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SUPERRESOLUTION USING PAPOULIS-GERCHBERG ALGORITHM BASED PHASE BASED IMAGE MATCHING

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Abstrak

Citra resolusi tinggi (*High Resolution Image*) akan memberikan informasi yang lebih detail, sehingga analisis terhadap citra tersebut menjadi lebih akurat. Banyak bidang memerlukan citra resolusi tinggi antara lain adalah medical, penginderaan *satelite*, citra dari teleskop serta pengenalan pola.Pada penelitian ini dilakukan proses untuk mendapatkan citra resolusi tinggi, yang dikenal dengan *superresolution*. Sebagai citra referensi, digunakan lebih dari satu citra, namun demikian, citra-citra tersebut berada pada *scene* yang sama. Dua tahap utama dalam *superresolution* adalah registrasi dan rekonstruksi. Registrasi yang akurat diperlukan untuk mendapatkan hasil rekonstruksi yang baik. *Phase-Based Image Matching* (PBIM) digunakan untuk estimasi translasi pada tahap registrasi. Hanya translasi sampai ketelitian *sub pixel* yang berkontribusi dalam rekonstruksi. Untuk mendapatkan translasi sampai *level sub pixel*, dilakukan *fitting* disekitar puncak. Sedangkan untuk rekonstruksi ke dalam Grid Resolusi tinggi digunakan algoritma *Papoulis-Gerchberg*. Penulis melakukan kolaborasi antara registrasi dengan PBIM dan rekonstruksi menggunakan algoritma *Papoulis-Gerchberg*. Uji coba dilakukan penulis dengan obyek serangkaian citra dengan banyak tekstur dan sedikit tekstur. Dari hasil uji coba, citra dengan banyak tekstur akan menghasilkan *Peak Signal to Noise Ratio* (PSNR) rata-rata 21,62. Sedangkan untuk citra yang kurang mengandung tekstur 19,54.

Kata kunci: *Superresolution*, Registrasi, Rekonstruksi, *Phased Based Image Matching.*

Abstract

High Resolution Image provide more detail information, so that it obtain more accurate image analysis. Many areas require high resolution image, such as medical, sensing satellite, image of the telescope and pattern recognition. This research make a process to obtain high resolution images, known as superresolution. This superresolution using a series of images in the same scene as the reference image. Two main stages in the super resolution are the registration and reconstruction. An accurate registration is required to obtain a great reconstruction results. Phase-Based Image Matching (PBIM) *will be used to estimate pixels translation at the registration stage. Only sub-pixels translation which contribute to the reconstruction phase. We used the function fitting around the peak point, to obtain sub pixel accurate shift. While reconstruct a high-resolution image use Papoulis-Gerchberg algorithm. The author collaborate registration and reconstruction. Registration using* PBIM *and reconstruction using Papoulis-Gerchberg algorithm. Experiments have been done with a series of images that contain much texture and less texture. The experimental results with images contain much texture produces an average Peak Signal to Noise Ratio* (PSNR) *21.62. While image contain less texture produces PSNR 19.54.*

Keyword: Superresolution, Registration, Reconstruction, Phased Based Image Matching.

INTRODUCTION

Nowadays image processing becomes quite important in human life. High Resolution Image provide more detaile information, so that the analysis of image becomes more accurate. For instance of high resolution medical images will help physicians to make appropriate diagnosis. Image can be obtained by using a recording device. The output can be photos, video and digital that can be directly stored in the magnetic tape. Images are often have decreased quality, for example, contains a defect or noise, the color is too much contrast, less sharp, blur and low resolution level [1].

Since 1970 recording system using Charge-Coupled Device (CCD) have been widely used to take digital images. CCD is a device with a light-sensitive surface which consists of two-dimensional sensor [1,2].

High-resolution image can be obtained by improving the quality of CCD, but it is require high cost. Another approach to obtain high-resolution image is superresolution, which requires a lower cost.

Super Resolution is a method to improve low-resolution images into high resolution image. Based on the number of reference images, superresolution can be grouped into two categories, namely superresolution by using a low resolution image, and superresolution using multiple low resolution images. This reference image used to be on the same scene [1,2] .

The advantage of superresolution is performed by signal processing, thus requiring a low cost. Another advantage can be using low-resolution images produced by only a regular camera. Several studies related to the superresolution has been done by researchers.

Barreto D et al [3] conducted research related to pixels translation which are the first step in superresolution. Their research evaluated the performance of translation non-parametric techniques which are translation estimation and optical flow. Translation estimation using block matching. The result is superresolution depends on the area that will be the object. Research on pixels translation using Phase-Based Image Matching (PBIM)has been performed by other researchers [4,5,6].

Balaji Narayanan, et al using the filter method Partition-Based Weighted Sum (PWS)[7]. In this method, parameter translations the pixels of image with low resolution is estimated using gradient based iterative technique. The results of this estimation will be used to determine the pixels position on the High Resolution Grid (Grid HR). On high resolution grid, some pixels value is not known. To determine those pixels, it is divided the grid into multiple windows, and in each the window will be filtering the PWS filter. At the each windows position, the output is formed by using a number that represents the weight of the corresponding pixels in the windows.

The other methods of a reconstruction is Papoulis-Gerchberg algorithm [8,9]. In this method, image reconstruction is done by projecting the pixels estimation on High Resolution Grid (Grid HR). These algorithm assumes that a pixels value contained in the HR grid is known, and images with high-frequency component is set to zero by using a low filtering image. The results of this study, the accuracy of the registration which is very influential on high-resolution image is generated. If the low-resolution image hasmuch same information, it can’t contribute to the superresolution.

SUPERRESOLUTION

Superresolution has two main stages, which are the registration and reconstruction. The registration is done by estimation of pixels translation. Pixels translation will be useful for reconstruction. If the translation pixels in integer, then each image will contain the same information, this can not be used in superresolution, but if the translation level in real pixels (sub pixels) it will obtain additional information that will be useful at the time of reconstruction [1,2]. Figure 1 is a step of the superresolution.

In this study, the authors collaborate registration and reconstruction. The author uses a registration with Phased Based Image Matching (PBIM), because the translation pixels create high estimation accuracy. Fitting function is used to obtain estimates on the level of sub-pixels translation. Image with higher resolution obtained by reconstruction using Papoulis-Gerchberg Algorithm.

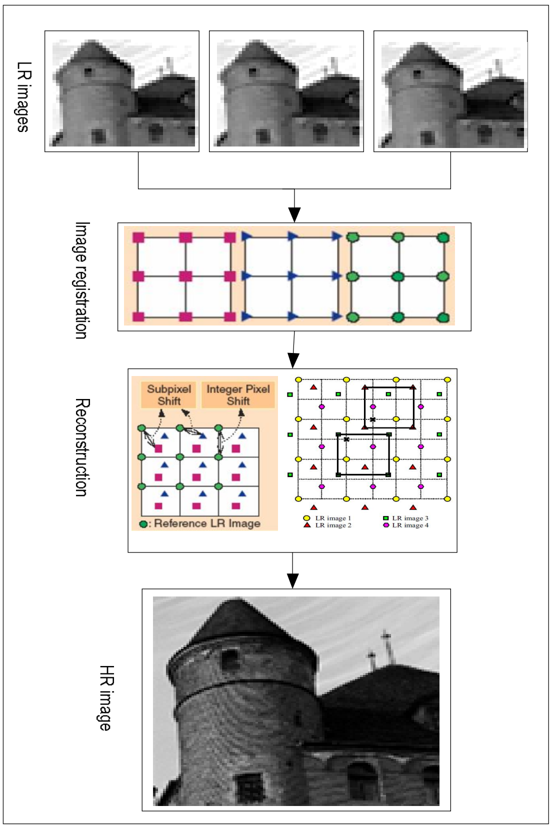


Figure 1. Stages of The Superresolution.

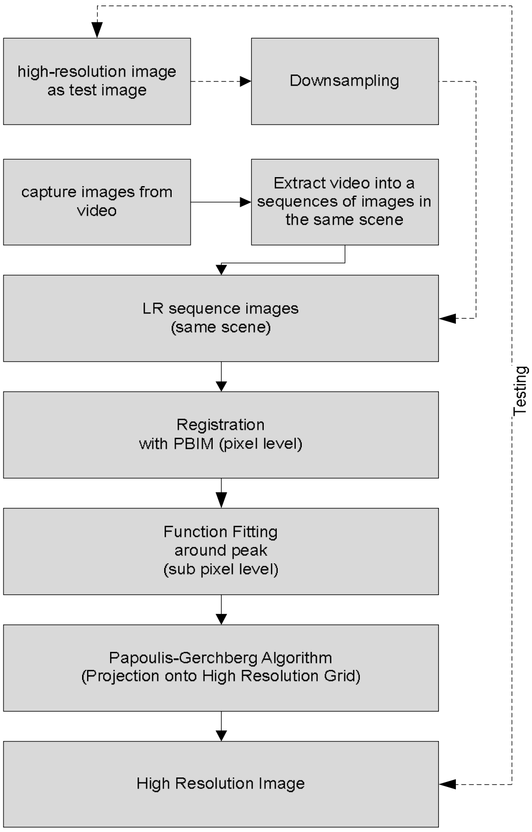


Figure 2. Diagram Block of Research.

Block diagram in Figure 2 are the stages that performed in this study. In this study, superresolution begin with taking objects using video. Furthermore, it is extracted to obtain a series of images in the same scene.Here in after, it is estimated pixels translation using Phased Based Image Maching.

PHASED BASED IMAGE MATCHING

Research on Phased Based Image Matching was conducted by several researchers. The following formula are given related to Phased Based Matching [4,5,6].

Suppose there are two image $f(n_1,n_2)$ and $g(n_1,n_2)$ with dimensions $N_1 x N_2$. Assumed index n_1 ranged from $-M_1,\ldots,M_1$ and $n_1$ranged from $-M_1,\ldots,M_1$. To simplify use $N_1 = 2M_1 + 1$ and $N_2 = 2M_2 + 1$. Discrete Fourier transform of image is:

$$F(k_1,k_2) = \sum_{n_1 n_2} f(n_1,n_2)^{W_{N_1}^{k_1 n_1} W_{N_2}^{k_2 n_2}}$$
$$= A_{F(k_1,k_2)^{j\theta_F(k_1,k_2)}} \quad (1)$$
$$G(k_1,k_2) = \sum_{n_1 n_2} g(n_1,n_2)^{W_{N_1}^{k_1 n_1} W_{N_2}^{k_2 n_2}}$$
$$= A_{G(k_1,k_2)^{j\theta_G(k_1,k_2)}} \quad (2)$$

In this case:

- $F(k_1,k_2)$and $G(k_1,k_2)$denote Discrete Fourier Transforms (DFT) from spatial domain $f(n_1,n_2)$and $g(n_1,n_2)$,
- n_1 and n_2 are elemen index in spatial domain at $f(n_1,n_2)$,
- $k_1$and k_2 are elemen index in frekuency domain at $F(k_1,k_2)$,
- $k_1 = -M_1,\ldots,M_1$,$k_2 = -M_2,\ldots,M_2$,
- $A_F(k_1,k_2)$ and $A_G(k_1,k_2)$ is the amplitude component,
- $e^{j\theta_F(k_1,k_2)}$,$e^{j\theta_G(k_1,k_2)}$is the phase component.
- operator$\sum_{n_1 n_2}$ show $\sum_{n_1=-M_1}^{M_1} \sum_{n_2=-M_2}^{M_2}$.
- $W_{N_1} = e^{j\frac{2\pi}{N_1}} = ,W_{N_2} = e^{j\frac{2\pi}{N_2}}$
- j is imaginer component

Cross spectrum phase $\hat{R}(k_1,k_2)$ defined in Equation (3) as

$$\hat{R}(k_1,k_1) = \frac{F(k_1,k_2)\overline{G(k_1,k_2)}}{\left|F(k_1,k_2)\overline{G(k_1,k_2)}\right|} = e^{j\theta(k_1,k_2)} \quad (3)$$

Phase-Based 2D Inverse of a function $\hat{R}(k_1,k_1)$ shown in the following equation:

$$\hat{r}(n_1,n_2) = \frac{1}{N_1N_2}\sum_{k_1k_2}\hat{R}(k_1,k_2)W_{N_1}^{-k_1n_1}W_{N_2}^{-k_2n_2} \quad (4)$$

The results of Phase-Based Functions for the function $f(n_1,n_2)$and $g(n_1,n_2)$which images are identical, it is obtained height of the dominant graph as shown above. While for the function which images are not identical, it is obtained graph that do not have the dominant height.

Figure 3 shows a graph of two images which are identical and not identical. The identical image, has a value cross phase spectrum high, while the other one, no value cross phase spectrum high.

The coordinates of the cross spectrum of the highest phase, expressed in units of pixels translation between two images. For example, the highest peak position of a graph PBIM located at coordinates (1,2) This indicates, the first image and second image of a global translation in direction as far as 1 unit in*x* and 2 units in *y* direction.

Sub-Pixel Level Translation

Image is processed using a computer is a digital image. During the digitizing process, many of information is lost, one of which is pixels translation. At continuous images, pixels translation are in the form of real number, but after digitizing, real translation information is lost. Therefore, we need a way to get the actual translation. One method to obtain the actual translation is by fitting of the function PBIM.

At phase correlation, sub-pixels translation will be searched by performing interation around the peak position. Fitting the function can be be used to obtain the actual translation, which is [8,9]:

$$\hat{r}(n_1,n_2) \cong \frac{\alpha}{N_1N_1}\frac{sin\{\pi(n_1+\delta_1)\}}{sin\{\frac{\pi}{N_1}(n_1+\delta_1)\}}\frac{sin\{\pi(n_2+\delta_2)\}}{sin\{\frac{\pi}{N_2}(n_2+\delta_2)\}} \quad (5)$$

In fitting process it is use least square quadratic, in order to obtain the value $\delta_1$and δ_2 which are translation in the sub pixel level.In this case:

- $N_1 \times N_2$is dimension of images
- n is elemen in matrix $N_1 \times N_2$
- δ is a shift in the subpixel level
- $\alpha \leq 1$

The Reconstruction Using Papoulis–Gerchberg Algorithm

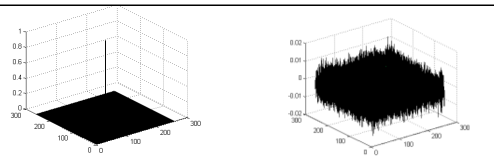
Gerchberg [8,9] proposed a method to reconstruct the signal given by the diffraction limit of the signal and a portion of the spectrum, Papoulis motivated research on the extrapolation of band-limited signals of a part of the original signal only. For example, the determination of transformation:

$$F(\omega) = \int_{-\infty}^{+\infty} f(t)e^{-j\omega t}dt \quad (6)$$

of signal *f*(t) gives the limited

$$g(t) = f(t)p_T(t), with \quad p_T(t) = \begin{cases}1, & |t| \leq T \\ 0, & |t| > T\end{cases} \quad (7)$$

This is apparent in Figure 2(c) which are version of the intersection of Figure 2(a).



(a) (b)

Figure 3. PBIM Graphs. (a)PBIM Graphs for Identical Image and (b)PBIM Graphs for Not Iidentical Image.

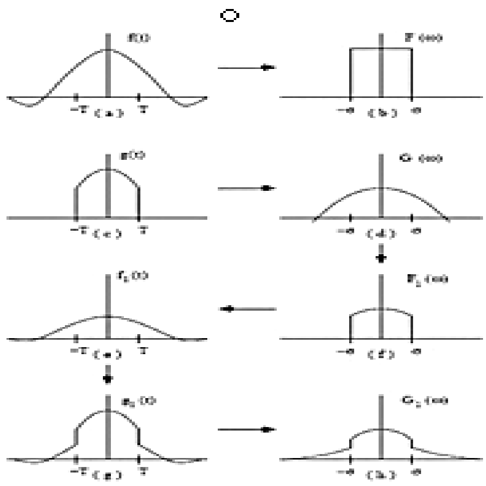
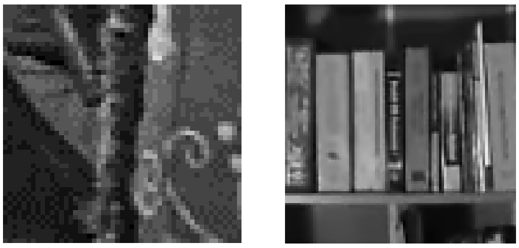


Figure 4. Extrapolation Illustration.



(a) (b)

Figure 5. (a) Image With Many Texture and (b) Image With Less Texture.

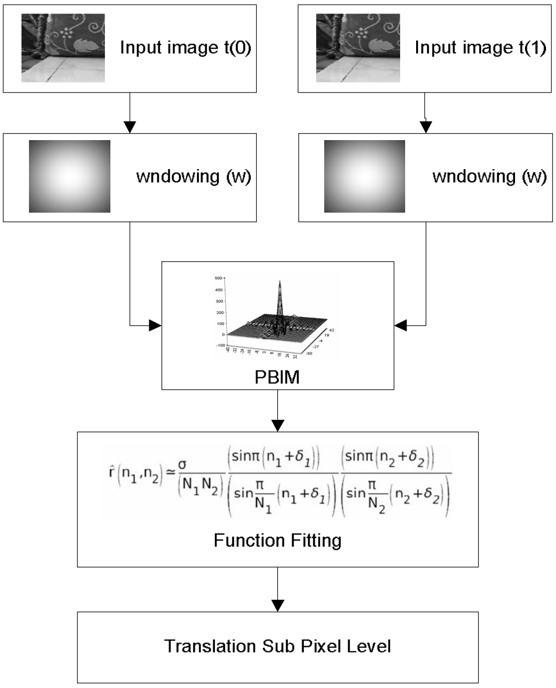


Figure 6. Pixel Translation Estimation.

Figure 4 shows the extrapolation of the signal $g(t)$ using Papoulis-Gerchberg algorithm. (*a*) Signal to be repaired, (*b*) These signal spectrum, (*c*) signals $g(t) = g_0(t)$are available time-limited signal is used as an initial estimate, (d) spectrum of (*c*), (*e*) signal in the time domain of (*f*), (*f*) spectrum using a low-pass filtered of (*d*), (*g*) part of (*c*) returned to the (*e*), (*h*) spectrum of (*g*).

Extrapolation of signals using alternate projection method, alternatively iterated between time and spectral domain. Signal $g(t)$ a low-pass filtered with a cut-off frequency of σ by assuming that σ is signal bandwidth. This is illustrated in the formation $F_1(\omega)$ in picture 2(*f*) $f(t)$ from that seen in Figure 2 (*d*). $G(\omega) = G_0(\omega)$At iteration n-th, it can be illustrated as:

$$F_n(\omega) = F_{n-1}(\omega)p_\sigma(\omega)$$

$$p_\sigma(\omega) = \begin{cases} 1, & |\omega| \le T \\ 0, & |\omega| > T \end{cases} \quad (8)$$

This process is then iterated until the which will be formed. In each iteration, the MSE (Mean Square Error) of the signal was reduced extrapolation

RESULT AND DISCUSSION

In this research, experiments were conducted in two parts, the test pixel translation estimation with PBIM to get the translation parameters and the experimental reconstruction using Papoulis-Gerchberg algorithm. The experimental scenario is as follows:

(a) Tests with simulated translations, conducted by assuming a high resolution image. Downsampling this image in a number of test images (low resolution image). Downsampling results in the estimation of the translation will be used to obtain parameter translation PBIM. Those parameters are used for high-resolution image reconstruction using Papoulis-Gerchberg algorithm. Reconstruction results are compared with the original image to its PSNR values obtained.

(b) experiments conducted of images that contain much texture Figure 5(a) and less textured Figure 5(b).

(c) experimental images without downsampling, is done by taking images of a video camera Sony DCR-HC52E Handycame, 30 frames per second. It is extracted a series of sequential images. Here in after, it is estimated translation parameters, which will be used for reconstruction of Papoulis-Gerchberg algorithm.

Translation Experiments

The steps of estimate translations to sub-pixels level shown in Figure 6. The experiment begin with the extraction of an image from a series of video frames, which will be used as a reference image.

From $\hat{R}$value in Table 1 and$\hat{r}$value in Table 2, it is presented in Figure 7.

Table 1. Pixels Level The Translation.

$\hat{R}$	x	y
0.77051	2	1
0.78682	2	1
0.87571	2	1
0.76449	2	1
0.78471	2	1
0.77602	2	1
0.72989	2	1
0.90126	2	1
0.82781	2	1

Table 2. Sub-Pixel Level Shift.

$\hat{r}$	x	y
0.80991	1.9624	0.9435
0.99999	1.9622	1.9859
0.88357	2.0294	1.5287
0.77474	2.0413	1.5121
0.78471	1.9887	1.6919
0.77602	1.9340	1.6611
0.73538	2.0360	0.6007
0.90126	2.0189	1.3225
0.83122	1.9907	0.9936

Table 3. PSNR of Much Texture Image.

Num Image LR	PSNR
4	21,47
6	21,80
8	21,34
10	21,90
12	21,46
14	21,42
16	21,70
18	21,85
20	21,61
Avg	21.63

Table 4. PSNR of Less Texture Image.

Num Image LR	PSNR
4	19,06
6	19,42
8	19,39
10	19,95
12	19,99
14	19,21
16	19,25
18	19,54
20	20,13
Avg	19,55

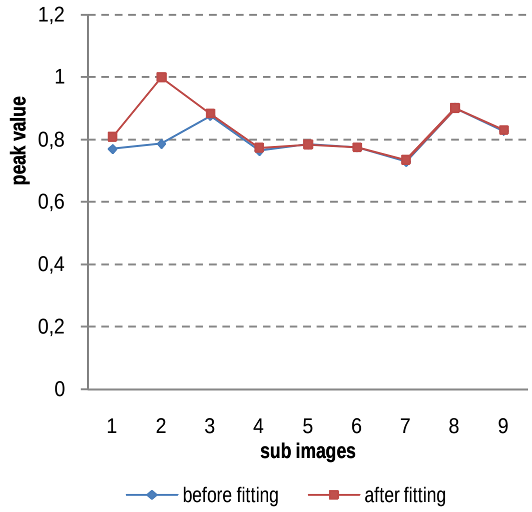


Figure 7. Peak Value of The Results of Fitting Chart.

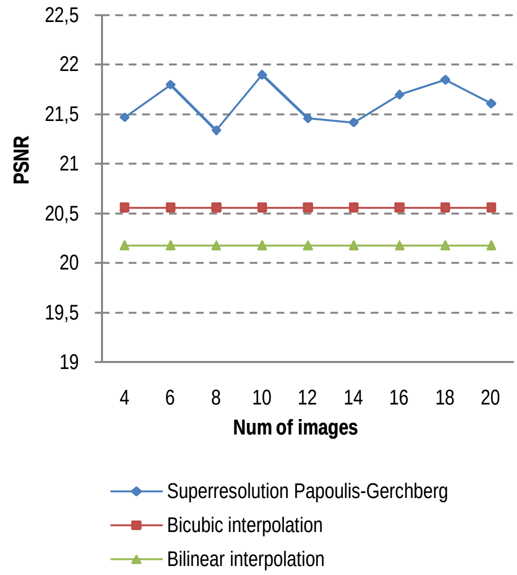


Figure 8. PSNR Graph Images Contain Much Texture.

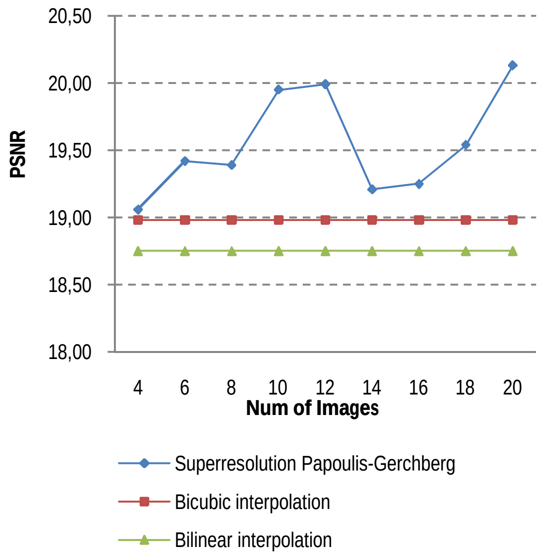


Figure 9. PSNR Graph Images Contain Less Texture.

(a)

(b)

Figure 10. OutputOf Superresolution. (a) Low Resolution Image And (b) High Resolution Image.

Then it is conducted a global translation of image, which will be assumed as the input image.Further, it is made samples for each reference image and input image, respectively T_0 and T_1, by making it into a number of blocks (sub image). Each sub-image is created with the same size as the windowing block, which in this case use Hanning windows.

The next process conducted on two sub PBIM image as in Equation (3), in order to determine the pixels level translations. Pixels level of the translation can be viewed in Table 1.

By using fitting function in Equation (5), it used results of pixels-level translation to obtain sub-pixels translation level. In Table 2 are presented sub pixels level translation.

Reconstruction Experiments

Estimation results of sub-pixels translations is further used for the reconstruction algorithm Gerchberg poupulish. In the following section, it is given some results of testing which has been done in image in Figure 7.

Figure 8 and Table 3 present PSNR graphs values for image superresolution with objects which contain much texture.

Experiment results of superresolution compared with bilinear and bicubic interpolation methods.

Figure 9 and Table 4 present PSNR graphs values for image superresolution with objects which contain less texture. Experiment results of superresolution compared with bilinear and bicubic interpolation methods.

Visually, the results of method proposed in this study shown inFigure 10. More clearly, Figure 10 (a) is a low-resolution images and 10 (b) is the high resolution image which is the results of superresolution image with this method.

CONCLUSION

The conclusion is as follows:(a) At less textured objects, the accuracy is reduced, the average PSNR is 19.54, while at much textured objects, the average PSNR is 21.62. (b) The number of images to be referenced in a high-resolution image reconstruction is not linear with the desired quality.

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