Reconstructing Vehicle License Plate Image from Low Resolution Images using Nonuniform Interpolation Method

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Abstract

In this study, non-uniform interpolation method was adopted to reconstruct license plate image from a series of low resolution vehicle license plate images. Several image registration methods which were used to estimate the position and orientation differences between these low resolution images are tested in this study. It was found that the Fourier method is superior to other methods. The non-uniform interpolation method is then used to reconstruct vehicle license plate images from images with a character size as small as 3 × 6 pixels. Results show that although the number or character is still not easy to read, the reconstructed image shows a better readability than the original image.

Keywords: image enhancement, image registration, license plate recognition.

1. INTRODUCTION

Frequently, there is a need to identify vehicle license plate images taken from a camera or CCD that is far away from the vehicle for security. The vehicle plate recognition systems developed by other researchers [1-5] were generally designed for parking lot management or automatic toll booth and might not be suitable for such an application.

In order to fulfill this need, techniques used to reconstruct high resolution image from low resolution image can be adopted. Besides interpolation methods, super resolution techniques are frequently used for this purpose.

By gathering more subpixels spatial information through multiframes of images the super resolution method used a set of low resolution image to reconstruct high resolution images. However, it is of important to know the relative position between these images before reconstructing the image.

There are various registration methods had been proposed by other researchers [6]. In this paper, several registration methods are adopted to estimate the relative position between images. These methods are presented in the following section. The non-uniform interpolation method used to reconstruct high resolution image is also briefly described. Effects of registration methods and number of image frame on the reconstructed image are then studied. The best registration method is then used to reconstruct several low resolution vehicle license plate images. Finally, conclusions are made based on the test results.

2. REGISTRATION METHODS AND RECONSTRUCTING METHODOLOGY

The registration methods frequently used can be categorized as area based method and feature based method [6]. In this study, one area based method and three feature based methods are tested. The area based method tested is the Fourier method [7, 8], and the feature based methods tested are Li [9], Lapalacian, and Lapalacian of Gaussian [10]. These methods are briefly described in the following.

Area-based method

There are two area based approaches generally used for image comparison. One is the cross correlation method and the other one is the Fourier method. The cross correlation method used correlation coefficient as an estimate to determine the similarity of two images [11]. This method may be adopted to estimate position error. But the subpixel image alignment problem we facing here including both position and orientation error estimation and compensation. Since the cross correlation method can not deal with images with rotation, this approach might not be suitable for this purpose.

The Fourier method used the Fourier transform to identify the frequency dormant information of examined images. By examining the orientation and phase difference in the Fourier transform of these images, the position and orientation difference can be estimated [7, 8]. Therefore, the Fourier method is tested in this study.

Feature-based methods

Barbara [12] divided the feature based method into four steps: (1) feature detection; (2) feature matching; (3) transform model estimation; and (4) image resampling and transformation. Feature detection is searching for region feature, line feature or point feature in the examined images.

In this study, pixel point with maximum gradient in local area or corner point are searched and used as feature points. By comparing the position differences of these feature points, the location and orientation differences between two images can be estimated.

Li [9] used Harris and Hessian operator to search for pixel point with maximum gradient in local area. Lapalacian and Lapalacian of Gaussian operator can also be used to estimate the image gradient and corner point [10]. In this study, these three feature–based methods are also tested.
After identifying the feature points, the related position change of feature points in images can be estimated. There are many methods had been proposed for this estimation [11, 14-15]. Since only translation and rotation is needed for consideration in this case, the method to calculate the differences is relatively simple and straight forward. The least square error method is used to calculate the position and orientation differences in this study.

Reconstruction methodology

There are many super resolution approaches had been proposed since Tsai and Huang [16]. These methods can be categorized as [17]: stochastic method, iterative back-projection method and nonuniform interpolation method. Comparing with other methods the nonuniform interpolation method is relatively easy to use, therefore this method is adopted here to reconstruct license plate image.

As indicated in Fig. 1, the relative position between a series of images are determined first, interpolation methods are then used to reconstruct high resolution image[18-20]. In this study the bi-cubic interpolation method is used.

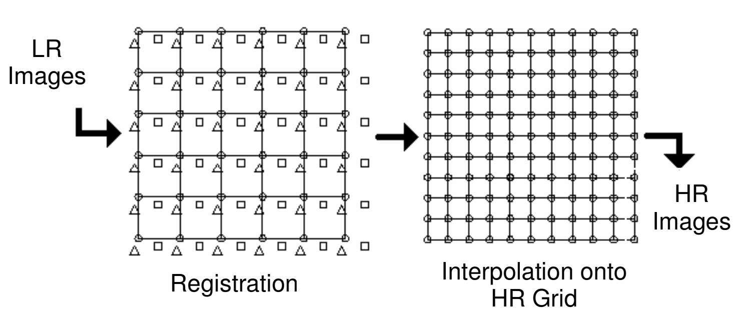


FIGURE 1: Schematic Diagram for Non-Uniform Interpolation Method.

3. TEST RESULTS AND DICUSSIONS

Effects of registration on image positioning

In order to study effects of registration methods on image positioning, a high resolution image (3200 × 2400) as shown in Fig. 2 was used as the referential images. Low resolution (320 × 240) images were made by averaging each 10 × 10 area of the standard image. A series of low resolution images with position and orientation difference are made from images with a shift of 0 to 12 pixels to the referential image (corresponding to a shift of 0. to 1.2 pixels in low resolution image) and 0.1 to 2.8^o degree rotation in the standard image.

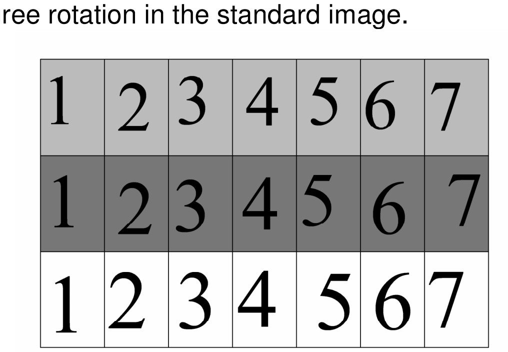


FIGURE 2: The Standard 3200x2400 Image Used In This Test.

Table 1 shows the summary of the comparison of position and orientation errors. Examining this table, it is observed the area method is superior to the feature based methods tested in this study. In the feature based methods, the use of Lapalacian mask is the best, and then of use of Lapalacian-Gaussian. Both the mean and standard deviation in orientation error for the Lapalacian (0.041, 0.064), and Lapalacian Gaussian (0.047, 0.070)are quite close to that of the Fourier area method(0.047, 0.051). However, the mean and standard deviation in orientation error for the Fourier method(0.021, 0.025) is much smaller than the Lapalacian(0.100, 0.131), and Lapalacian Gaussian method(0.109, 0.140).

TABLE 1: Comparison of position and orientation error resulted from various registration methods.

		Li	Lapalacian	Lap. Of Gau.	Fourier
Position errors (pixels)	Maximum	0.54	0.36	0.36	0.1
	Minimum	0.1	0.	0.	0.
	Average	0.129	0.100	0.109	0.021
	SD*	0.159	0.131	0.140	0.025
Orientation errors (degree)	Maximum	0.3	0.1	0.1	0.1
	Minimum	0.	0.	0.	0.
	Average	0.094	0.041	0.047	0.047
	SD*	0.132	0.064	0.070	0.051

*SD: standard deviation

Effects of registration method and number of image frames on image reconstruction

In order to study effects of registration methods as well as the number of images used for reconstruction on the reconstructed image, a series of low resolution images with position and orientation difference are made from images with a shift of 1 to 10 pixels to the referential image (corresponding to a shift of 0.1 to 1.0 pixels in low resolution image) and 0.1 to 1.0^{o} degree rotation in the standard image.

These images are then randomly picked as the base for image reconstruction. Registration methods introduced in the previous section are used to estimate the position and orientation differences between these images.

Fig. 3 shows interaction effects of image number and registration method on the correlation coefficient of the referential image and the reconstructed image. The correlation coefficient between the original high resolution image and the reconstructed image are used as the performance index.

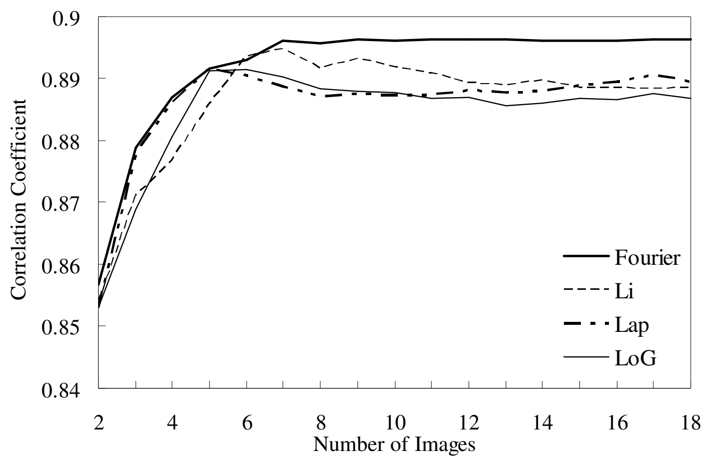


FIGURE 3: Interaction Effects of Image Number and Registration Method on the Correlation Coefficient of the Referential Image and the Reconstructed Image.

As shown in the figure, it was found that for all registration methods tested, the performance index increased as the frame number increased in the beginning (<7). However, no further improvement in the performance index was observed when the frame number further increase. In most cases the correlation coefficient might slightly decrease as the frame number further increased. Theoretically, a better image can be reconstructed with more fames of image with the cost of more computing time. However, it is found that errors are not avoidable when estimating the position and orientation differences between images, using more frames of image might make the reconstructed image more blur instead of more clear. It is also expected that the Fourier method is superior to other methods no matter how many image frames were used for image reconstruction since the Fourier method had performance in image positioning than other methods.

Comparison of reconstructed vehicle license plate

From the previous section, the Fourier method is considered as the best approach for image registration. This method is then adopted here to reconstruct vehicle license plate image. For comparison, the results generated by using the Lapalacian method as the registration method were also presented. 3 sets of vehicle images as shown in Fig 4 are taken using a Pentax Optio SV digital camera. There are 16 frames taken or each sample for reconstruction.

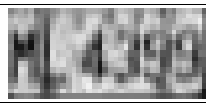
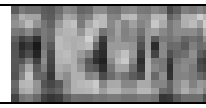
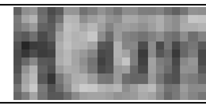
	Sample 1	Sample 2	Sample 3
Original vehicle Image			
Size	320 x 240	320 x 240	320 x 240
License Plate			
size	38 x 17	27 x 13	24 x 11

FIGURE 4: Dimensions of Test Samples.

Figures 5 to 7 shows the images reconstructed using 4, 7 and 16 frames, and two registration methods. It is obvious that image reconstructed from 7 frames of image had better results than that reconstructed from 4 frames of image. However, there is no evident that image reconstructed from 16 frames of image had better results than that reconstructed from 7 frames of image. These results are consistent with the study shown in the previous section.

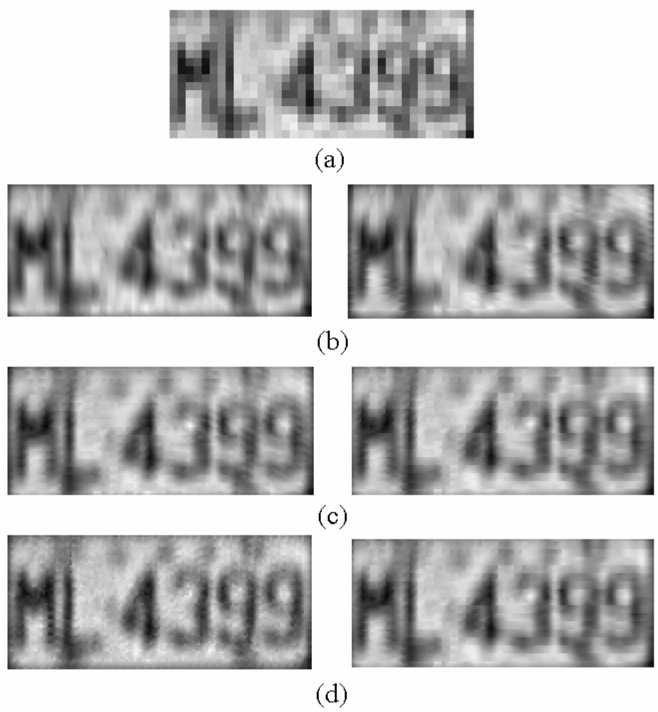


FIGURE 5: Comparison Of Images Reconstruct From a 38 X 17 Vehicle License Plate Image (a) Original Image (b) Images Reconstructed Using 4 Low Resolution Images (c) Images Reconstructed Using 7 Low Resolution Images (d) Images Reconstructed Using 4 Low Resolution Images(Left: Using Fourier Method; Right: Lap Method).

In Fig. 5, the size of license plate image is 38 × 17 pixels while the size of each number is around 5 × 10 Pixels. The plate number is readable even without reconstruction. However, the image is much easy to read after reconstruction. And the images reconstructed by using the Fourier method as the registration method seems a little clearer than those using the Lapalacian method.

In Fig. 6, the size of license plate image is 27 × 13 pixels while the size of each number is around 3.5 × 7 Pixels. The plate number is hardly readable without reconstruction. Although, the reconstructed images are still not quite readable, but it quite easy to identify the first three characters are "M" "L" and "4". Although we can not read 3 directly from the fourth character, 3 is a quite obvious guess for the fourth character. For the last two characters, one might guess they are 0, 5 or 9 instead of other numbers.

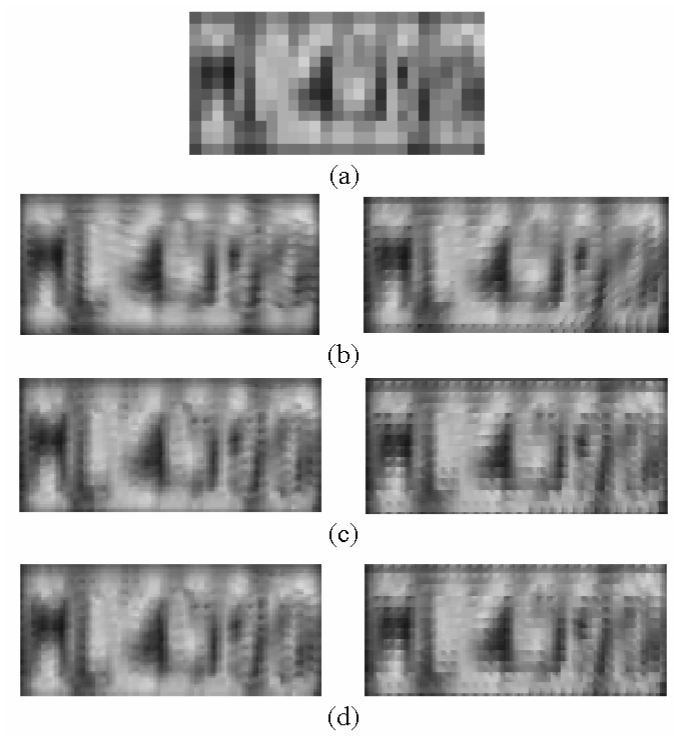


FIGURE 6: Comparison Of Images Reconstruct From a 27 X 13 Vehicle License Plate Image (a) Original Image (b) Images Reconstructed Using 4 Low Resolution Images (c) Images Reconstructed Using 7 Low Resolution Images (d) Images Reconstructed Using 4 Low Resolution Images(Left: Using Fourier Method; Right: Lap Method).

In Fig. 7, the size of license plate image is 24 × 11 pixels while the size of each number is around 3 × 6 Pixels. The plate number is hardly readable even after reconstruction. However, there is a good chance to guess the first four characters as "ML43". For the last two characters, one might guess they are 0, 5 or 9 instead of other numbers.

4. CONSLUSIONS

In this paper, non-uniform interpolation method was adopted to reconstruct low resolution license plate image. This method used a series of low resolution images to reconstruct high resolution image. It is of importance to know the position differences between these images before the reconstructing process. Several image registration methods are tested here to estimate the position and orientation differences between these images. It was shown that the Fourier method is superior to other methods tested in this study. Vehicle license plate images with a character size as small as 3 × 6 pixels were tested. Results show that although the character is still not easy to read, the reconstructed image do improved the readability. The study shows the bottle neck for this study is the methodology for registration. Without better registration methodology, a better super resolution method is still useless. It was also found that without further improvement in the registration technique, not much improvement can be achieved by increasing frame number.

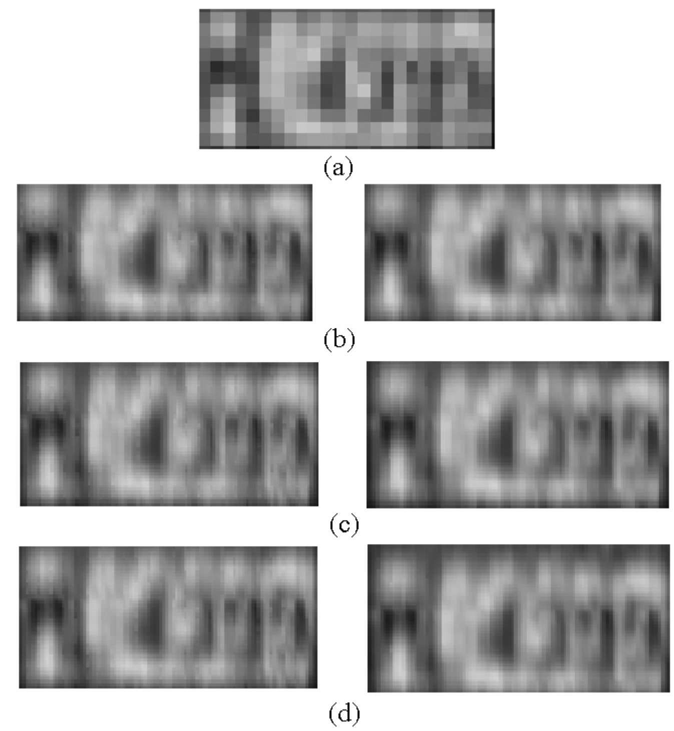


FIGURE 7: Comparison Of Images Reconstruct From a 24 X 11 Vehicle License Plate Image (a) Original Image (b) Images Reconstructed Using 4 Low Resolution Images (c) Images Reconstructed Using 7 Low Resolution Images (d) Images Reconstructed Using 4 Low Resolution Images(Left: Using Fourier Method; Right: Lap Method).

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