Effects of Image Alignment Error on Vehicle License Image Reconstruction using Non-uniform Interpolation Method

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***Abstract*—In this study, effects of image alignment error on vehicle license image reconstruction using the non-uniform interpolation method were studied. It is expected that the increase in measurement error will degrade the reconstructed image. Several image registration methods which were used to estimate the position and orientation differences between low resolution images are also tested. 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 enlargement, image registration, super resolution**

I. INTRODUCTION

There are many vehicle license image recognition techniques or systems had been developed generally for parking lot management or automatic toll booth [1-5]. These systems generally achieved with high resolution vehicle license image taken from the right angle. However, 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 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. The super resolution method used a set of low resolution image to reconstruct high resolution images. By gathering subpixels spatial information through multiframes of images, the super resolution techniques show its ability to improve the image quality. The non-uniform interpolation method is a super resolution approach which is relatively easy to understand and implement.

However, it is of importance to know the relative position between these images before reconstructing the image. Various registration methods had been proposed by other researchers [6]. However, no comparison of the accuracy of these registration methods had been made. Therefore, it is of interest to study effects of the measurement errors (alignment errors) on vehicle license image reconstruction and the optimal registration method for this application.

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 misalignment on image reconstruction are then studied. Effects of registration methods and number of image frame on the reconstructed image are also 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.

II. 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], Laplacian, and Laplacian of Gaussian [10]. These methods are briefly described in the following.

A. 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 cannot 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.

B. 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. Laplacian and Laplacian 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.

C. 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]. In this study the bi-cubic interpolation method is adopted here to reconstruct the high resolution image.

III. EFFECTS OF MISALIGNMENT ON IMAGE RECONSTRUCTION

In this study, a high resolution image (3200 × 2400) as shown in Fig. 2 was used as the standard image. Low resolution (320 × 240) images were made by averaging each 10 × 10 area of the standard image. Fig. 3 shows a typical example of low resolution image made.

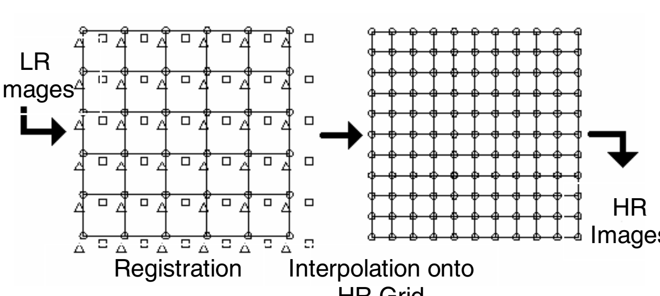


Figure 1. Schematic diagram for non-uniform interpolation method.

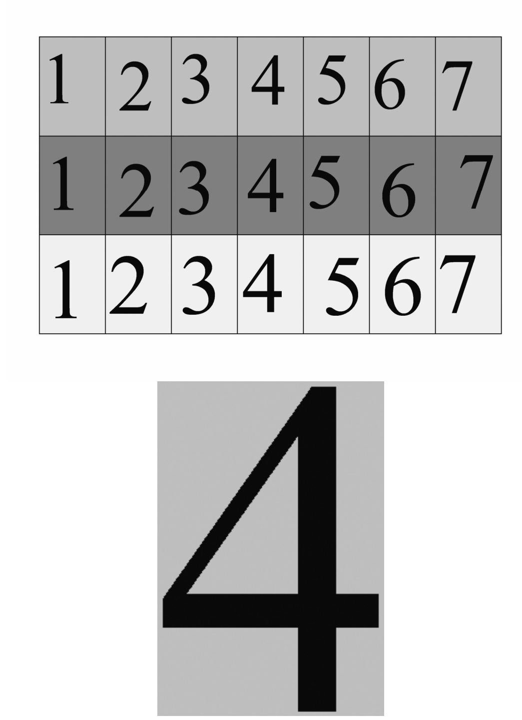


Figure 2. The standard 3200x2400 image used in this test

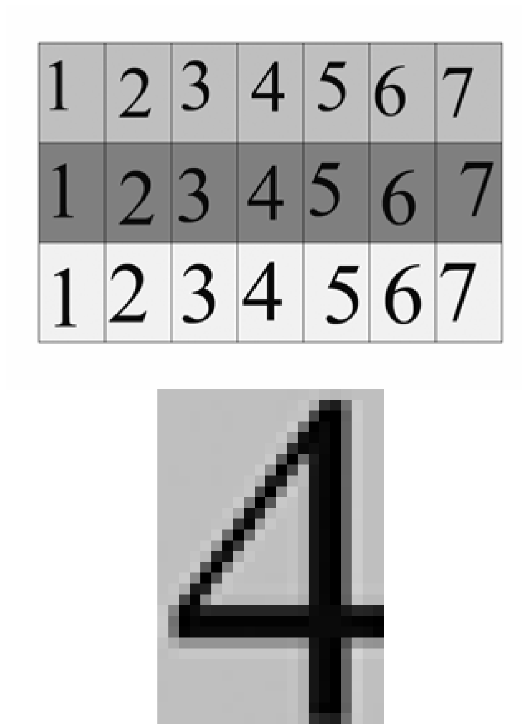


Figure 3. A 320x240 low resolution refernce image made in this test

In order to study effects of the measurement error (misalignment) on image reconstruction, a series of low resolution images with position and orientation difference are made. Table I lists the position and orientation shift of these referential images.

Two cases are designed for this study. In the first case, we consider only the position measurement error ranging from 0.1 to 0.4 pixels. Table II demonstrate an example of assumed measurement with a position measurement error of 0.1 pixels. As compared with Table I, each of the 18 low resolution images is randomly assigned a position measurement error of 0.1 pixels in x- or y-direction position shift measurements. In the second case, we consider only the orientation error ranging from 0.05 to 0.4 degrees.

Fig. 4 shows effects of position or orientation measurement error on the reconstructed results. It was shown that without misalignment the correlation coefficient is 0.8945. When the position error is small (0.1), the correlation coefficient is about the same. However, significant effects had been observed even with small orientation error. The correlation coefficient is greatly decreased as the position error greater than 0.5 pixels or the orientation error greater than 0.35 degrees.

TABLE I. THE POSITION AND ORIENTATION SHIFT OF THE REFERENTIAL IMAGES.

Sample	X-shift (Pixel)	Y-Shift (Pixel)	Rotation (Degree)
1	0	0	0
2	1	0.1	0
3	0.8	0.3	0
4	0.6	0.5	0
5	0.4	0.7	0
6	0.2	0.9	0
7	0	0	1
8	0	0	1.4
9	0	0	1.8
10	0	0	2.2
11	0	0	2.5
12	0	0	2.8
13	1.2	0.1	1
14	1	0.3	1.4
15	0.8	0.5	1.8
16	0.6	0.7	2.2
17	0.4	0.9	2.5
18	0.2	1.1	2.8

TABLE II. THE ASSUMED POSITION AND ORIENTATION SHIFT OF THE REFERENTIAL IMAGES.

Sample	X-shift (Pixel)	Y-Shift (Pixel)	Rotation (Degree)
1	0	0	0
2	0.9	0.1	0
3	0.8	0.2	0
4	0.6	0.4	0
5	0.4	0.6	0
6	0.3	0.9	0
7	0.1	0	1
8	-0.1	0	1.4
9	0	0.1	1.8
10	0	-0.1	2.2
11	0	0.1	2.5
12	0.1	0	2.8
13	1.3	0.1	1
14	0.9	0.3	1.4
15	0.7	0.5	1.8
16	0.6	0.8	2.2
17	0.4	0.8	2.5
18	0.2	1	2.8

Fig. 5 shows a typical example of image reconstructed with misalignment. For comparison, the image reconstructed without misalignment is shown in Fig. 6. As shown in these figures that even with the similar correlation coefficient level, the image reconstructed without misalignment is better than the other one.

IV. EFFECTS OF REGISTRATION ON IMAGE POSITIONING

In order to study effects of registration methods on image positioning, 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 degree rotation in the standard image.

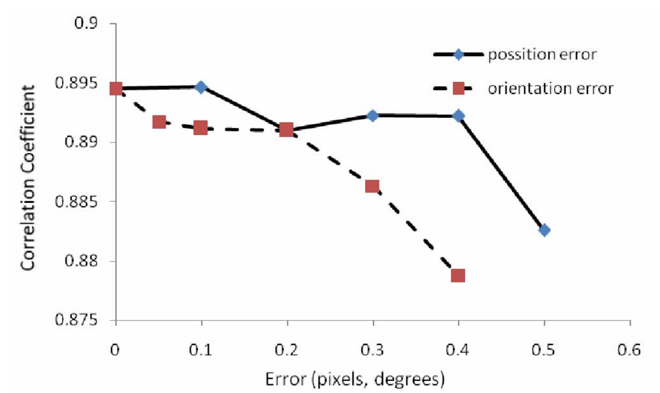


Figure 4. Effects of measurement error on the correlation coefficient of the referential image and the reconstructed rmage.

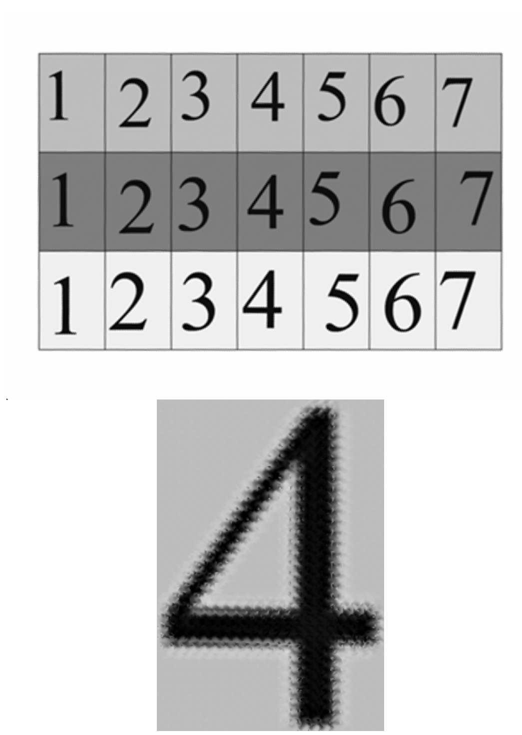


Figure 5. A typical example of reconstructed image with misaligment (with a position meaurement error of 0.3 pixels)

In this study, one area based method and three feature based methods are tested. The area based method tested is the Fourier method, and the feature based methods tested are Li, Lapalacian, and Lapalacian of Gaussian.

Table III shows the summary of the comparison of position and orientation errors between the measured and designed position and orientation shift. 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)

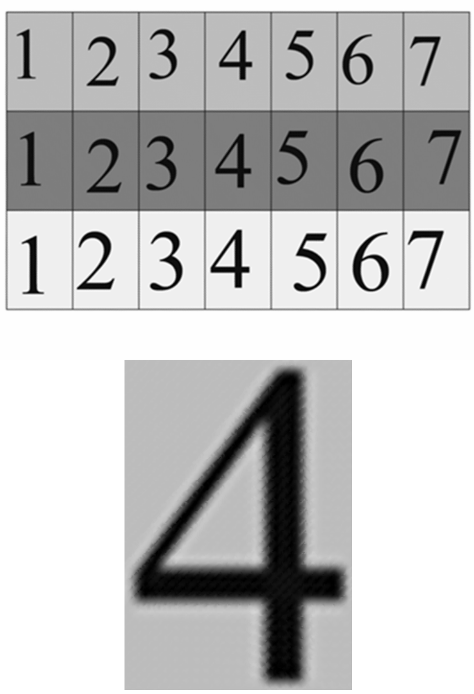


Figure 6. reconstructed image without misaligment

TABLE III. COMPARISON OF POSITION AND ORIENTATION ERROR RESULTED FROM VARIOUS REGISTRATION METHODS.

		Li	Lap	Lap of Gau	Fou
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; Lap: Laplacian; Gau:Gausian; Fou: Fourier

V. 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 1.0o 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. 7 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.

As shown in the figure, it was found that, 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.

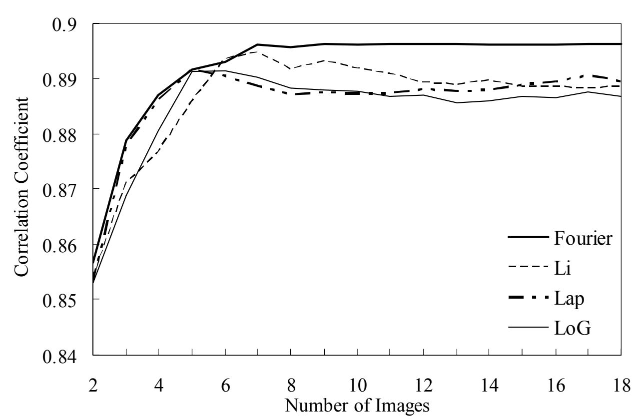


Figure 7. Interaction effects of image number and registration method on the correlation coefficient of the referential image and the reconstructed rmage.

VI. 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 Laplacian method as the registration method were also presented. 3 sets of vehicle images as shown in Fig 8 are taken using a Pentax Optio SV digital camera. There are 16 frames taken or each sample for reconstruction.

Figs. 9 to 11 shows the images reconstructed using 4, 7 and 16 frames. 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.

In Fig. 9, 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 Laplacian method.

In Fig. 10, 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 guess the first three characters are "M" "L" and "4". Although we cannot 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.

In Fig. 11, 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.

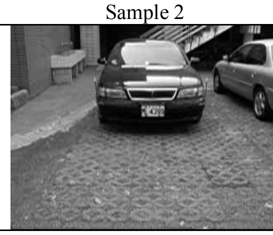
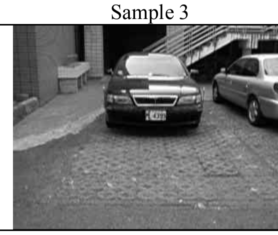
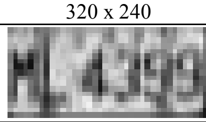
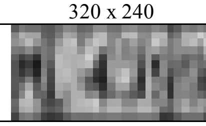
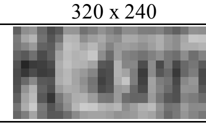
	Sample 1	Sample 2	Sample 3
Original vehicle Image			
Size	320 x 240	320 x 240	320 x 240
License Plate			
size	38 x 17	27 x 13	24 x 11

Figure 8. Dimensions of test samples.

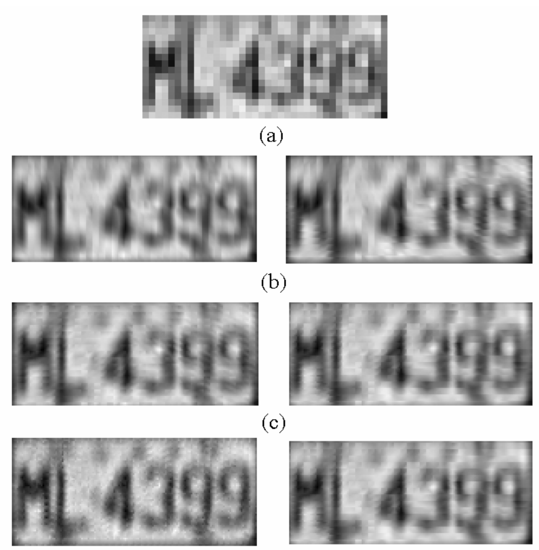


Figure 9. Comparison of images reconstruct from a 38 X 17 vehicle license plate image (a) original image (b) images reconstructed using 7 low resolution images (c) images reconstructed using 16 low resolution images (d) images reconstructed using 4 low resolution images (left: using Fourier method; right: Laplacian method).

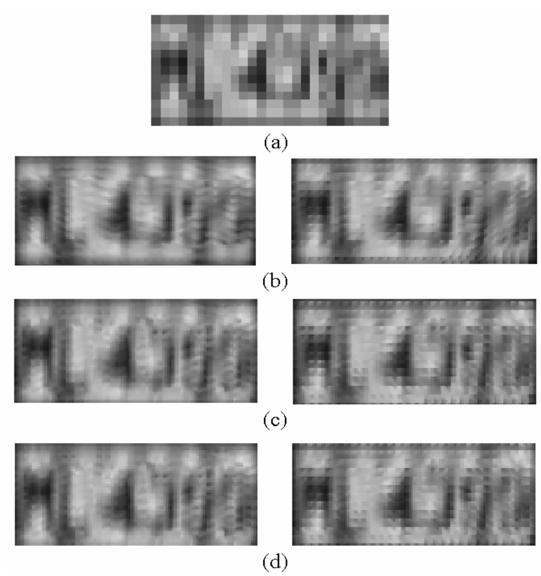


Figure 10. Comparison of images reconstruct from a 27 X 13 vehicle license plate image (a) original image (b) images reconstructed using 7 low resolution images (c) images reconstructed using 16 low resolution images (d) images reconstructed using 4 low resolution images (left: using Fourier method; right: Laplacian method).

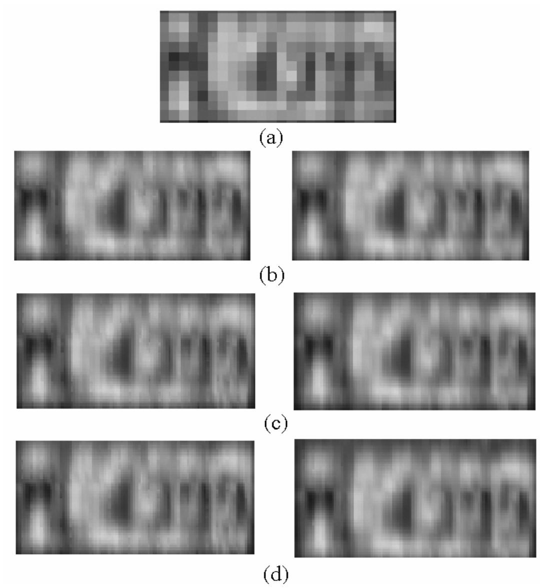


Figure 11. Comparison of images reconstruct from a 24 X 11 vehicle license plate image (a) original image (b) images reconstructed using 7 low resolution images (c) images reconstructed using 16 low resolution images (d) images reconstructed using 4 low resolution images (left: using Fourier method; right: Laplacian method).

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.

VII. CONCLUSIONS

In this paper, effects of image alignment error on vehicle license image reconstruction using the non-uniform interpolation method were studied. The non-uniform interpolation 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. The study demonstrated the effects of misalignment on the reconstructed image. As expected that the increase in measurement error will degrade the reconstructed image.

Several image registration methods which were used to estimate the position and orientation differences between low resolution images are also tested. 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.

The study shows the bottle neck for this study is the methodology for registration. The average orientation measurement error is around 0.05 degree while the average position shift measurement error is 0.02 pixels with the Fourier method. 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.

ACKNOWLEDGMENT

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