SUPER RESOLUTION RECONSTRUCTION FROM IMAGE SEQUENCE

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ABSTRACT:

Super resolution image reconstruction method refers to image processing algorithms that produce a high resolution(HR) image from observed several low resolution(LR) images of the same scene. This method is proved to be useful in many practical cases where multiple frames of the same scene can be obtained, such as satellite imaging, video surveillance, video enhancement and restoration, digital mosaicking, and medical imaging. In this paper we applied super resolution reconstruction method in spatial domain to video sequences. Test images are adjacently sampled images from continuous video sequences and overlapped for high rate. We constructed the observation model between the HR images and LR images applied by the Maximum A Posteriori(MAP) reconstruction method that is one of the major methods in the super resolution grid construction. Based on this method, we reconstructed high resolution images from low resolution images and compared the results with those from other known interpolation methods.

KEY WORDS: Super Resolution(SR), Image reconstruction, Resolution enhancement

1. INTRODUCTION

High resolution images are required in many visual applications, and their demand is gradually increasing. When resolution can not improved by replacing sensors, either because of cost or hardware physical limits, super resolution image reconstruction method is what can be resorted to.

Recently, resolution enhancement approach has been one of the most active research areas, and it is called super resolution (SR) image reconstruction or simply resolution enhancement. Super Resolution image reconstruction method is to use signal processing toward resolution enhancement techniques to obtain an HR image from observed multiple LR image.

We applied the Maximum A Posteriori (MAP) algorithm to video sequence image that is one of the major methods in the super resolution construction

2. SUPER RESOLUTION RECONSTURCTION

The super resolution restoration idea was first presented by Tsai and Huang. They used the frequency domain approach to demonstrate the ability to reconstruct one improved resolution image from several down-sampled noise-free version of it, based on the spatial aliasing effect.

The basic principle in SR reconstruction method is the availability of multiple LR images captured from the same scene. In SR, typically, the LR images represent different looks at the same scene. That is, LR images are subsampled as well as shifted with subpixel precision.

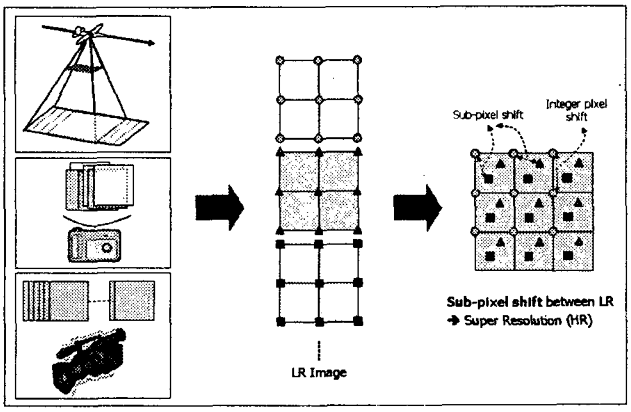

Figure 1. Basic super resolution reconstruction

2.1 Observation model

In the process of recording a digital image, there is a natural loss of spatial resolution caused by the optical distortion, motion blur due to shutter speed and additive noise that occurs within the sensor or during transmission.

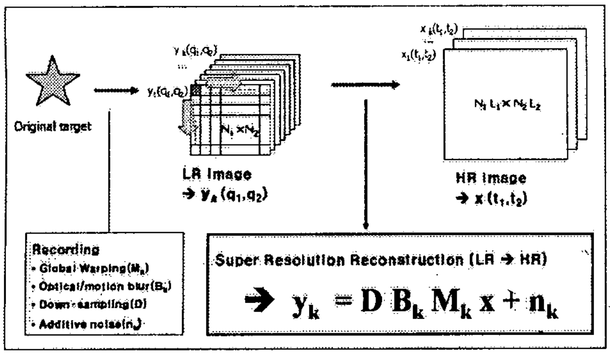

Figure 2. Super resolution observation model

Given the general SR observation model by lexicographical notation,

$$y_k = DB_k M_k x + n_k \tag{1}$$

where y_k = observation LR images
D = subsampling matrix
B_k = blur matrix
M_k = geometric warping matrix
n_k = additive noise
x = reconstructed HR image

The motion that occurs during the image acquisition is represented by warp matrix M_k. It may contain global or local translation, rotation, and so on. Since this information is generally unknown, we need to estimate the scene motion for each frame with reference to one particular frame. The warping process performed on HR image x is actually defined in terms of LR pixel spacing when we estimate it. Thus, this step requires interpolation when the fractional unit of motion is not equal to the HR sensor grid.

Blurring may be caused by and optical system, relative motion between the imaging system and the original scene, and the point spread function (PSF) of the LR sensor. It can be modeled as linear space invariant (LSI) or linear space variant (LSV), and its effects on HR images are represented by the matrix B_k. In single image restoration applications, the optical or motion blur is usually considered. In the SR image reconstruction, however, the finiteness of a physical dimension in LR sensor is an important factor of blur.

The subsampling matrix D generates aliased LR images from the warped and blurred HR image. Although the size of LR images is the same here, in more general cases, we can address the different size of LR images by using a different subsampling matrix. Although the blurring acts more or less as an anti-aliasing filter, in SR image reconstruction, it is assumed that aliasing is always present in LR images

2.2 Super resolution reconstruction algorithm

SR algorithm is divided by specific domain, observation model, the reconstruction method, algorithm is applied. Commonly the SR algorithm is classified into spatial domain and frequency domain. Spatial domain SR reconstruction is a pixel value based method. There are SR in spatial domain non-uniformly interpolation method, stochastic method, set theoretic method, hybrid method. Spatial domain SR algorithm is better than frequency domain on reconstruction performance. In this paper, kinds of stochastic method MAP (Maximum A Posteriori) algorithm is applied.

2.3 MAP (Maximum A Posteriori)

Schultz and Stevenson extend their earlier work on Bayesian (MAP) image interpolation for improved definition using a Huber Markov Random Field (HMRF) prior to the problem of super resolution image. The blur of the measured images is assumed to be simple averaging, and the measurements additive noise is assumed to be independent and identically distributed Gaussian vector. This choice of prior causes the entire problem to be nonquadratic, thus complicating the resulting minimization problem.

If the general observation model is $y_k = Hx + n_k$, this is not unique solution for image expansion. MAP method is proposed to compute an estimate of the high resolution images. MAP approach to estimating x seeks the estimate x_{MAP} for which the a posteriori probability, $P(x \mid y_k)$ is a maximum. Formally, we seek x_{MAP} as,

$$\hat{x}_{MAP} = \arg\max_x P(x \mid y_1, y_2 \cdots, y_k) \tag{2}$$

Where $P(x \mid y_k)$ is the log-likeihood function. This function can be computed using Bayes rule.

$$\begin{aligned} P(x \mid y_k) &= \log P(x \mid y_k) \\ &= \log P(y_k \mid x) + \log P(x) - \log P(y_k) \end{aligned} \tag{3}$$

Applying Bayes rule yields,

$$\hat{x}_{MAP} = \arg\max_x \left[\frac{P(x \mid y_k) P(x)}{P(y_k)} \right] \tag{4}$$

And since the maximum x_{MAP} is independent of y we have,

$$\hat{x}_{MAP} = \arg\max_x \left[P(y_k \mid x) P(x) \right] \tag{5}$$

Since the logarithm is a monotonic increasing function, this is equivalent to finding,

$$\hat{x}_{MAP} = \arg\max_x \left[\log P(y_k \mid x) + \log P(x) \right] \tag{6}$$

Where log $P(y_k \mid x)$ is the log-likelihood function and log P(x) is the log of the a priori density of x. Schultz and Stevenson use the Huber Markov Random Field(HMRF) for the priori tern log P(x), which is a discontinuity preserving image model, which allows edge reconstruction while imposing smoothness constraints on reconstruction.

3. TEST

3.1 Test data

The video image for test is recorded by DCR-pc100 (sony) digital video camera on UAV (Unmanned Aerial Vehicle) around daejeon city. We sampled image sequence on 30 frames/sec using Pinnalcle studio version 7.0.

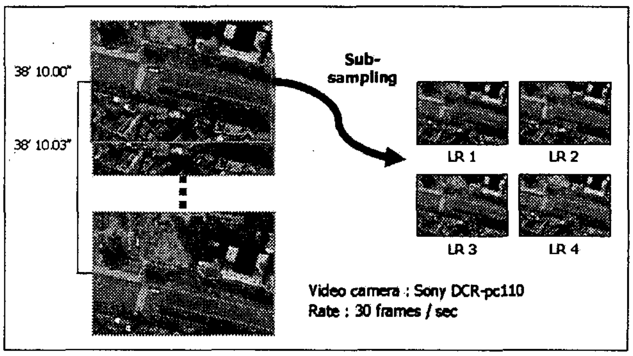

Figure 3. Test image

All the simulations correspond to synthetic data, in order to bypass problems which are beyond the scope of this paper such as motion estimation. 4 LR images for test were sampled from one video frame that is assumed to the original image. A HR image of size 480×720 pixels is reconstructed from LR image of size 240×360 pixels by SR method.

3.2 Implementation

In the figure 4, flowchart of implemented software is represented.

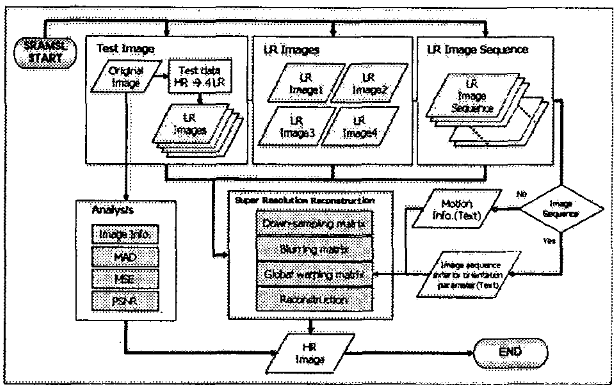

Figure 4. SR implementation – flowchart

Low quality Test images are input and then subsampling matrix, blurring matrix, global warping matrix are constructed. Because of poor video camera information, sub-pixel precision motion is randomly assumed in this simulation test.

Using MAP algorithm reconstructed SR image is compared with the original HR image quantitatively. MAD (Mean Absolute Deviation), MSE (Mean Squared Error), PSNR (Peak Signal to Noise Ratio) are implemented for quantitative analysis.

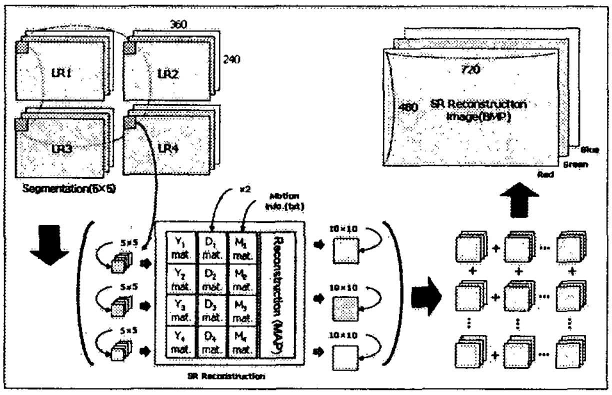

Figure 5. SR implementation - process

Each 240×360 LR image is separated R, G, B bands and segmented into 5×5 image fragments for calculation efficiency. 5×5 image fragment is reconstructed into 10×10 image using MAP SR reconstruction method. All reconstructed image fragments are merged into one reconstructed SR images.

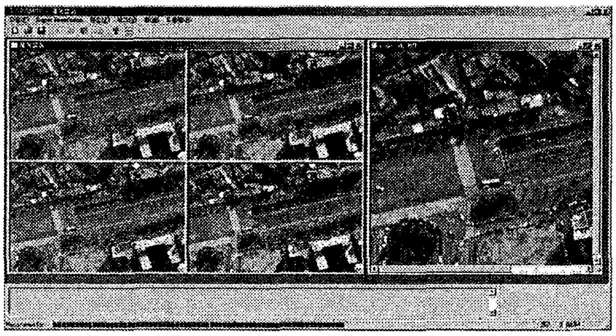

Figure 6. SR implementation – execution

In Figure 6, executing SR implementation software is the SRAMSL (Super Resolution Application by Mapping Systems Laboratory), developed by Microsoft visual c++ 6.0 MDI interfaced.

3.3 Result

SR(MAP) result(figure 7) that provides improved definition image expansion, when compare to various methods such as nearest neighbour interpolation(figure 8), bicubic interpolation(figure 9).

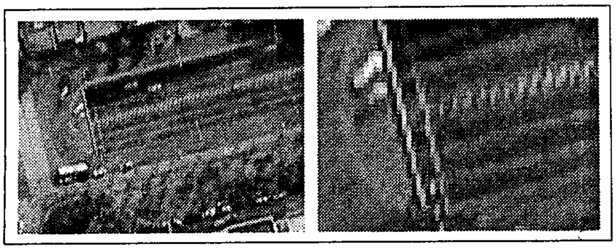

Figure 7. Nearest neighbor interpolation

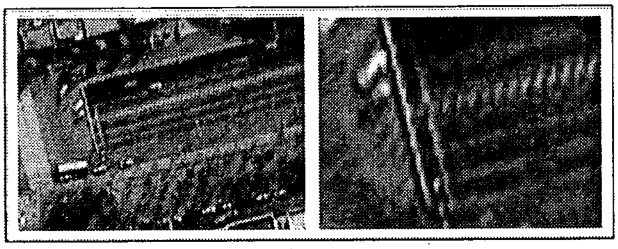

Figure 8. Bicubic interpolation

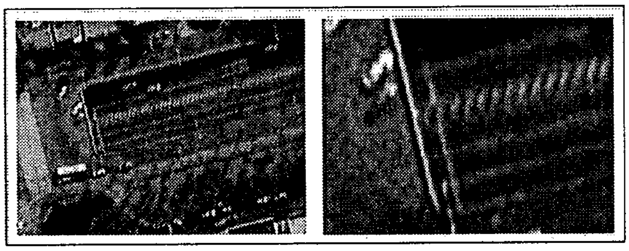

Figure 9. Result of SR reconstruction

Using MAP algorithm SR result provides the most qualitatively detailed representation. In the quantitative analysis, SR result also provides best performance.

Table 1. Comparison with original image

Method		MAD	MSE	PSNR(dB)
SR	**R**	**4.6193.**	**22.7620**	**34.5587**
	G	**4.5687**	**22.1545**	**34.6762**
	B	**4.3154**	**19.6004**	**35.2081**
Nearest Neighbor	R	4.8308	104.3898	27.9442
	G	4.8035	104.4330	27.9424
	B	4.7882	103.7430	27.9825
Bilinear	R	4.8761	74.4634	29.4114
	G	4.8406	74.3707	29.4168
	B	4.8350	74.1201	29.4314
Bicubic	R	4.7318	70.6398	29.6569
	G	4.6971	70.1905	29.6680
	B	4.6916	69.9499	29.6829

In the Table 1, MAD, MSE and PSNR values of SR result image compared with original image are respectively 4.5011, 21.5056, 34.8143 on the average. These values mean SR result image has the best similarity with the original image.

4. CONCLUSION

Summarizing the obtained results, we applied super resolution algorithm to video sequence recorded on UAV. We implemented the software for super resolution reconstruction using visible programming tool and applied the MAP algorithm. Although test data set is simulated because of poor information about vehicle, reconstructed result SR image provides more highly performance than other interpolation method.

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