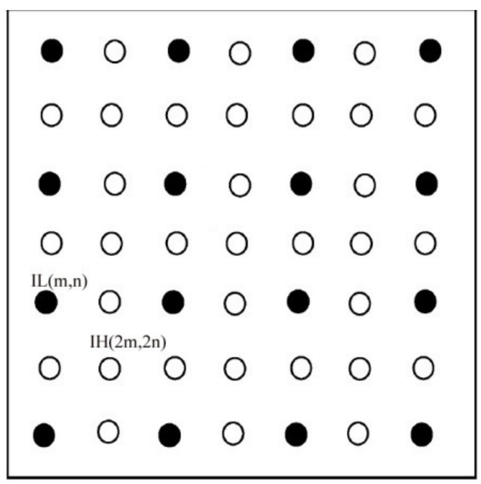

FIGURE 6 : Interpolation Image Structure

Interpolation method for HR image reconstruction suffers from aliasing problem if signal of LR image is down sampled and exceeds Nyquist sampling limit. In spatial locations our human visual system is very sensitive to the edges in image so it is important to suppress interpolation artifacts at the same time maintaining the sharpness and geometry of edges.

For interpolation process edge direction is very important and that's why we have use An Edge-Guided Image Interpolation Algorithm via Directional Filtering and Data Fusion presented in [7]. We can use wavelet based Interpolation method presented in [10] also to do super resolution. For edge information they have partition pixels into two directional and orthogonal subsets. Directional interpolation is made for each Subset and two interpolated values are fused. Algorithm presented in [7] work for gray scale images only so we have done some modification so that it will work for RGB images. As shown below, We have stored each R,G and B components of one image into three different images of two dimension (same as gray scale image) and give that as a input to original algorithm. Finally we have merged all three output arrays into single RGB image.

```
for i=1:m
for j=1:n
R(i,j)=Input(i,j,1);
G(i,j)=Input(i,j,2);
B(i,j)=Input(i,j,3);
end
end


for i=1: (2*m)
for j=1: (2*n)
RGB(i,j,1)=Output(i,j);
end
end      % same way RGB(i,j,2)and RGB(i,j,3)is achieved
```

5. PROPOSED SUPER RESOLUTION ALGORITHM

Here we have presented our proposed algorithm.

1. Take three shifted, low resolution and noisy images.
2. Apply shift estimation algorithm as explained above and find shift in x and y coordinates and align all three images.
3. Apply Gaussian filter to remove some noise.
4. Fused all three images using the fusion method explained and get a single image.
5. Apply HAAR Wavelet Lifting Scheme on this single image(we will get four subbands LL,LH,HL and HH).
6. Apply LWT based denoising method on LH,HL and HH subbands.
7. Apply inverse lifting scheme to recover image with less noise.
8. Get super resolution image by applying interpolation method explained in above section.

For experiment, we have generated three shifted, low resolution and noisy images from single HR image. We have performed experiment on the computer with configuration of Intel i3 processor, 4GB RAM and 512MB NVidia graphics card. For performance evaluation of algorithm, we have considered PNSR ratio and visual quality as parameter. The PSNR is defined as: $PSNR = 20 \cdot \log 10(MAX\ i / \sqrt{MSE})$. We have shown single input image instead of three as other input images are same except little shift in x and y coordinates.

6. CONCLUSION

SR image reconstruction is very important in many practical applications. We have taken LWT base denoising method as lifting schemes are easy to implement, fast ,require less memory and inverse lifting has same complexity as forward lifting. Interpolation method that we have taken is also gives good result as it works on edges as well. In our future studies, we would like to make this algorithm faster for practical use and want to use different lifting scheme and interpolation methods.

7. REFERENCES

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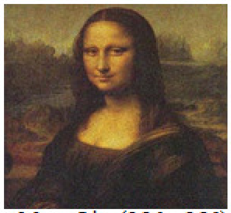
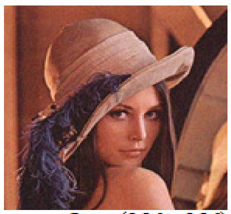
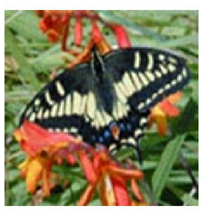

Mona Lisa(256 x 256)

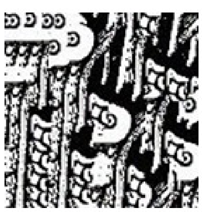

Super Resolution Mona Lisa Image(512 x 512)


Lena(256 x 256)


Super Resolution Lena Image(512 x 512)


Butterfly(120 x 120)


Super Resolution Butterfly Image(240 x240)


African face(120 x 120)


Super Resolution African face Image(240 x240)

PSNR(dB)

Mona Lisa	Lena	Butterfly	African Face
28.7684	33.6667	31.2543	29.8879

FIGURE 7 : Experiment Results