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Conference Paper · November 2014

DOI: 10.1109/AIMS.2014.21

11 authors, including:

Pejman Rasti
University of Tartu

Anastasia Bolotnikova
University of Tartu

Morteza Daneshmand
University of Tartu

Rudolf Kiefer
Ton Duc Thang University

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Pejman Rasti, Iiris Lüsi, Armen Sahakyan, Andres Traumann, Anastasia Bolotnikova, Morteza Daneshmand, Rudolf Kiefer, Alvo Aabloo, Gholamreza Anbarjafari*
IMS Lab, Institute of Technology
University of Tartu, Tartu, 50411
Estonia
*Corresponding author: Gholamreza Anbarjafari, phone +37258865559,
Email: sjafari@ut.ee

Hasan Demirel
Department of Electrical and Electronics Engineering,
Eastern Mediterranean University,
Famagusta, North Cyprus, via Mersin 10, Turkey
hasan.demirel@emu.edu.tr

Cagri Ozcinar
Centre for Vision, Speech and Signal Processing
Faculty of Engineering and Physical Sciences, University of Surrey
Guildford, GU2 7XH, UK
c.ozcinar@surrey.ac.uk

Abstract **- In this paper, we propose a new super resolution technique based on iterative interpolation followed by registering them using back projection (BP). Firstly the low resolution image is interpolated and then decimated to four low resolution images. The four low resolution images are interpolated and registered by using BP in order to generate a sharper high resolution image then high resolution image is down sampled and back to the first step. The proposed method has been tested on some bench mark images. The peak signal-to-noise ratio (PSNR) and structural similarity index (SSIM) results as well as the visual results shows the superiority of the proposed technique over the conventional and state-of-art image super resolution techniques. In Average, the PSNR is 2.72 dB higher than the bicubic interpolation.**

Keywords — Super resolution; Back Projection Kernel; Image Registration; Image Resolution; High-Resolution Imaging.

I. INTRODUCTION

Nowadays there is a big desire for resolution enhancement in digital imaging systems. This desire comes from two significant application areas [1]:

1. Improvement of pictorial information for human interpretation. 2. Helping representation for automatic machine perception.

One of the limitation of the image resolution is created by the imaging sensors or the imaging acquisition devices. The spatial resolution of the image to capture is determined by the sensor size or equivalently the number of sensor elements per unit area in the first place. So, for increasing the spatial resolution of an imaging system, one of the easiest and most straightforward ways is to increase the sensor density by reducing the sensor size. However, as the sensor size decreases, the amount of light incident on each sensor also decreases, causing the so-called shot noise. Also, the hardware cost of a sensor increases by making sensor density greater or corresponding image pixel density.

The other approach for enhancing the resolution is the employment of various signal processing which are specifically referred to as Super-Resolution (SR) reconstruction [2]. High-resolution (HR) images are restricted by low-resolution (LR) images in SR technique. Huang and Tsay [3] started researching about the SR in 1984. There was a significant spread in this field after that. Approaches using Frequency Domain [4-6], Bayesian [7], Example-Based [7], Set Theoretic [8,9] and Interpolation [10] have been applied to SR techniques. A wide range of purposes such as surveillance video [11], remote sensing [12], medical imaging such as Computerized Tomography (CT) scan, Magnetic Resonance Imaging (MRI), Ultrasound [13] is covered by the application of SR techniques.

The main idea of the SR is to combine the non-redundant information contained in multiple LR frames to create an HR image. Single-image interpolation approach is one of the closest technique to SR which increases the size of the image.

One of the fundamental steps in most image SR processes is the registration of the images [14]. Two or more images of the same scene that are taken at different times, from different viewpoints overlay in image processing [15]. Registration is one of the basic and the principal subjects in the image processing and there are various algorithms for it [16-19]. Image registration techniques are used in various fields of approach such as change detection [20], estimation of wind speed and direction for weather forecasting [21], fusion of medical images [22] like Positron Emission Tomography-Magnetic Resonance Imaging (PET-MRI) [23], Computed Tomography- Positron Emission Tomography (CT-PET) [32], and cartography [24]. These applications are divided into four principal groups according to the manner of the image acquisition [15]: different viewpoints (multiview analysis), different times (multitemporal analysis), different sensors (multimodal analysis), and scene to model registration.

978-1-4799-7600-3/14 $31.00 © 2014 IEEE
DOI 10.1109/AIMS.2014.21

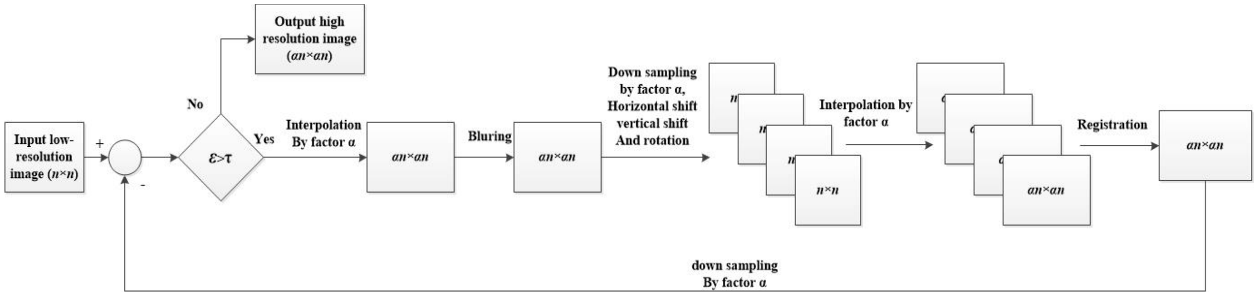

Figure 1: The block diagram of the proposed IIBP super resolution technique.

The process of determining the values of a function between its samples is called interpolation. This process accomplishes by conforming to a continuous function through the discrete input samples. The famous interpolation techniques are nearest neighbor interpolation, bilinear interpolation, and bicubic interpolation.

There are some SR techniques which are using multiple LR images as input in order to generate a super resolved image. These techniques are benefiting from registration [14]. In this research, iterative back projection (IBP) registration [14] is to be used.

The proposed technique is using BP in the registration stage. Iterative BP (IBP) model has two critical steps: the first is to construct the model for imaging process, and the second step is image registration. The first step can be described as

$$g_k(y) = DH^{psf} \times f(x) + n_k \quad (1)$$

Where g_k are k^{th} observed LR images, y denote the pixel of LR images influenced by the area of x of the SR image f, H^{psf} is the PSF of blur kernel, D means decimating operator and n_k is an additive noise term.

In the first part of this method a true(initial) SR image is assumed. Based on the imaging model given in eqn. (2), different LR images are evaluated. Given the calculated LR images a new SR image is being obtained. Afterwards this new SR image is used to generate the new set of LR images. If this new set of LR images is the same as the earlier(previous) set, then the assumed SR image is the true SR image, otherwise the error image obtained from the difference between the LR images are back projected to the assumed SR image. This process is being repeated till no error image is left. IBP can be mathematically represented as

$$f^{(n-1)}(x) = f^n(x) + \sum_y \left(g_k(y) - g_k^n(y)\right) \times H^{BP} \quad (2)$$

where f^n is estimated SR image after n iteration, g_k^n are calculated LR images from the imaging model of f^n after n iteration and H^{BP} is the back projection kernel.

The method proposed in this research is benefitting from bicubic interpolation and BP registration technique iteratively. It is also compared with conventional bicubic interpolation, wavelet zero padding (WZP), Irani and Peleg method[14], and as well as the state-of-the-art technique [26].

II. THE PROPOSED SUPER RESOLUTION TECHNIQUE

The proposed SR technique is benefiting from iterative interpolation and BP registration (IIBP). First, the LR image is interpolated by using bicubic interpolation. Then is decimated to four LR images. The four LR images obtained by taking some sequential images or artificially generated by using blurring filter, are being interpolated by using bicubic interpolation. The interpolated images are not sharp and due to the smoothing caused by interpolation, a sharpening is required. Hence these four interpolated images are being used as an input to the BP registration technique. Finally, the output HR image is decimated and returned to the first step. This process repeats until the amount of error function becomes smaller. In proposed method after each iteration output image has higher resolution rather than intitial one. Figure1 illustrates the block diagram of the proposed IIBP SR technique.

III. RESULTS AND DISCUSSION

For comparison purposes, the proposed method as well as other conventional and the state-of-the-art techniques are being tested on several well-known images namely, Lena, Elaine, Pepper, and Baboon. Table 1 shows the PSNR values in dB for Bicubic interpolation, WZP, Irani and Peleg, and the proposed SR technique of the aforementioned images. The LR images are 128x128 and the HR images are 256x256. For further comparison, Table 2 shows the performance of the proposed SR technique compared to the other techniques from structural similarity index (SSIM) point of view [27].

TABLE I: THE PSNR VALUES (DB) FOR RESOLUTION ENHANCEMENT OF DIFFERENT IMAGES BY USING SEVERAL SR TECHNIQUES.

Images	Technique				
	Bicubic Interpolation	IBP	WZP (db.9/7)	Int+IBP[26]	IIBP
Lena	23.44	24.47	23.59	24.73	25.55
Baboon	20.12	20.40	17.07	20.81	21.06
Peppers	24.07	25.03	22.11	25.91	27.00
Elaine	27.65	27.25	26.87	27.97	30.10
Cameraman	22.32	24.20	24.23	25.53	26.29
Living room	22.59	23.57	23.53	24.66	25.80
Pirate	23.45	24.92	22.57	26.02	26.78
Woman blonde	24.64	25.24	20.12	26.62	27.52
Average	23.54	24.39	22.51	25.28	26.26

TABLE II: THE SSIM FOR RESOLUTION ENHANCEMENT OF DIFFERENT IMAGES BY USING SEVERAL SR TECHNIQUES

Images	Technique				
	Bicubic	IBP	WZP (db.9/7)	Int+IBP[34]	IIBP
Lena	0.7429	0.8284	0.8111	0.8579	0.8612
Baboon	0.3636	0.5129	0.6250	0.5827	0.5282
Peppers	0.7590	0.8324	0.8170	0.8604	0.8622
Elaine	0.8351	0.8925	0.8764	0.9138	0.9165
Cameraman	0.7230	0.8260	0.8492	0.8811	0.8796
Living room	0.5693	0.7347	0.7511	0.8004	0.7992
Pirate	0.6196	0.7736	0.7745	0.8336	0.8300
Woman blonde	0.7385	0.8252	0.8120	0.8701	0.8692
Average	0.6689	0.7782	0.7895	0.8250	0.8183

Figuer 2 shows the visual comparison between bicubic interpolation , Irani - Peleg SR technique, and the proposed method for Lena image. The graph of PSNR results for different number of iteration is demonstrated in Figure 3. This graph shows 3 methods proposed IIBP technique, Irani and peleng method [14] and Interpolation+IBP method. It is clear that the seconds and the third methods have the same PSNR values after about 20 iterations, but the PSNR results of the proposed method is better than the other ones.

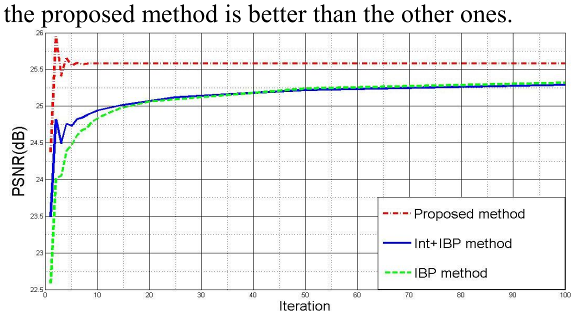

Figure 2: The graph of PSNR results for different number of iteration of different BP based SR techniques for Lena image.

IV. CONCLUSION

In this research work a proposed method based on iterative interpolation followed by registering them using BP was proposed. First the LR image interpolated and then decimate that to four LR images. The four LR images interpolated and registered by using BP in order to generate a sharper HR image then HR image reduces and return to the first step. The Proposed Method was tested on Lolena, Elaine, Pepper, and Baboon and compared by conventional and the state-of-the-art techniques by means of PSNR and SSIM. Quantitative and qualitative results showed the superiority of the proposed IIBP technique over the other SR techniques.

ACKNOWLEDGMENT

The research was supported by the European Union through the European Social Fund (MTT76) and ERDF program "Estonian higher education information and communications technology and research and development activities state program 2011-2015 (ICT program)".

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(a) (b) (c) (d)

Figure 3: The visual comparison between: (a) original low resolution Lena image (128x128) and the super resolved image (256x256) by using (b) bicubic interpolation, (c) Irani and Pelege SR technique, and (d) the proposed IIBP method