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QUICK SUPER RESOLUTION TECHNIQUE

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Abstract—The rising rate of usage of super resolution technique leads to an introduction to a method having improvement in the execution time and computational cost reduction. A video super resolution technique is tailored with the Restore algorithm to make use of the inter frame similarity property. Given a sequence of low resolution video frames, the QSRT (Quick Super-Resolution Technique) separates the video into keyframes and inbetween frames. The Restore algorithm is designed in such a way to shift the high resolution blocks in the keyframes to the similar blocks in the subsequent low resolution inbetween frames. This kind of restoring takes less amount of time for execution. The computational cost is less compared with the single frame super resolution technique applied to all the individual frames. The simulation results show that the proposed method outperforms the bicubic interpolation technique.

Keywords— low resolution, video frames, keyframes, between frames, blocks, high resolution

I. Introduction

Now a days, the High Definition Television (HDTV) is accepted by lot of people because the resolution of an image provided by the system is more than the resolution provided by the Standard Definition TeleVision (SDTV). Each pixel provided by the system is much realistic. Therefore, the people are giving warm welcome to such realistic effect present in the pictures and videos. The main focus of any

SR reconstruction technique is to build a HR image from the LR images. In measuring the quality of images as well as video sequences, the resolution takes a major role. During reconstructing the LR image into HR image, care should be taken to retain the edge details in the image. Practical applications like Surveillances, Medical applications, Satellite imaging need the HR images or videos.

There are two kinds of super-resolution reconstruction techniques available. They are,

- Single frame SR techniques
- Multi frame SR techniques

Multi frame SR techniques run offline. Implementing single frame SR technique in each individual frame of video sequences is faster than implementing the multi frame SR techniques for video sequences. A popular also faster single frame SR technique, SRCNN needs 0.4 seconds for reconstructing a single frame of size 256 x 256. If the scaling factor is increased, the SRCNN would take several seconds for reconstruction.

In real time implementations, the SR reconstruction techniques should meet with the bottleneck of execution time and the computational cost reduction and the bottleneck is to be resolved at any cost. Actually, the video frames in most of the surveillance cameras do not get changed quickly. So, the idea here is to make use of the inter frame similarity property to reconstruct the LR frames without applying the single frame SR technique to all the frames to achieve less execution time.

This paper presents a new SR technique to produce the HR frames by using the inter frame similarity property. In the given video sequences, the keyframes, are identified and the motion vectors (MV), residual error (RE) are calculated by using any of the available techniques. The Structure Modulated Sparse Representation (SMSR) method is the single frame SR technique to be applied in the keyframes reconstruction.

If the video is a compressed video, then all the details of MV, RE and also the block values will be available by default at the time of extracting the video using any of the standard video coder and the QSRT makes use of all the available details for further processing without spending much time for calculating the details externally.

II. PROPOSED TECHNIQUE

The proposed technique is an integrated solution which utilizes the available simple techniques for finding the keyframes, the motion value and the error values. It uses only keyframes to perform super resolution of the entire low resolution video with the help of inter frame similarity property. Initially, the frames of a video are separated into keyframes and inbetween frames. The keyframe is the only frame that undergone to the single frame super resolution technique. After that, the blocks of the keyframe are restored in the forth coming inbetween frames. The exact location of the blocks in the forth coming inbetween frames are found from the block motion estimation technique. The QSRT takes care of finding the motion values and error values between the frames and also the keyframe super resolution. The Restore algorithm takes care of restoring the pixel values. This algorithm intellectually decides whether to perform the scaling in the error value or not, whether to add the motion value or not. This kind of intellectuality reduces the execution time. The representation of video is given in figure 1.

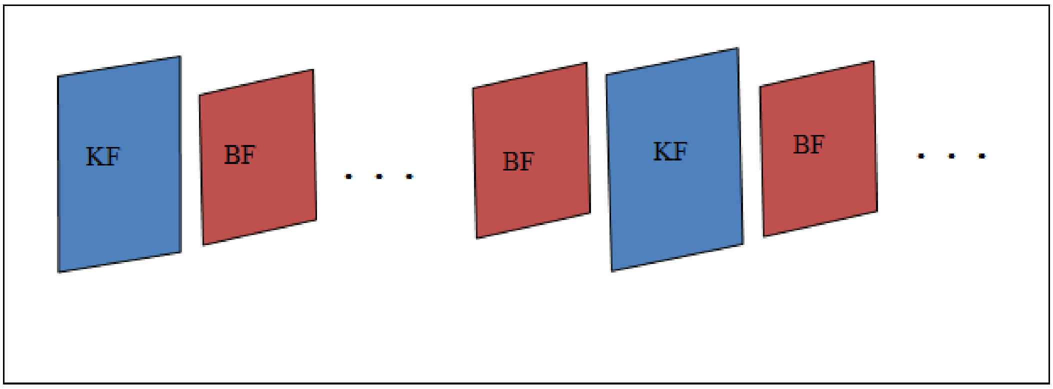

Figure1. Frames of a video

The notational representation of the input LR video is defined as the combination of low resolution keyframes and inbetween frames such as,

$$V^l = KF_1^l, BF_{11}^l, BF_{12}^l, ..., BF_{1p}^l, KF_2^l, BF_{21}^l, BF_{22}^l, ..., BF_{2p}^l, ..., BF_{np}^l, KF_t^l, \quad (1)$$

Here t represents the total no. of keyframes in the video, np represents the total no. of inbetween frames and the superscript l represents that the video is the low resolution video.

The notational representation of the output HR video is represented as the combination of high resolution keyframes and inbetween frames such as,

$$V^h = KF_1^h, BF_{11}^h, BF_{12}^h, ..., BF_{1p}^h, KF_2^h, BF_{21}^h, BF_{22}^h, ..., BF_{2p}^h, ..., BF_{np}^h, KF_t^h, \quad (2)$$

Here t represents the total no. of keyframes in the video, np represents the total no. of inbetween frames and the superscript h represents that the video is the high resolution video.

A. The proposed technique QSRT

The proposed QSRT utilizes the existing simple techniques for finding the keyframes, the motion value and the error values. The first two LR frames in the input video are taken as LRKF1 and LRBF1 and are respectively denoted as KF_1^l and BF_1^l in the video sequences. For easier understanding and manipulating convenience, they may be denoted as $previous_{t-1}^l$ and $current_t^l$ frames, respectively. The superscript l in the notations denote that the frames are LR frames and the subscript indicates the frame number.

Step1: The two input LR frames in the LR video are

$previous_{t-1}^l$ and $current_t^l$

Step2: Divide the frames into non overlapping blocks. Then perform keyframes extraction, calculate the motion vectors (MV), residual error (RE) and store it in an array for further calculations.

Step3: Apply the SMSR technique on the LR keyframe1 (previous_{t-1}^l)

$$\text{previous}_{t-1}^h = \text{SMSR}(\text{previous}_{t-1}^l) \quad (3)$$

The output is the HR keyframe1 previous_{t-1}^h

Step4: Shift the blocks from the previous_{t-1}^h to the related blocks of the $current_t^l$ to get the equivalent $current_t^h$ using the **Restore** technique.

Step5: Repeat step 4 to all subsequent frames in the video till the next new keyframe arrived

$$\text{previous}_{t-1}^h = current_t^h \quad (4)$$

$$current_t^l = \text{next}_{t+1}^l \quad (5)$$

Step6: Repeat from step 3 to 5 to produce the new HRKF2 and the subsequent frames till the next new keyframe .

Step : The final output will be the HR frames

$$V^h = KF_1^h, BF_{11}^h, BF_{12}^h, ..., BF_{1p}^h, KF_2^h, BF_{21}^h, BF_{22}^h, ..., BF_{2p}^h, ..., BF_{np}^h, \mathrm{KF}_t^h \quad (6)$$

t =total no. of keyframes in the video and np =total no. of inbetween frames in the video

As a result, the LR frames are changed into HR frames in a small period of time. To calculate the pixel difference, the following equation is used.,

$$\mathrm{D(m,n)} = \left| previous_{t-1}(\mathrm{m,n})^l - current_t(\mathrm{m,n})^l \right| \quad (7)$$

The error frame $RE(i,j)$ is calculated between the blocks. The motion vector (MV) is estimated using the following equation,

$$AAD = \frac{1}{x^2} \sum_{m=1}^{x} \sum_{n=1}^{x} \left| \mathrm{previous}_{t-1}^l(\mathrm{m,n}) - current_t^l(\mathrm{m,n}) \right| \quad (8)$$

B. ***Algorithm RESTORE in QSRT***

Step 1: The input is the HR keyframe1 $\mathrm{previous}_{t-1}^h$ and the LR inbetween frame1 $current_t^l$.

$$\mathrm{previous}_{t-1}^h = \mathrm{SMSR}(\mathrm{previous}_{t-1}^l) \quad (9)$$

Step2: Split the frames into non overlapping blocks

Step3: For every block of the $\mathrm{previous}_{t-1}^h$ frame,

Step3.1: Check for the availability of motion in $current_t^l$ blocks. If yes, then add the motion vector MV with the block's coordinates of the $\mathrm{previous}_{t-1}^h$ frame using the following equation

$$current_t^h(\alpha x) = previous_{t-1}^h(\alpha(x + mv_{\mathrm{t-1,t}}(x))) \quad (10)$$

α is the value of scaling factor.

Step3.2: Check for the existence of error value with the $current_t^l$ frame. If yes, then apply the bicubic interpolation to the error value in order to magnify the error i.e., $\mathrm{BI}(RE_{t-1,t}^l(x))$

Step4: Restore the block values to the $current_t^l$ frame. This is given in the following equation,

$$current_t^h(\alpha x) = previous_{t-1}^h(\alpha(x + mv_{\mathrm{t-1,t}}(x))) + \mathrm{BI}(RE_{t-1,t}^l(x)) \quad (11)$$

Step 5: Repeat step 3 for every blocks in the $\mathrm{previous}_{t-1}^h$ frame

Step6: The output is the high resolution between frame1 $current_t^h$ frame

Step 7: Interchange the frames until new keyframe is obtained. This is given in the following equations,

$$\text{previous}_{t-1}^{h} = current_{t}^{h} \quad (12)$$

$$current_{t}^{l} = \text{next}_{t+1}^{l} \quad (13)$$

Step8: Repeat steps 1 to 7 until the last frame of the video. The output HR video sequences given in the following equation,

$$V^{h} = KF_{1}^{h}, BF_{11}^{h}, BF_{12}^{h}, ..., BF_{1p}^{h}, KF_{2}^{h}, BF_{21}^{h}, BF_{22}^{h}, ..., BF_{2p}^{h}, ..., BF_{np}^{h}, \text{KF}_{t}^{h}$$

$t =$ total no. of keyframes in the video and $np =$ total no. of inbetween frames in the video (14)

Thus, the HR video is obtained. The Restore function reduces the execution time compared to the other state – of – the art algorithms. The scaling factor is denoted as α.

$$current_{t}^{h}(\alpha x) = previous_{t-1}^{h}(\alpha(x + mv_{\text{t-1,t}}(x))) + BI(RE_{\text{t-1,t}}^{l}(x)) \quad (15)$$

In the above equation, $current_{t}^{h}(\alpha x)$ shows the scaled HR frame obtained from the $\text{previous}_{t-1}^{h}(\alpha x)$. The figure 2 shows the calculation of how the HR frame is generated from the LR frame.

To explain the concept in the example, the LR foreman video frames1 and 2 are taken. The frame1 is the keyframe1 and frame 2 is the inbetween frame1. The motion vector values (MV) and the residual error values (RE) are calculated. The foreman keyframe1 is given as an input to the SMSR algorithm. The High Resolution (HR) foreman keyframe1 is obtained. The residual error value is interpolated by using the existing bicubic interpolation method. The motion vector and the interpolated residual error are added with the HR foreman keyframe1 block and the result is restored in the output HR foreman inbetweenframe1 block. Thus, the high resolution foreman frames are generated.

The problem while seeing the HR video is the ringing artifacts. The reason behind the artifact is that if one block in the $previous_{t-1}^{l}$ LR frame has sharp edges in it, then the edge is to be preserved at the time of running the SMSR technique. Unfortunately, the residual error (RE) block also has the sharp edge at the same location. By applying the bicubic interpolation on the RE value $BI(RE_{\text{t-1,t}}^{l}(x))$, the sharp edge is blurred. While adding the bicubically interpolated residual patch

$BI(RE^{l}_{t-1,t}(x))$ with the block in the HR $\text{previous}^{h}_{t-1}(\alpha x)$ frame, it results overlapping of edges i.e., the ringing artifact.

To prevent the artifact, the average absolute magnitude of the residual error block is to be calculated and a suitable threshold is to be chosen to make a decision to execute the restore function or not. In case of presence of edge in the residual error block, the average absolute magnitude will be high. If it is high, then the corresponding block in the LR $current^{l}_{t}$ frame is up sampled by using the existing bicubic interpolation technique $BI(\text{current}^{l}_{t}(x))$. If not, the $current^{h}_{t}(\alpha x)$ HR frame is obtained by simply adding the $\text{previous}^{h}_{t-1}(\alpha x)$ with $BI(RE^{l}_{t-1,t}(x))$. Here the threshold value plays vital role. Therefore, the value is to be chosen with care. After performing more experiments, the value selected is 10.

Moreover, the motion vector (MV) is also to be analyzed to ensure performing the restore function or not, or performing the bicubic interpolation of the residual or not. If no motion is in the blocks of the $\text{previous}^{h}_{t-1}(\alpha x)$ frame with the $current^{l}_{t}$ frame, then bicubic interpolation $BI(RE^{l}_{t-1,t}(x))$ will not be needed and simply the contents will be copied. This is given in the following equation

$$current^{h}_{t}(\alpha x) \approx previous^{l}_{t-1}(\alpha(x + mv_{t-1,t}(x))) \tag{16}$$

Furthermore, the residual error block will be empty i.e., zero in some situation. That time too the bicubic interpolation $BI(RE^{l}_{t-1,t}(x))$ of residual is left out. It reduces the time complexity and it leads to faster execution.

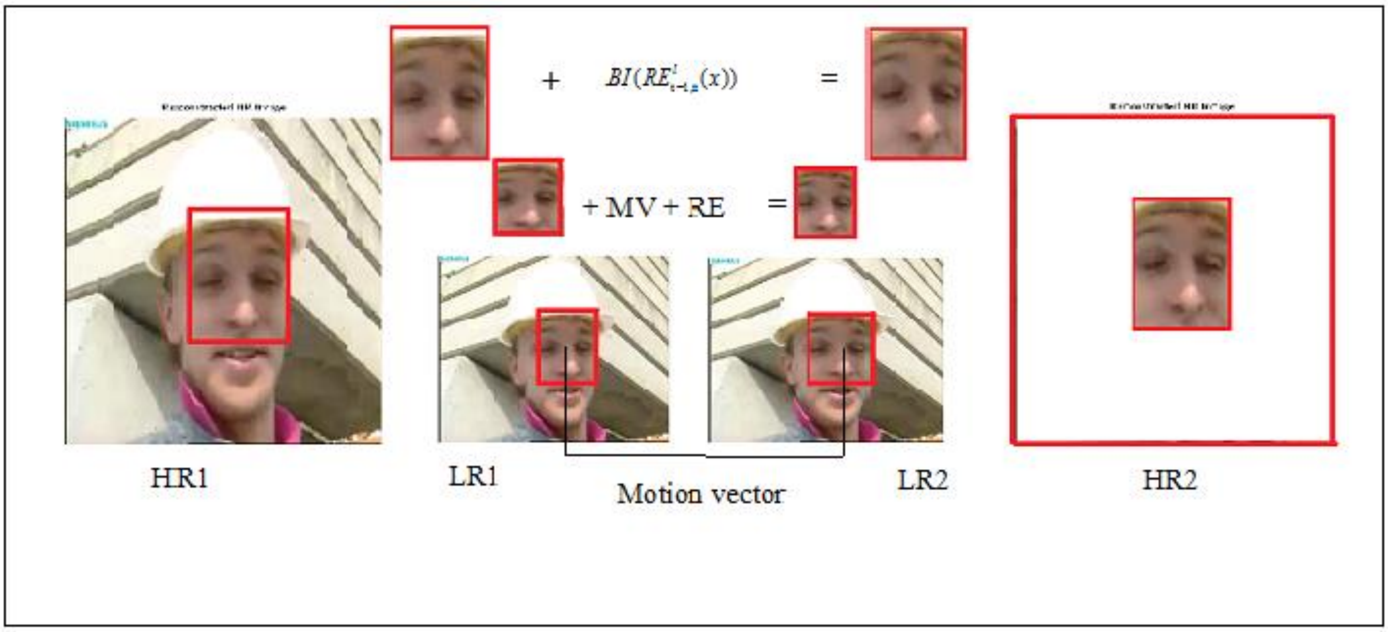

Figure 2. Execution of QSRT

DEBLOCKING FILTER

In this algorithm, all the works are carried out by splitting the frames into blocks of non overlapping. The non overlapping blocking concept is entertained in our algorithm because each and every pixel is exactly covered by only one block otherwise it will be covered by multiple blocks which leads to high computational complexity. The disadvantage of processing in the non overlapping blocking concept is that it may create false edges on the boundary. These differences on both the sides of the block boundary creates artificial edges. This problem can be solved by using any of the deblocking filter and the original edges are preserved. On Comparing the time complexity of using the overlapping blocks, and the execution of deblocking filter, the time complexity of executing the deblocking filter is less.

III. EXPERIMENTAL RESULTS

A. Super-Resolution on Images

The proposed SR algorithm is tested with the Set 5 and Set 14 images to compare between the bicubic interpolation method and the proposed QSRT method. PSNR calculation is done to measure the quality of the obtained output and the values are listed in the tables. Table I shows the PSNR results values for the existing bicubic interpolation method and the proposed QSRT for the scaling factors 2, 3, 4.

From the Table I, it is observed that the proposed technique produces high PSNR values than the bicubic interpolation method. The visual comparison is given in the Figure 3. The qualitative and quantitative evaluation shows that the proposed technique outperforms the existing bicubic interpolation technique.

Fig. 3 Visual Comparison of butterfly, baboon, comic, monarch from left to right correspond to: original, bicubic interpolation method, QSRT method

TABLE I. THE RESULTS OF PSNR (DB) ON THE TEST DATASETS SET5 FOR THE SCALING FACTORS 2,3.4

Images	Scaling Factor	Bicubic Method	QSRT Method
woman	2	32.11	34.89
head	2	34.84	35.59
butterfly	2	27.39	32.08
bird	2	36.78	40.49
baby	2	37.01	38.37
woman	3	28.51	30.87
head	3	32.85	33.59
butterfly	3	23.98	26.55
bird	3	32.53	34.74
baby	3	33.87	35.05
baboon	3	23.17	23.56
barbara	3	26.26	26.73

bridge	3	24.37	25.00
coastguard	3	26.52	27.16
comic	3	23.04	24.33
face	3	32.76	33.44
flowers	3	27.19	28.87
foreman	3	31.13	33.27
lenna	3	31.63	33.32
man	3	27.00	28.12
monarch	3	29.39	32.36
pepper	3	32.36	34.22
ppt3	3	23.66	25.87
zebra	3	26.59	28.77
woman	4	26.41	28.17
head	4	31.55	32.19
butterfly	4	22.01	24.49
bird	4	30.12	31.85
baby	4	31.75	32.89
baboon	3	23.17	23.56
barbara	3	26.26	26.73
bridge	3	24.37	25.00
coastguard	3	26.52	27.16
comic	3	23.04	24.33
face	3	32.76	33.44
flowers	3	27.19	28.87
foreman	3	31.13	33.27
lenna	3	31.63	33.32
man	3	27.00	28.12
monarch	3	29.39	32.36
pepper	3	32.36	34.22
ppt3	3	23.66	25.87
zebra	3	26.59	28.77
14092	3	29.06	29.69
335094	3	22.19	23.76
384022	3	25.31	26.66

The sets of images with different textures, color and edge details are tested with the proposed QSRT method. Because, the single frame super

- resolution technique is used to provide the high resolution video sequences. Thus, the capability of the technique is first evaluated with the images of set5, set14 and then with the HD videos. The images are scaled for the factor of 2, 3 and 4.

B. Super - Resolution on HD Videos from Xiph database

High resolution video transmission needs high bandwidth to transmit. If the display screen is large, the video should be interpolated to fit to the size of the screen. The interpolation may be done by any one of the following techniques, single frame or multi frame super resolution techniques. Instead of multi frame SR technique, single frame SR technique is executed for all the frames. Because, the multi frame SR technique needs more time to execute. The proposed QSRT method is tested with the HD videos from Xiph databasefor the scaling factors 3,4 and the results are listed in the Table IV.

TABLE II. **THE RESULTS OF PSNR (DB) ON THE HD VIDEOS FROM XIPH DATABASE FOR THE SCALING FACTORS 3 AND 4**

Dataset Videos	Scaling Factor	Bicubic Method	QSRT Method
Aspen	3	32.64	34.61
Crowd Run	3	26.79	28.09
Ducks Take Off	3	26.52	2749
Old Town Cross	3	31.15	32.47
Pedestrian Area	3	37.61	39.18
Station2	3	36.40	38.16
Sun Flower	3	41.60	42.97
Snow Mnt	3	25.65	27.09
Aspen	4	29.87	31.60
Crowd Run	4	25.00	26.19
Ducks Take Off	4	24.52	25.33
Old Town Cross	4	29.15	30.46
Pedestrian Area	4	35.30	36.87
Station2	4	34.05	35.75
Sun Flower	4	38.77	40.96
Snow Mnt	4	24.03	25.10

Thus, the image databases and video databases are tested with the proposed method and the bicubic interpolation method and the proposed method performs well.

Let's consider another situation that some times, there will be no change among the inbetween frames i.e., the contents of the inbetween frames remain constant for a certain period of time. In that scenario, the proposed method doesn't need to calculate the residual error values and also the motion values. The time to execute the video involves only the time to produce the high resolution keyframe and the time to shift the blocks to the inbetween frames. The situation can be explained with help of the Foreman video. The video contains totally 597 frames with 13 keyframes. Among them, it can be noted that the frames 218 to 382 i.e., 164 frames remain constant or unchanged. The proposed takes this as an added advantage to produce the high resolution frames within a short period of time by shifting the contents without any calculations. In particular, the high resolution keyframe is generated by admitting the frame into the single frame super resolution technique SMSR and is produced in 0.9 seconds, and the 13 high resolution keyframes are produced in 11.7 seconds. Each unchanged inbetween high resolution frame is produced in 0.04 seconds. Therefore, the 164 unchanged between frames are produced in 6.56 seconds by restoring the contents without any calculations. The remaining 420 inbetween frames which involves all kinds of calculations are produced in 168 seconds i.e., 0.4 seconds for each frame. To produce the high resolution foreman video which is played for about 23 seconds, the QSRT algorithm produces the output in 186.03 seconds only. The bicubic interpolation method produces the output in 238.8 seconds. It shows that the proposed algorithm produces the output faster than the bicubic interpolation method. If the intra frame similarity property is also utilized in this , then the execution time is further reduced and also the speed is increased.

IV. CONCLUSION

The proposed QSRT is an integrated solution which includes the inter frame similarity property. It utilizes the available simple techniques for finding the keyframes, the motion value and the error values. It uses only the keyframes to produce the high resolution video of low resolution video sequences. The keyframes undergo the single frame super resolution technique. After that, the blocks of the keyframes are restored in the forth coming frames which is done by the Restore algorithm. This algorithm provides an improved high resolution version of a video which is better than the high resolution video obtained from the bicubic interpolation method. In addition, the significant time reduction is achieved by the usage of Restore algorithm. This algorithm itself takes care of performing scaling in the error value, adding the motion value. This kind of intellectuality reduces the execution time. Thus the execution time and computational cost is reduced.

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