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MOTION-BASED LOCALIZED SUPER RESOLUTION TECHNIQUE FOR LOW RESOLUTION VIDEO ENHANCEMENT

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ABSTRACT

Super resolution (SR) can be used for enhancing the resolution of images or video sequences. However, because of the computational complexity, SR is not an efficient way to improve the quality of a given video sequence. In order to overcome this problem we proposed a method, where we super resolve consecutive frames in a given video sequence in such a way that only the moving regions in the frames instead of the whole frames are processed, saving the computational cost. The proposed motion-based localized SR method not only reduces the processing time but also increases the quality of the resulting super resolved frames. The results based on PSNR measures show that the proposed localized method, in comparison with the global SR method, show improvement in quality and motion localization reduces the number of pixels to be registered, hence provides faster processing.

1. INTRODUCTION

Super resolution refers to the process of creating a higher-resolution image with additional details, by utilizing the information of multiple low-resolution images taken from almost the same scene [1].

There are several ways of performing super-resolution algorithms, but most of them are variations on two main approaches. The first challenging approach is multi-frame super-resolution which is based on the combination of image information from several similar images taken from a movie sequence, or consecutive shots from a still camera. This method is consists of two main parts, first estimating motion parameters between two images (registration), and second projecting the low-resolution image onto the high-resolution lattice (reconstruction). The second main 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 work we are using multi frame super resolution taken from low resolution video sequences.

The super-resolution idea was first proposed by Tsai and Huang [2] who used the frequency-domain approach. In [3] Keren, et al. describe a spatial-domain approach to image registration using a global translation and rotation model and a two-stage approach to super-resolution restoration. L. Lucchese and G. M. Cortelazzo [4] presented a method for estimating planar roto-translations that operates in the frequency domain and, as such, is not based on features. Another frequency domain approach presented by Reddy et al.[5]. Their method utilizes separately rotational and translational components property of the Fourier transform similar to [4]. Irani et al. [6] has developed a motion estimation algorithm. This algorithm considers translations and rotations in spatial domain.

Computational complexity and error rate are two main fundamental problems in super resolution methods. Simple super resolution method with less error is essential for the success of many applications.

In this paper, we propose a localized SR method based on the registration of the localized moving regions, in a low resolution video sequence, to achieve faster and better registration of the frame. Localised moving region registration is more precise than global registration of the entire frame, due to the fact that local alignement of the changes in the local neighbourhood is more efficient. Localized registration is also faster due to the fact that localized SR deals with a smaller region than the entire frame.

The proposed localized SR method is tested using different SR methods [5], [4], [6] to achieve enhanced high resolution video sequences.

2. DIFFERENT SUPER RESOLUTION METHODS

This section gives a brief introduction to the registration of three super resolution methods which are chosen for this work. For simplicity, following the registration, bicubic interpolation technique is used to reconstruct the high resolution frame.

2.1. L. Lucchese et al. super resolution method

This super resolution method is presented by Lucchese and Cortelazzo [4] and operates in the frequency domain. The estimation of relative motion parameters between the reference image and each of the other input images is based on the following property: The amplitude of the Fourier transform of an image and the mirrored version of the amplitude of the Fourier transform of a rotated image have a pair of orthogonal zero-crossing lines. The angle that these lines make with the axes is identical to half the rotation angle between the two images. Thus the rotation angle will be computed by finding these two zero crossings lines. This algorithm uses a three-stage coarsest to finest procedure for rotation angle estimation with a wide range of degree accuracy. The shift is estimated afterwards using a standard phase correlation method.

2.2. Reddy et al. super resolution method

Reddy et al. [5] proposed a registration algorithm that uses the Fourier domain approach to align images which are translated and rotated with respect to one another. Using a log-polar transform of the magnitude of the frequency spectra, image rotation and scale can be converted into horizontal and vertical shifts. These can therefore also be estimated using a phase correlation method. Their method utilizes reparability of rotational and translational components property of the Fourier transform which is similar to [4]. According to this property, the translation only affects the phase information, whereas the rotation affects both phase and amplitude of the Fourier transform. One of the properties of the 2D Fourier Transform is that if we rotate the image, the spectrum will rotate in the same direction. Therefore, the rotational component can first be estimated. Then, after compensating for rotation, and by using phase correlation techniques, the translational component can be estimated easily.

2.3. Irani et al. super resolution method

Irani et al. [6] has developed a motion estimation algorithm. This algorithm considers translations and rotations in spatial domain. The motion parameters which are unknown can be computed from the set of approximation that can be derived from the following equation (1), where the horizontal shift a, vertical shift b, and rotation angle θ between two images $g1$ and $g2$ can be expressed as:

$$g2(x, y) = g1(x\cos\theta - y\sin\theta + a,\; y\cos\theta + x\sin\theta + b) \qquad (1)$$

Finally, after determining and applying the results, the error measure between images g1 and g2 is approximated by (1) where this summation is counted over overlapping areas of both images.

$$E(a, b, \theta) = \sum\Big[g1(x, y) + (a - y\theta - x\theta^2/2)\,\partial g_1/\partial x + (b + x\theta - y\theta^2/2)\,\partial g_1/\partial y - g_2(x,y)\Big]^2 \qquad (2)$$

For reducing E to its minimal value and obtaining more accurate result, the linear system in (5) is applied. By solving the following matrix, the horizontal shift a, vertical shift b, and rotation angle θ will be computed as follows.

$$M = \begin{bmatrix} a \\ b \\ c \end{bmatrix}, \quad B = \begin{bmatrix} \sum \frac{\partial g1}{\partial x}(g1 - g2) \\ \sum \frac{\partial g1}{\partial y}(g1 - g2) \\ \sum R(g1 - g2) \end{bmatrix} \qquad (3)$$

$$A = \begin{bmatrix} \sum\left(\frac{\partial g1}{\partial x}\right)^2 & \sum\left(\frac{\partial g1}{\partial x}\frac{\partial g1}{\partial y}\right) & \sum\left(R\frac{\partial g1}{\partial x}\right) \\ \sum\left(\frac{\partial g1}{\partial x}\frac{\partial g1}{\partial y}\right) & \sum\left(\frac{\partial g1}{\partial y}\right)^2 & \sum\left(R\frac{\partial g1}{\partial y}\right) \\ \sum\left(R\frac{\partial g1}{\partial x}\right) & \sum\left(R\frac{\partial g1}{\partial y}\right) & \sum R^2 \end{bmatrix}_{3\times 3} \qquad (4)$$

$$AM = B \Rightarrow A^{-1}AM = A^{-1}B \Rightarrow M = A^{-1}B \qquad (5)$$

Fig. 1(a-d) shows the four low resolution consecutive frames, where (e), (f) and (g) shows super resolved high resolution images by using Cortelazzo et. al. [4], Reddy et. al [5] and Irani et. al [6] methods respectively.

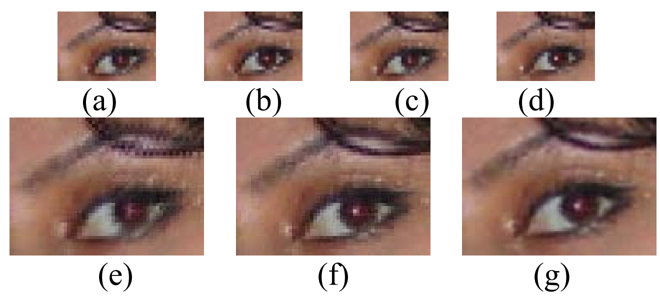


Fig. 1. (a) through (d) are four low resolution images taken from a video sequence. (e) High resolution image of (a) through (d) using Cortelazzo et. al (f), Reddy et. al (g) and Irani et. al methods.

3. SUPER RESOLVING VIDEO SEQUENCES USING FRAME DIFFERENCES

An effective approach to local motion analysis is significant for understanding the detailed activities from video sequences. Multi frame super resolution can be efficient to reach this goal. It should be considered that if there are no changes in images interpolation is a convenient method to enhance the resolution of frames with less complexity. The proposed method is a combination of both interpolation and super resolution in order to have a simple method with higher performance.

The algorithm can be summarized in five parts:

1. Taking frames from video and finding motion part(s) using frame subtraction.
2. Extracting local motion(s) by applying connected component labeling.
3. Using bicubic interpolation for enhancing resolution of static background.
4. Super resolving the extracted motion regions(s) by applying any multi frame super resolution method.
5. Replacing the super resolved moving object(s) in bicubic interpolated background.

In the first stage four consecutive frames will be used where each frame is subtracted from the reference frame so the differences between frames are shown. After applying OR operation for all subtracted images local motion(s) will appear. In the second stage the area of local motion(s) can be found by using connected component labeling. In the third stage the rest of image which does not include any motion and it is totally constant, will be interpolated with the help of bicubic interpolation method.

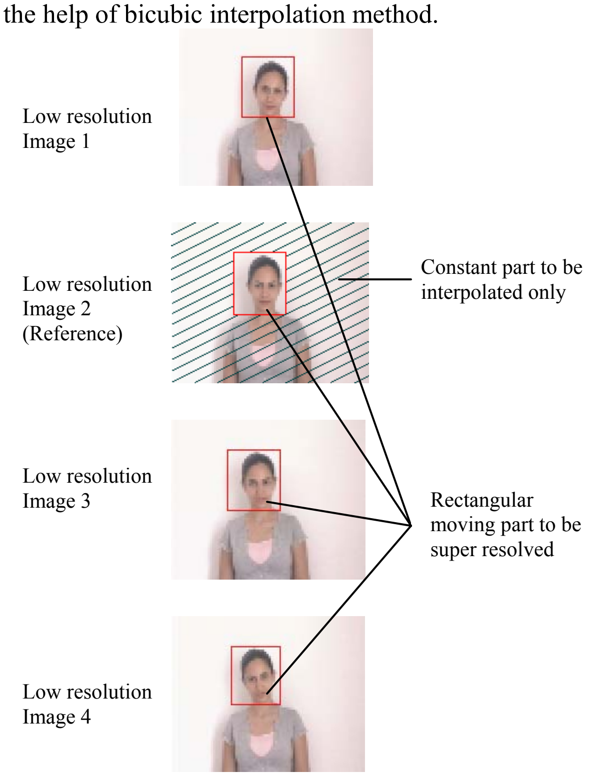


Figure 2: first four consecutive frames taken from a video sequence with one moving object. The rectangular moving part for each four frames is changing adaptively.

Fig. 2 shows four consecutive frames taken from a video sequence. The second frame is used as the reference frame in super resolution operation. The rectangular part shown in each frame is the moving part. The rest of the reference frame is the constant part which will be interpolated only. In every four frame the rectangular moving part will change according to the moving part in those frames.

In the forth stage new small frames (motion parts) will be super resolved by using any SR method. Small frame for SR means less computational cost and less error rate. The result shows the validity of this claim.

In the final stage, we need to combine small super resolved frame with the interpolated background to achieve the new high resolution image. The algorithm is shown in fig. 3.

4. RESULTS AND DISCUSSIONS

Global super resolution method (i.e. consider entire frame for SR operations) and the method presented above are applied to the low resolution video to generate high resolution video sequences. The original low resolution video sequences used in this comparison are 4 seconds records (30 fps) of a single slowly moving object in constant background. A total of 2 video sequences were tested. First, for a video sequence, that has only one motion part and second, for another video with two motion parts. The frames are of size 288x352 pixels. The motion regions change adaptively for each frame in comparison of next two frames and the last frame.

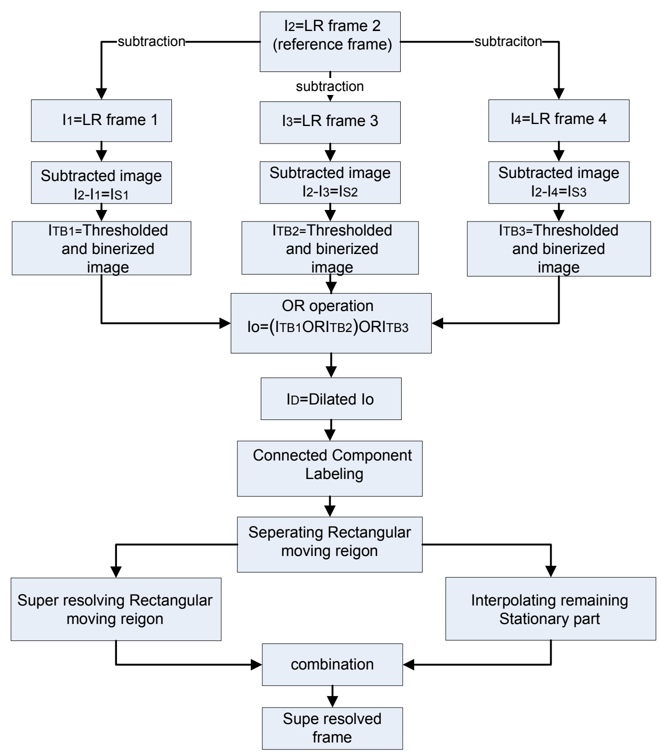


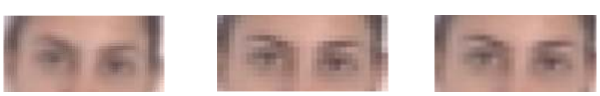
Figure 3: The algorithm of the motion based localized super resolution technique for video enhancement.

The low resolution video sequences are generated by shrinking each frame down to half size by using nearest neighbor interpolation. In this way we keep the original high resolution video sequences for comparison purposes. The PSNR value for each frame is calculated according to the mean squared error (MSE) calculated between the super resolved low resolution image and the original high resolution image.

Fig. 4 shows the visual results of applying global SR, proposed local SR and bicubic interpolation. It is visually clear that the proposed local SR has the highest PSNR result. The moving region is only the head of the lady in this example which is a local motion in the video sequence. Because, it is easier to align local variations in a local neighborhood, the registration part of the SR of the proposed method can estimate the shift and rotation parameters more effectively. This is the main reason of generating higher quality images in the proposed method.

Table 1 and table 2 show the result of calculated average PSNR of two different video sequences containing one and two moving object. The PSNRs are calculated for three different multi frame super resolution methods and bicubic interpolation.

Fig. 5 shows the calculated PSNR for the video sequence containing 30 super resolved and interpolated frames using Irani et. al SR approach and bicubic interpolation. The proposed method generates highest PSNR and fastest operation. Localized motion based SR method typically considers a much smaller rectangular region than the entire frame. In our example the moving parts enclosed by the rectangular region is approximately 5 times less than the entire frame, which indicates that the localized SR method is 5 times faster the Global method. The results show the superiority of the proposed localized SR method both in PSNR based frame quality and speed of processing.



(a) (b) (c)

Figure 4: A part of high resolution frame using (a)bicubic interpolation, (b)global SR and (c)local SR.

Table 1: Average PSNR of a video sequence with one moving object.

Methods used to enhance the resolution	PSNR of super resolved motion part (dB)	PSNR of motion part of global SR (dB)
Irani et.Al	31.65	31.52
Reddy et.Al	30.68	30.36
Cortelazzo et.Al	30.07	29.85
Bicubic interpolation	29.65	29.61

Table 2: Average PSNR of a video sequence with two moving object.

Methods used to enhance the resolution	PSNR of super resolved motion part (dB)	PSNR of motion part of global SR (dB)
Irani et.Al	32.98	32.78
Reddy et.Al	32.01	31.89
Cortelazzo et.Al	31.97	31.89
Bicubic interpolation	30.42	30.29

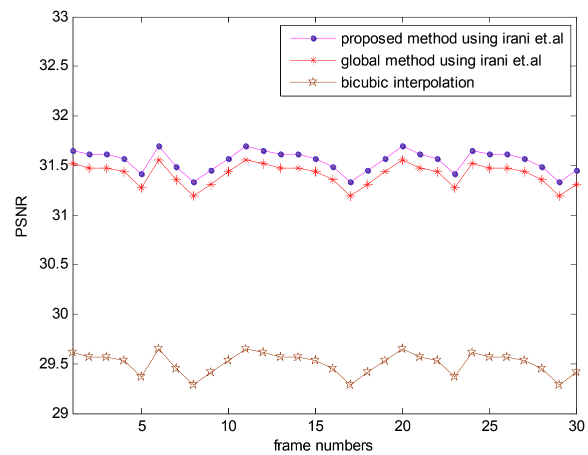


Figure 5: PSNR of 30 super resolved motion region of frames using Irani's et al. approach for proposed local and standard global method and bicubic interpolation.

5. CONCLUSION

A motion-based localized super resolution technique for low resolution video enhancement is presented. The method implemented and investigated by using three super resolution approaches. For all input low resolution frames in each method we compared both motion region and whole image in different super resolution algorithms. In all implementations, the results indicate that the proposed method has better quality. The results based on PSNR measures show that the proposed localized SR method, in comparison with the global SR method, show improvement in quality and provide faster processing.

6. REFERENCES

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