Image registration using PCA and Gradient Method for Super-resolution Imaging

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Abstract— **Super-resolution (SR) enhancement from multi-frame low-resolution (LR) images (multi-frame super-resolution) has been a well-studied topic in the literature. Image registration is the most important part for multi-frame super-resolution, and accurate alignment of LR images would contribute a critical role for the final success of SR image reconstruction. In this paper, we propose to combine the Principle Component Analysis (PCA) based registration method, which can perform object alignment in real-time and without constraints on the three registration parameters (i.e., translation, rotation, and scaling), and gradient registration method, which can perform precise registration with minor image movement. Experimental results show that the reconstruction SR images by our proposed method have much higher quality than those by the state of art algorithms.**

Keywords-super-resolutiont; image alignment; principal component analysis ;gradient method ;

I. INTRODUCTION

Super-resolution enhancement of images has been a well-studied topic in the literature, with a wide variety of solutions. All of these methods attempt to solve the same problem: to increase the resolution (the number of pixels) of a given image or given multi-frame LR images while also estimating the missing high frequency [1-2]. Recently, the super-resolution problem arises in a number of biometric applications, for example, person authentication from a low-resolution input or a set of LR inputs such images sent by mobile phones or taken from the closed-circuit televisions (CCTV). However, the low-resolution images lose detailed information of important features in biometric person authentication such as suspect identification. Therefore, how to recover lost information from multi-frame LR images to a high-resolution one is important for building effective image based biometric applications.

Multi-frame super-resolution consists of two essential steps—image alignment (registration) and interpolation. In the first step, a set of LR images are aligned (registered) onto a target high-resolution (HR) image, and then some learning-based techniques or interpolation processing are used to estimate perceptually plausible high frequency components of a low resolution image. Therefore, accurate image registration plays a critical role for the final success of SR image reconstruction. Some image registration algorithms for super-resolution such optical flow [3] and gradient method [4] were popularly in recently researches. However these conventional registration methods do require the two images under registration bearing similar image contents; that is, only small amount of shift or rotation between images are allowed, and cannot deal with scale problem for the registration images. In addition, the optical flow based registration method cannot deal with rotation movement in two registration images. Turgay Celik [5] proposed a fast object-based image registration using principal component analysis for super-resolution imaging. In the PCA-based registration method, a concerned region of interest (ROI) such as human face needing high-quality imaging are extracted from a sequence of video, and then use PCA based method for alignment of the sets of LR images for super-resolution. The PCA based registration method can perform object alignment in real-time and without constraints on the three registration parameters (i.e., translation, rotation, and scaling); which means that large amount of shift or rotation between images are allowed, and scale variance can also be solved. However, the PCA based method need to firstly segment the ROI from the global image. If the ROI part cannot be segmented accurately, the achieved movement parameters (i.e., translation, rotation) would be also inaccurate; that means that the PCA based registration method can only achieve approximated movement parameters in images. Therefore, this paper proposes to combine the PCA based and gradient method for image registration. We firstly use PCA-based method to extract the approximated registration parameters for the LR images, and then apply gradient method on the aligned LR image by PCA to achieve more accurate registration parameters for super-resolution imaging.

The paper is organized as follows. In section 2, we describe the multi-frame super-resolution imaging model. Section 3 gives the used registration methods, and section 4 presents experimental results. Conclusions are given in Section 5.

II. MULTI-FRAME SUPER-RESOLUTION IMAGING

SR imaging is to restore a high-quality image from one LR image or a set of LR images, which has been researched in the field of image processing for a long time. The imaging processing, yielding the observed LR image from the SR image, is modeled by:

$$y = FHDx + n \quad (1)$$

where x is an original HR image, which SR method wants to achieve; F is a linear transformation and H represents image warping; D is the down-sampling operator and n represents noise. Therefore, SR imaging is a kind of inverse problem, that seeks HR image x from one LR image or a set of LR images. In this paper, we mainly restore the SR image from a set of LR images, which is usually called multi-frame SR.[4] Fig. 1 shows the SR imaging concept for a set of LR images.

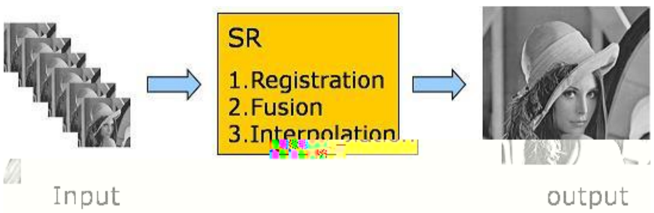


Fig. 1 SR imaging procedure

In multi-frame SR, there are usually three steps---Image registration, image fusion and interpolation. In the first step, the movement parameters of a set of LR images to a reference image are achieved using some registration methods for image alignment. All the set of LR images are aligned to a target onto a target high-resolution (HR) image according the obtained movement parameters in the first step, and then some learning-based techniques or interpolation processing are used to estimate perceptually plausible high frequency components of a low resolution image for output the HR image. Therefore, accurate image registration plays a critical role for the final success of SR image reconstruction. This paper mainly contributes to explore the new registration method for super-resolution imaging introduced in the following section.

III. Image Registration

Image registration is a basic processing that estimates the movement parameters (i.e. shift, rotation), and align images to decrease the difference between the reference image and the changing image. There are mainly three registration parameters: translation parameters, which represent displacement of horizontal and vertical directions; rotation parameter, which represents rotary quantity between images, and scale parameters, which represent size variance in the same object. In multi-frame SR, a reference image is needed to be selected from the available LR images, which the other LR images would be registrated to. As we mentioned in ‘introduction’ section that the conventional gradient method can achieve accurate translation and rotation parameters with small amount of movement in two similar images, but it cannot deal with large amount of movement and scale variance in the same object. In the other hand, PCA based registration can obtain approximate movement parameters and scale variance parameter. However, it cannot achieve accurate parameters due to inaccurate segmentation of ROI part from the LR images. Therefore, this paper proposed to combine the gradient and PCA based registration methods for image registration. Next, we introduce the two used registration method and our proposed algorithm.

A. PCA based registration method

This PCA based registration method is to enhance image equality of a special part (such as human face in a video) in an image. So we must firstly segment the focused part from the original image, and binarize it with the special part’s pixel value as 1 and otherwise as 0, where the special part is called as BROI. Then, the PCA registration technique estimate registration parameters using the extracted BROI image and PCA. Usually the BROI is needed to be clear and be easily extracted from the original LR images, and often represent some objects or special thing part. In a following part, we give a example for extracting human face and do registration using PCA based method.

For segmenting human facial (BROI) from an image, the simple color information can be used for achieving acceptable face region. Firstly, we translate the original R, G, B color space into YCC space, and then use a threshold value in following equation to decide if a pixel belongs human facial pixels.

$$BROI(x,y) = \begin{cases} 1, & (85 \le C_b(x,y) \le 125) \cap (135 \le C_r(x,y) \le 165) \\ 0, & otherwise \end{cases} \quad (2)$$

Furthermore, we apply morphological operators (opening and closing processing) to the initial BROI face image for removing noise or filling non-facial color part such as nose hole, eye, mouth, in human face, so can make the binary image without holes don’t bear any flesh color (e.g, nose hole, eye, mouth). An example for human facial part extraction is shown in Fig.2.

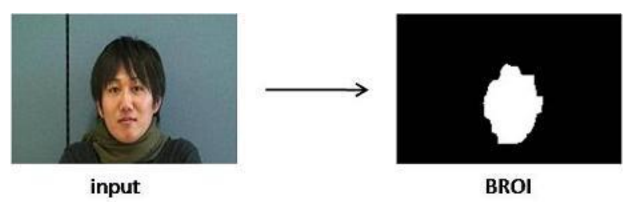


Fig. 2 BROI image Extraction

For all LR images including the same face, we need to extract the BROI part, and calculate a center of gravity of BROI to estimate translation parameter between the reference image and the other LR images. Here, N denotes the number of total pixel of a BROI image, (x_i, y_i) represents the pixel coordinates in the BROI, and then the center $(\bar{x}, \bar{y})$ of the BROI can be calculated by the following equation:

$$\bar{x} = \frac{1}{N}\sum_{i=1}^{N} x_i \quad and \quad \bar{y} = \frac{1}{N}\sum_{i=1}^{N} y_i \quad (3)$$

After obtaining the gravity center of the BROIs in all LR images, we can estimate the translation parameters by simply using gravity center for the changing LR image minus that of the reference LR image.

In order to estimate rotation parameter, we calculate eigenvector of pixel coordinates covariance matrix corresponding to the gravity center in BROI using PCA. The symmetric covariance matrix C can be obtained by:

$$C = \frac{1}{N}\sum_{i=1}^{N}\begin{pmatrix} x_i - \bar{x} \\ y_i - \bar{y} \end{pmatrix}\begin{pmatrix} x_i - \bar{x} \\ y_i - \bar{y} \end{pmatrix}^T = \begin{bmatrix} a & b \\ b & c \end{bmatrix} \quad (4)$$

Then, we use PCA to calculate the eigenvalue λ and the eigenvector e of this symmetric covariance matrix C:

$$\lambda = \frac{(a+c) + \sqrt{(a+c)^2 - 4(ac - b^2)}}{2}$$

$$e = \frac{1}{\sqrt{1+\gamma^2}}\begin{bmatrix} 1 & \gamma \end{bmatrix}, \quad \left(\gamma = \frac{a - b - \lambda_1}{c - b - \lambda_1}\right) \quad (5)$$

Then, the global orientation θ of BROIs in each LR image can be calculated by:

$$\theta = \tan^{-1}(\gamma) = \tan^{-1}\left(\frac{a - b - \lambda_1}{c - b - \lambda_1}\right) \quad (6)$$

The rotation parameters of all LR images to a reference image can be obtained by the difference in the global orientation between two BROI images.

Finally, we can get the scale variance parameter in two BROI images by only simply comparing the total pixel numbers in BROIS.

Therefore, the registration parameters including shift, rotation and scale can be estimated using PCA analysis of the extracted BROI from original LR images. However, the PCA based registration method dependent the segmentation accuracy of extracted BROI very much. Usually, the BROI for the same object part in several images cannot be extracted precisely due to even minor imaging environment variance such illumination changing and a little noise. So this method just achieves the approximated registration parameters for super resolution imaging. [5]

B. *Gradient based registration method*

Gradient based registration method can accurately calculate translation and rotation parameters with the constraints, where the two images (a reference image and a image for estimating movement parameters) have similar contents, the amount of movement is small in the two images. The main idea of this method is to optimize a cost (evaluation) function, which evaluates similarity between the reference and the ready registrating images by simple intensity difference or mutual information measurement, and then it can be implemented by the steepest descent method. In the implementation procedure, we need to decide an initial value of movement parameters. If the predefined initial values of the parameters are near to real movement parameters, we can fast achieve optimized or precise movement parameters by steepest descent method. However, the predefined initial values is far from real movement parameter, the optimization solver with the gradient method maybe converge as a local minimum point, and cannot achieve real movement parameters. Therefore, the correct setting of initial values for movement parameters has an essential role final success estimation of movement parameters.

C. *Combined algorithm of PCA and Gradient method*

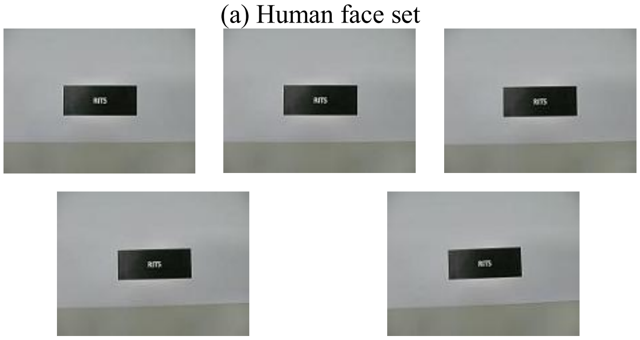
This paper proposes to combine the PCA based and gradient based registration method together for more accurate image registration. Firstly, the PCA based method estimate an approximated movement parameters including shift, rotation and scale, and then calculate the more accurate registration parameters using gradient method with the PCA estimated parameters as initial values. Therefore, our proposed registration method can not only achieved the approximated movement parameters for large amount movement and also obtain the more accurate parameters for minor amount movement. In addition, the scale parameter is also can be calculated with the PCA based method. Therefore, our proposed method would be suitable for most real cases in real applications.

IV. EXPERIMENTAL RESULTS

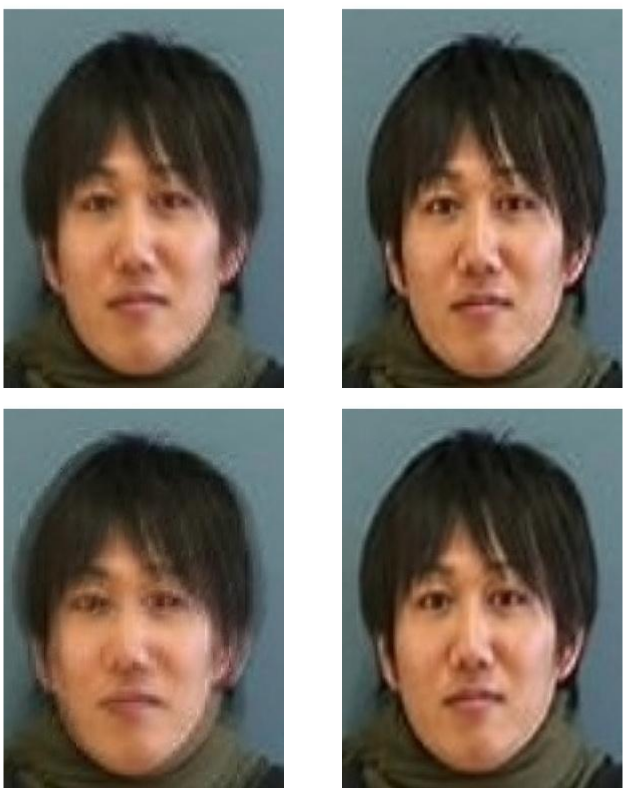
We use two sequences of LR images, each includes 5 images, for validating the efficiency of our proposed method compared to some conventional methods. The two sequences of LR images are shown in Fig. 3 (a) and Fig. 3(b), where one is human face set in Fig. 3(a) and the other is a text set with ‘RITS’ in Fig. 3(b). The LR image size of the human face set is 180×120, and for the text set is 160×120. Fig. 4 gives the reconstruction SR images using 4 types registration method: Optical flow [3], PCA [5], gradient (initial parameter values: 0) [4] and our proposed method in (a) and (b) for human face and text set, respectively. The left top SR image in Fig. 4(a) and (b) are the results using Optical flow method; the right top are those using PCA; the left bottom using gradient method and the right bottom using our proposed method.

It is obvious that the reconstruction HR images for face set using optical flow and gradient method are very blurring. The one using PCA seems very sharp, but some noise is appeared near nose and line of under face. The HR image by our proposed method is very sharp and looks very natural. For the text set, the result by our proposed method is also much clearer than those using the conventional optical flow, PCA and gradient method. In order to give objective validations using different methods, we also give PSNR values of the reconstruction HR images in Table 1. It can be seen that the PSNR of the HR image by our proposed method is much higher than those using conventional algorithms.

(a) Human face set



(b) Test ‘RITS’ set
Fig. 3 two sets of LR images



(a) For human face set

(b) For text set
Fig. 4 HR reconstruction images using 4 algorithms

Table1 PSNR [dB] of reconstruction images

	Optical Flow	PCA	Gradient	Ours
face	22.9854	28.6591	23.7447	31.7041
RITS	26.4461	27.1639	26.9097	28.6397

V. CONCLUSIONS

This paper proposed to combine PCA based and gradient based method for image registration in super-resolution imaging. The proposed registration method can not only achieved the approximated movement parameters for large amount movement and also obtain the more accurate parameters for minor amount movement. In addition, the scale parameter is also can be calculated with the PCA based method. Experimental results showed that the reconstruction SR images by our proposed method have much higher quality than those by the state of art algorithms.

ACKNOWLEDGMENT

This work was supported in part by the Research Matching Fund for Private Universities from MEXT (Ministry of Education, Culture, Sports, Science, and Technology).

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