Journal of Signal Processing Systems
https://doi.org/10.1007/s11265-018-1408-1

Auto-regularized Gradients of Adaptive Interpolation for MRI Super-Resolution

Leandro Morera Delfin[1] · Raul Pinto Elias[1] · Humberto de Jesús Ochoa Domínguez[2] · Osslan Osiris Overgara Villegas[2]

Received: 1 December 2016 / Revised: 20 March 2018 / Accepted: 13 September 2018

Abstract

In this paper, a method for adaptive pure interpolation (PI) of magnetic resonance imaging (MRI) in the frequency domain, with gradient auto-regularization, is proposed. The input image is transformed into the frequency domain and convolved with the Fourier transform (FT) of a 2D sampling array (interpolation kernel) of initial $L x M$ size. The inverse Fourier transform (IFT) is applied to the output coefficients and the edges are detected and counted. To get a denser kernel the sampling array is interpolated in the frequency domain and convolved again with the transform coefficients of the original MRI image of low resolution and transformed back into the spatial domain. The process is repeated until a maximum count of edges is reached in the output image, indicating that a local optimum magnification factor has been attained. Finally, the edges are sharpened by using an auto-regularization method. Our procedure is deterministic and independent of external information of large databases of other MRI images for obtain the high resolution output image. The proposed system improves the bi-cubic interpolation method by a mean of 3dB in peak of signal-to-noise ratio (PSNR) and until 6 dB in the best case. The structural similarity index measure (SSIM) is improved over bicubic interpolation with a mean of 0.04 and until 0.08 in the best case. It is a significant result respect to novel algorithms reported in the state of the art.

Keywords Super-resolution · MRI · Pure interpolation · Auto-regularized gradients

1 Introduction

The nuclear magnetic resonance (NMR) is a property of atoms that was first observed by Bloch in [1] and Purcell in [2]. The knowledge of this property allows developing techniques to measure the response to the magnetic field of the subjects under study. Furthermore, the external magnetic environment can be manipulated in space and time, to modify the NMR signal without significantly affecting the body exposed to the magnetic field. It can be used to diagnose and monitor many brain diseases and disorders such as congenital abnormality of the brain, bleeding in the brain, infection, tumours, hormonal disorders, multiple sclerosis and others. A MRI study of brain can also determine the cause of muscle weakness and some other symptoms or signs as difficulty speaking, vision problems, dementia. However, the MRI has technical limitations studied in [3, 4] when a high resolution image is required.

The magnetic field of the gradients applied during a MRI study is proportional to the resolution of the acquired data. The energy applied over the patient must be limited. Therefore, some super-resolution (SR) techniques are proposed in order to increase the information density of the image per area. SR is a process to estimate a high-resolution (HR) image from one or multiple low-resolution (LR) images considered a degraded version of the HR image [5–8]. In this work, a single image problem formulation is carried out.

The SR methods include procedures such as pure interpolation (PI) [9–11], reconstruction [12–14], learning [15–17] and gradient prior methods [18, 19]. In [6], the

✉ Leandro Morera Delfin
lmorera@cenidet.edu.mx

Raul Pinto Elias
rpinto@cenidet.edu.mx

Humberto de Jesús Ochoa Domínguez
hochoa@uacj.mx

Osslan Osiris Overgara Villegas
overgara@uacj.mx

[1] CENIDET, Cuernavaca, Morelos, Mexico

[2] UACJ, C Juarez, Chihuahua, Mexico

Published online: 10 October 2018