ENHANCEMENT OF ITERATIVE BACK PROJECTION TECHNIQUE FOR SUPER RESOLUTION IMAGE

by

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May Allah accept our good deeds, forgive our sins and accept us in His paradise.

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LIST OF ABBREVIATIONS

1D	One Dimensional
2D	Two Dimensional
AD	Anisotropic Diffusion
ADC	Anisotropic Diffusion Clip
AWGN	Additional White Gaussian Noise
CAT	Computer Aided Tomography
CCD	Charge-Coupled Device
CG	Conjugate Gradient
CIDS	Colour and Intensity Distribution of Segment
CMOS	Complementary Metal-Oxide Semiconductor
CT	Computerized Tomography
DVF	Displacement Vector Field
GD	Gradient Descent
GEF	Gradient Exponential Filter
GGMRF	Generalized Gaussian Markov Random Filed
HR	High Resolution
HVS	Human Visual System
IBP	Iterative Back Projection
ICA	Independent Component Analysis
ICR	Iterative Convex Refinement
IIBP	Iterative Interpolation Back Projection
IID	Iterative Interpolation De-convolution
ISEF	Infinite Symmetric Exponential Filter
LoG	Laplacian of Gaussian
LR	Low Resolution
LSI	Linear Space Invariant
LSISEF	Lorentzian Infinite Symmetric Exponential Filter
MAP	Maximum a Posteriori
ML	Maximum Likelihood
MPREG	Moving Picture Experts Group
MR	Magnetic Resonance

MRF	Markov Random Field
MSE	Mean Square Error
PDE	Partial Differential Equation
POCS	Projection onto Convex Sets
PPLT	Point to Point Line Topology
PSF	Point Spread Function
PSNR	Peak Signal to Noise Ratio
ROI	Region of Interest
SDEF	Second directional Derivative Exponential Filter
SISEF	Sharp Infinite Symmetric Exponential Filter
SR	Super Resolution
SRUM	Super Resolution with Un-sharpening Mask
TGV	Total Generalized Variation
TV	Total Variation

LIST OF SYMBOLS

dB	Industry standards measure SNR in decibel
log	The logarithm is the inverse operation to exponentiation
MAX_f	Maximum intensity value existence in image
Y_k	Multiple Low Resolution images matrices
D	Decimation parameter matrices
B	Blurry parameter matrices
W	Wrapping parameter matrices
X	High Resolution matrices
η	Additional noise parameter
$\sin\theta$	Sine with angle of theta
$\cos\theta$	Cosine with angle theta
ξ	Error estimated
exp	Exponential
$p(\,)$	Probability function
$L(\,)$	Likelihood function
argmax	Argument of maximum
argmin	Argument of minimum
σ	Variance of function
$\Gamma(\,)$	Priori energy function
λ	Regularization parameter
h_{bp}	Back projection de-blurring kernel
α	Multiplication enlargement factor
Q	Error relation matrix algorithm
e	The error between simulated and observed low resolution image
∇	Gradient function
r	Residual error
s	Conjugate residual error
β	Ratio of correlation residual error
sup_x	Supremum value along x axis
$Hf(x)$	Hessian function of f along x axis
tan	Tangent
$\otimes$	Convolution operation
π	Pi or ratio of circle
div	Divergence operation
$*$	Multiplication of sparse matrices form
$\gamma(\,)$	Thikonov Regularization
LoG	Laplacian of Gaussian
ρ_{LOR}	Lorentzian error norm function
ψ_{LOR}	Lorentzian influence norm function

T	Soft threshold
$\tilde{\varepsilon}$	Median

PENAMBAHBAIKAN TEKNIK UNJURAN BELAKANG BERULANG UNTUK IMEJ RESOLUSI SUPER

ABSTRAK

Kajian ini membincangkan tentang penambahbaikan teknik Unjuran Belakang Berulang dalam Resolusi Super. Teknik ini mengalami kesulitan daripada penghasilan artifak deringan di sekeliling pinggiran imej yang kuat dan menggunakan sejumlah besar lelaran semasa proses anggaran. Selain itu, teknik ini mempunyai pretasi yang lemah semasa mengendalikan imej yang bising. Dalam usaha untuk mengurangkan artefak deringan, tesis ini mencadangkan pendekatan baru dalam pembinaan semula Unjuran Belakang Berulang dengan hibrid penambahbaikan pinggiran pengaturcaraan. Pertama, pengawal selia menggunakan Penapis Tajam Simetri Eksponen Tak Terhingga untuk memberikan bimbingan pinggiran yang benar dan tepat semasa unjuran belakang ke grid Resolusi Tinggi. Pinggiran yang tepat ini menghalang pembinaan semula Unjuran Belakang Berulang daripada dislokasi Resolusi Tinggi. Oleh itu, ia mengurangkan artifak deringan dan meningkatkan kualiti output secara purata sehingga 1.755 dB. Pengatur Penapis Tajam Simetri Eksponen Tak Terhingga ini membekalkan maklumat tambahan yang tepat dan membantu penganggar untuk menjimat 70% lelaran dari teknik konvensional dalam menentukan imej Resolusi Tinggi. Kedua, untuk meningkatkan kekukuhan pembinaan semula Unjuran Belakang Berulang, kajian ini mencadangkan penambahbaikan dengan pelaksanaan peraturan menggunakan Penapis Lorentzian Tajam Simetri Eksponen Tak Terhingga. Teknik ini dapat meningkatkan kadar penambahbaikan pinggiran selepas menetapkan tahap ketepuan Lorentizan lebih besar dari 1. Hasilnya, kualiti keluaran imej yang dihasilkan adalah meningkat secara purata sehingga 2.126 dB dan proses anggaran lebih jimat sehingga 63% lelaran semasa pembinaan semula Unjuran Belakang Berulang. Penapis Lorentzian Tajam Simetri Eksponen Tak Terhingga ini juga boleh melakukan pengurangan bising selepas menetapkan semula tahap ketepuan Lorentzian di bawah 1. Dalam pengurangan bising, teknik ini dapat meningkatkan kualiti pengeluaran secara purata sehingga 2.645 dB dan menjimatkan lelaran anggaran sehingga 78.2%. Ketiga, kajian ini diteruskan dalam meningkatkan keteguhan teknik rekonstruksi Unjuran Belakang Berulang dengan melaksanakan pengawalseliaan Klip Penyebaran Anisotropik. Pengawal Klip Penyebaran Anisotropik ini mempunyai keupayaan untuk menghapuskan kesan bising dalam banyak arah dan ia juga dilengkapi dengan teknik pemeliharaan pinggiran. Hasilnya, teknik ini dapat meningkatkan kualiti pengeluaran secara purata sehingga 3.134 dB dan lelaran anggaran dijimatkan sehingga 75.5%. Penemuan telah membuktikan bahawa kaedah yang dicadangkan ini meningkatkan teknik pembinaan semula Unjuran Belakang Berulang melalui penghapusan artifak, memelihara maklumat yang hilang dan mengurangkan implikasi bising. Selain itu, teknik yang dicadangkan ini lebih baik dari segi kualiti imej dan bilangan lelaran berbanding dengan teknik pernambahbaikan pinggiran dan pengurangan bising yang lain.

ENHANCEMENT OF ITERATIVE BACK PROJECTION TECHNIQUE FOR SUPER RESOLUTION IMAGE

ABSTRACT

This study concerns in on improvements of the Iterative Back Projection (IBP) Super Resolution reconstruction technique. This technique suffers from self produces the ringing artefacts around the strong edge of the image and consumes a large number of iterations during the estimation process. Besides that, this technique has poor performances during handling the noisy image. In order to reduce the ringing artefacts, this thesis proposes a novel approach of the IBP reconstruction by hybrid with the edge enhancement regularization. First, the regulator uses the Sharp Infinite Symmetrical Exponential Filter (SISEF) to provide an accurate and precise edge guided during back projection to High Resolution (HR) grid. This precise edge guided prevents the IBP reconstruction from dislocating the HR projection. Thus, it reduces the ringing artefacts and increases the output quality averagely up to 1.755 dB. This SISEF regulator supplies accurate additional information and helps the estimator to save 70% iterations from conventional technique in determining the HR image. Second, in order to increase the robustness of IBP reconstruction, this study proposes an improvement with implementation of the Lorentzian Sharp Infinite Symmetrical Exponential Filter (LSISEF) regulations. This LSISEF technique is able to increase the rate of edge enhancement after set the Lorentzian saturation level larger than 1. As a result, the quality of the produced output image is averagely up to 2.645 dB and the estimation process is rapidly saving up to 63 % iterations in the IBP reconstruction. This LSISEF also can perform as noise reduction after reset the Lorentzian saturation level below than 1. In noise reduction, this technique is able to increase the output quality up to 2.645 dB and saving up the iterations of estimation up to 78.2%. Third, this study continues in improving the robustness of the IBP reconstruction technique by implementing the Anisotropic Diffusion Clip (ADC) regulator. This ADC regulator has the ability to remove noise effects in many directions and it is also equipped with edge preservation technique. Consequently, this technique is able to increase output quality averagely up to 3.134 dB and the iteration of estimation is saving up to 75.5%. The findings have proved that these proposed methods enhance the IBP reconstruction technique through removing the artefacts, preserving the lost information and reducing the noise implications. Also, these proposed techniques perform better in term of image quality and number of iterations compared to the other edge enhancement and noise reduction techniques.

CHAPTER 1 : INTRODUCTION

1.1 Research Significant

This study focuses on the Super Resolution reconstruction algorithm, especially in the Iterative Back Projection (IBP) technique in order to deal with several limitations of IBP technique such as a preserves high frequency component (Cheref & Yousfi, 2014), oscillates between the same solutions (Nasrollahi & Moeslund, 2014) and unpleasant effects (Shah & Gupta, 2012). The examples of unpleasant effects are additional noise, ringing artefacts and aliasing effects. These effects always disturb the quality of the image. Precisely, the IBP technique is known as good performance in real image application when it capable to execute in parallel for faster hardware implementation (Michal Irani & Peleg, 1991). Indeed, the image applications require small time processing and less complexity computational algorithm. Furthermore, this study also provides some solutions which are edge guidance and noise remover to increase the robustness technique toward the aforementioned unpleasant additional effects.

The IBP was introduced by Irani and Peleg (1993). This technique is technically designed similarly with the reconstruction of 2 Dimensional projection from the 1 Dimensional projection in Computer Aided Tomography (CAT) ideas. Generally, this technique can be divided into three sub tasks which are image registration, interpolation and restoration. Normally, the image registration will take place in the first stage in Super Resolution technique procedure. At this stage, this task will do aligning process and combine the relative motion geometric of multiple input images. Meanwhile, the information for different motions are collected in advance. After completing the first stage task, the interpolation task will be performed to enlarge the resolution an aligned input image by projecting to the High Resolution (HR) grid's size matrix. Then, reconstructing and restoring of HR image will occur at the final stage. Usually, this task manipulates the prior knowledge and any negative influence factors to the input image in order to determine the finer HR image. However, the IBP technique still requires some improvements, especially in the reconstruction part that enhancement of the algorithm in terms of robustness in lost information and noise effects can be done. The finding from the proposed technique in this study is useful for further developments and meets the demand of applications in the digital image.

1.2 Background

Most applications in the digital image demand for higher quality image acquisition. The finest quality of image or High Resolution (HR) image is important to gain more useful information as possible. However, the image acquisition system introduces degraded output image or Low Resolution (LR) image in reality. There are many factors that contribute to this low quality of image. For instance, a finite number of resolution acquisition sensor may draw the limit information on the image. The motion blur is appeared when there is an occurrence of poor handling imaging system between the scenes. The system may introduce noise due to limitations of the device and additional signals during the transmission medium. An improvement on the sensor acquisition system would lead to expenditure budget, and unreliable for the real applications. Thus, image recovery through Super Resolution technique is the best choice to produce a finer image. Also, the goal of image recovery is to restore the number of degraded input images and transform to the better quality with enlargement of the size of output image.

In particular, this study is intended to investigate the constraints of the Super Resolution technique and provide some improvements. The design of the Super Resolution reconstruction technique is based on the imaging problem model. This model is designed based on the existence of several limiting factors in the real applications such as constraints in the Point Spread Function (PSF) of a camera that contains information of blur, translation and decimation factors. In addition, some constraints on the image acquisition may lead to the presence of global noise and contaminate the acquired image.

This research area is kept going for more five decades in order to provide effective solutions to handle the aforementioned problems. For example, several types of reconstructive techniques have been proposed such as a direct method, frequency domain reconstruction, and iterative based reconstruction (Bannore, 2009). However, the iterative based approach has been selected as one of the best designed techniques and gains high attention in the Super Resolution reconstruction development as such reported in the survey article (Nasrollahi & Moeslund, 2014). But, this approach suffers some weaknesses and limitations such as highly consumed high number of iterations, less robust toward noise effects and fail to preserve the lost information. Hence, the interest of this study is to offer an efficient solution in improving the features of the iterative based Super Resolution reconstruction. Also, the proposed technique would bring to light computation complexity and robust toward the blur and noise effects.

1.3 Problem Statement

Several issues are identified as indicators when conducting this study.

1.3.1 The IBP technique has difficulty to estimate the finest High Resolution image due to blurry effect.

The IBP reconstruction technique executes the de-blurring and enlarging process during reconstruction of the High Resolution (HR) image. This technique only performs well in removing the blurry effect if the image registration stage delivers an accurate blurry information. Yet, this technique still fails to preserve several lost in high frequency information due to blurry and decimation effects. The loss of high frequency information happens when the edge of the image is embedded inside the contour of an image.

Moreover, the ill-posed problem will arise after projecting the input image to the HR grid. The ill-posed problem occurs after the inversion of mathematical operation which produces bad interpolated result. Also, the edge of image cannot be well defined (Bertero, Poggio, & Torre, 1988). This is due to the very limited information from small size of input image. This interpolation process may eliminate the edge of the image due to randomly pick up the neighbour pixel value. Thus, to solve this edges image problem, the IBP technique requires an edge detector which will be enhanced into regulator to strengthen the possible weak edges and information (Cheref & Yousfi, 2014; Tan, Tao, Cao, Li, & Zhang, 2016).

1.3.2 The IBP technique commonly generates a huge number of iterations

The large numbers of iterations give a negative impact on the performance of the IBP technique which will slow down the performance and unsuitable to be practically deployed in the digital image applications. The presence of this problem occurs when the estimation process attempts to converge toward one of possible solutions and then oscillates between them (M Irani, Irani, Peleg, & Peleg, 1993; Nasrollahi & Moeslund, 2014). As a result, the complexity of computational may increase and consume a lot of time processing (Farsiu, Elad, & Milanfar, 2006a; Farsiu, Robinson, Elad, & Milanfar, 2004; Georgis, Lentaris, & Reisis, 2013; J. Yang et al., n.d.).

The injection of the very first initial HR resolution as initial condition is suggested by Peleg and Irani (1993). This injection value of HR gives large impact for the IBP reconstruction to determine the next possible truth of HR image (Michal Irani & Peleg, 1993). If the initial HR guess is closely reached to the truth HR value, it means that the technique only requires a few of iterations before reaching the best estimation. In short, the precision in the calculation of the initial guess helps to reduce the number of iterations during the reconstruction process which would yield to better performance of the system.

1.3.3 The IBP technique is less robust toward noise effects.

During the reconstruction process, the IBP reconstruction technique tends to produce jaggy or ringing artefacts. This ringing effect is also known as the Gibbs phenomenon in mathematical terms. This undesired effect produces an annoying effect in the image and appears as ripple artefacts around the edges of the image. This problem arises when the IBP algorithm keeps on repeating the projection from low resolution grid to high resolution grid inversely without any edge guided (S. Dai, Han, Xu, Wu, & Gong, 2007; Patel Shreyas A., 2013; X. Yang, Zhang, Zhou, & Yang, 2015).

Furthermore, the IBP technique is not concentrating on the existence of additional noise in the imaging model. This has proved that this system has a weakness in handling noisy image. Additionally, the IBP reconstruction only implements an average operation for noise reduction (M Irani et al., 1993). This technique also is poorly performed in differentiating useful information and additional noise elements inside the image. Thus the fusion of noise power inside the simulated image also happens in the reconstruction process. Therefore, in order to increase the robustness of the system, the regularization technique is deployed in order to overcome this problem and increase the robustness of the system (Cheref & Yousfi, 2014; Kohler et al., 2016; X. Yang et al., 2015).

1.4 Research Objectives

Based on the aforementioned problems, several objectives of this study are highlighted and divided into three main folds as follows:

- The first objective is to improve the IBP reconstruction algorithm by increasing the de-blurring quality image output.
- The second objective is to reduce the number iterations of the IBP reconstruction function.
- The third objective is to enhance the level of robustness of the IBP method toward the ringing and additional noise effect.

1.5 Research Scope

The scope of this study is converging to the implementation of the spatial domain Super Resolution, which has mainly contributed to the improvement of the Iterative Back Projection (IBP) method. This improvement includes the implementation of the edge enhancement and noise reduction techniques. Also, the light cost computation is another