Image Zooming and Multiplexing Techniques based on K-Space Transformation

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Abstract

Image zooming have become an important topic in image processing and analysis. New image zooming is introduced in this paper based on K-Space transformation technique. The main aim of the proposed scheme is to achieve high zooming factor without much effect on the image quality. Simulation results on real digital images are given to show effectiveness and reliability of the proposed algorithm.

Keywords: *Image zooming, image processing, Image Multiplexing, K-Space Transformation*

1. Introduction

Due to the development of modern information technology, image processing is becoming more and more important in our life. Image zooming is an important type of that image processing. Image zooming is a task of applying certain transformations to an input image such as to obtain a visually more pleasant, more detailed, or less noisy output image. Image zooming is encountered in many real applications such as World Wide Web, digital video, DVDs, scientific imaging, electronic publishing, image database, digital camera, visible wireless telephone, medical imaging and so on. In order to have better and fine images for users, images often need to be zoomed in and out or reproduced to higher resolution from lower resolution. Image resizing is necessary when you need to increase or decrease the total number of pixels, whereas remapping can occur under a wider variety of scenarios: correcting for lens distortion, changing perspective, and rotating an image.

In fact, a zoom can be easily seen as a homogeneous scaling of the image or scaling of specific part of image (ROI). A region of interest (ROI) is a portion of an image that you want to filter or perform some other operation on. The regions can be geographic in nature, such as polygons that encompass contiguous pixels, or they can be defined by a range of intensities. In the latter case, the pixels are not necessarily contiguous. Perhaps the most interesting feature of digitally encoded image data is that the image can be analytically manipulated. With the rise of consumer based digital photography, users expect to have a greater control over their digital images. Digital zooming has a role in picking up clues and details in surveillance images and video. In medical imaging, neurologists would like to have the ability to zoom in on specific parts of brain tomography images. Another application is found in web pages with images. To shorten the response time of browsing such web pages, images are often shown in low-resolution forms.

A generic zooming algorithm takes as input an image and provides as output a picture of greater size preserving the information content of the original image as much as possible. Unfortunately, the methods can preserve the low frequency content of the source image well, but are not equally well to enhance high frequencies in order to produce an image whose visual sharpness matches the quality of the original one especially, when the image is zoomed by a large factor. Pictures to be handled in real world are always bitmap, whose zooming task is a difficult one considering the fact that there is no general unifying theory of image enhancement [1]. Furthermore, speed and efficiency are hard to have good balance.

This paper is organized as follows. Image zooming techniques reviews are presented in Section 2. K-Space is illustrated in Section 3. The proposed scheme for image zooming is presented in Section 4. Simulation results and discussions are given in Section 5 and finally conclusions are drawn in Section 6.

2. Image Zooming Techniques Reviews

By a wide survey, it's obvious that most common image zooming techniques based on Different types of interpolation. The image magnification is obtained by interpolating the discrete source image and this interpolation can be conventionally done by the techniques such as pixel replication, bilinear interpolation [2]. In most traditional image zooming algorithms, when zooming image, pixels are inserted into the image in order to expand the size of the image, and the major task is the interpolation of the new pixels form the surrounding original pixels. Weighted medians have been applied to similar problems requiring interpolation, such as interlace to progressive video conversion for television systems. The advantage of using the weighted median in interpolation over traditional linear methods is better edge preservation and less of a "blocky" look to edges. To introduce the idea of interpolation, suppose that a small matrix must be zoomed by a factor of 2, and the median of the closest two (or four) original pixels is used to interpolate each new pixel:

$$
\begin{bmatrix} 7 & 8 & 5 \\ 6 & 10 & 9 \end{bmatrix} \longrightarrow
\begin{matrix} 7 & 0 & 8 & 0 & 5 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 \\ 6 & 0 & 10 & 0 & 9 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 \end{matrix} \longrightarrow
\begin{matrix} 7 & 7.5 & 8 & 6.5 & 5 & 5 \\ 6.5 & 7.5 & 9 & 8.5 & 7 & 7 \\ 6 & 8 & 10 & 9.5 & 9 & 9 \\ 6 & 8 & 10 & 9.5 & 9 & 9 \end{matrix}
$$

Figure 1. Interpolation Concept

Image zooming commonly required a change in the image dimensions by a factor, such as a 50 % zoom where the dimensions must be 1.5 times the original. Also, a change in the length-to-width ratio might be needed if the horizontal and vertical zoom factors are different. The simplest way to accomplish zooming of arbitrary scale is to double the size of the original as many times as needed to obtain an image larger than the target size in all dimensions, interpolating new pixels on each expansion. Then the desired image can be attained by sub sampling the large image, or taking pixels at regular intervals from the larger image in order to obtain an image with the correct length and width. Image interpolation works in two directions, and tries to achieve a best approximation of a pixel's color and intensity based on the values at surrounding pixels. The following example illustrates how resizing / enlargement works:

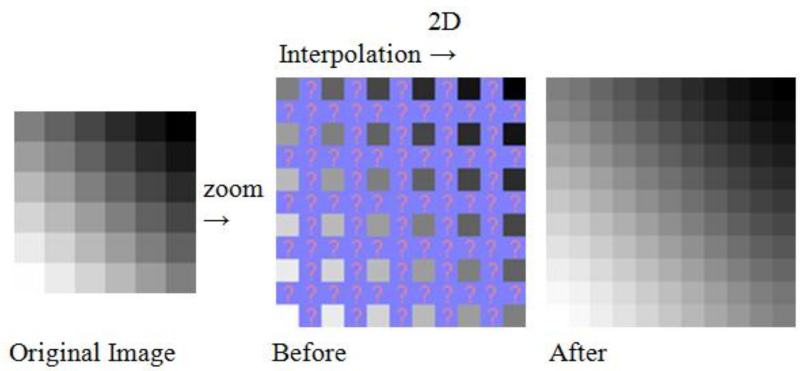

Figure 2. Image Zooming Based on Interpolation

Unlike the ideal gradient above, pixel values can change far more abruptly from one location to the next. As with the more you know about the surrounding pixels, the better the interpolation will become. Therefore results quickly deteriorate the more you stretch an image, and interpolation can never add detail to your image which is not already present. Common interpolation algorithms can be grouped into two categories: adaptive and non-adaptive. Adaptive methods change depending on what they are interpolating (sharp edges vs. smooth texture), whereas non-adaptive methods treat all pixels equally. There are some other methods used in image zooming such as the method based on partial Differential Equations (PDEs) [3] and the method based on sampling theorems [4]. But these methods still depend on the same principle of interpolation.

Image Zooming Artifacts

Image zooming via Traditional Image zooming methods often produces some undesirable artifacts, in particular, when the magnification factor is large. These three undesirable artifacts: edge halos, blurring and aliasing as shown in figure 3. In order to remove the artifact and to form reliable zoomed image, additional post processing are required. In other word, image zooming using most traditional methods need extra processing to overcome artifacts yielded form image zooming.Most of the image zooming techniques leads to image distortion. This distortion can be from many ways such like jagging-blocks are formed due to replication of pixels, burring- It is unclearity of the image, ghosting- it is the distortion of the image. Current interpolation algorithms attempt to solve these artifacts in a number of ways. There are other factors have to be kept in mind while making an algorithm like speed (zooming should not take much time for enlargement), memory requirement (the algorithm should not take much memory space). The proposed technique takes into consideration all artifacts and zooming problems to solve and overcome them.

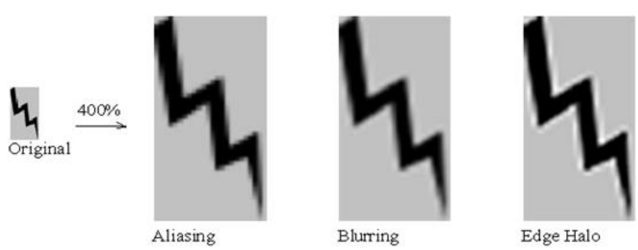

Figure 3. Some Image Zooming Artifacts

3. K-Space Transformation

K-Space is the main point in MRI (Magnetic Resonance Imaging) and understanding it is very important to know how MRI works. Data collected during an MRI scan corresponds to samples of the two-dimensional Fourier transform of the image. The domain for this data set is commonly referred to as 'k-space' [5]. MRI is a medical imaging technique used in radiology to visualize detailed internal structures.

The k-space is an extension of the concept of Fourier space well known in MR imaging. The k-space represents the spatial frequency information in two or three dimensions of an object. The k-space is defined by the space covered by the phase and frequency encoding data. The relationship between k-space data and image data is the Fourier transformation. The data acquisition matrix contains raw data before image processing. In 2-dimensional (2D) Fourier transform imaging, a line of data corresponds to the digitized MR signal at a particular phase encoding level. The discrete Fourier transform of a function f(x,y), which is the actual image, of size m x n can be expressed as:

$$F(u,v) = \frac{1}{mn}\sum_{x=0}^{m-1}\sum_{y=0}^{n-1} f(x,y)\cdot e^{-2\pi i(\frac{ux}{m}+\frac{vy}{n})}$$ ---------------(1)

For u = 0, . . . ,m− 1 and for v = 0, . . . , n – 1. And the inverse by

$$f(x,y) = \sum_{u=0}^{m-1}\sum_{v=0}^{n-1} F(u,v)\cdot e^{2\pi i(\frac{ux}{m}+\frac{vy}{n})}$$ --------------------(2)

For x = 0, . . . ,m − 1 and for y = 0, . . . , n − 1

The variables u and v used in equation (1) are the frequency variables, x and y are the spatial or image variables. Note that f(x,y) is the image and is real, but F(u,v) is the FT and is, in general, complex. In the literature, F(u,v) is often represented by its magnitude and phase rather than it's real and imaginary parts, where

$$magnitude(F(u,v)) = \sqrt{R^2(u,v) + I^2(u,v)}$$ --------------------(3)

$$phase(F(u,v)) = \tan^{-1}[\frac{I(u,v)}{R(u,v)}]$$ -----------------------------(4)

Basically, the magnitude tells how much of a certain frequency component is present and the phase tells where the frequency component is in the image. A point in the raw data matrix in K-Space domain does not correspond to a point in the image matrix. Every point in the raw data matrix in K-Space domain contains part of the information for the complete image, See Figure.5. The outer rows of the raw data matrix, the high spatial frequencies, provide information regarding the borders and contours of the image, the detail of the structures. The inner rows of the matrix, the low spatial frequencies, provide information on the general contrast of the image [6-8].

4. The Proposed Image Zooming Technique

The main philosophy of our image zooming technique is based on the concept of representation of image in k-space domain. Where, the k-space is a temporary memory of the spatial frequency information in two or three dimensions of an image. Our proposed method introduces a new image zooming technique with high zooming factor and little image zooming artifacts and problems. These artifacts produce mostly because of the most zooming methods process on each pixel and surrounding pixels in time domain and didn't process on the whole picture. In K-space domain, most problems and artifacts are corrected to obtain images with high quality. Since K-space is a 2D plot of spatial frequencies, and so there is no positional relationship between points in k-space and points on the image. Every single point in k-space contributes to the entire image. Since image processing in k-space domain give us more prefect solutions of image problems than processing in image domain. From this point this image zooming technique on transforming images into K-Space domain and zoom image, then re-transform image back to image domain. Transforming image to K-Space domain is conducted by performing two inverses Fourier transforms orthogonal to each other. The proposed technique can be zoom image in two directions, zoom in and zoom out.

4.1 Zoom Out Image

First, Image or Sub-pixel from image (ROI) is selectively resized or "zoomed" translated from time domain into K-space domain using K-space transformation. After transforming the image into K-space domain, the new image or sub-pixel from image has the same dimension of the original image (say: [64x64]). Then fill a round the new image in K-space domain by zero padding to reach to new desired dimension (say: [256x256]). After zero padding of the image in k-space domain data, retranslate the new image back into time domain using Inverse K-space transformation [256x256]). The new image data after retransformation provides spatial domain data which when displayed provide an image that is resized relative to images provided from the k-space domain. A "zoom" or magnification factor can be selected and the quantity of zoomed images varied in response to the zoom factor to provide different zoom ratios. Restricting zoom factors to certain values permits the fast k-space transform to be used in Transformation.

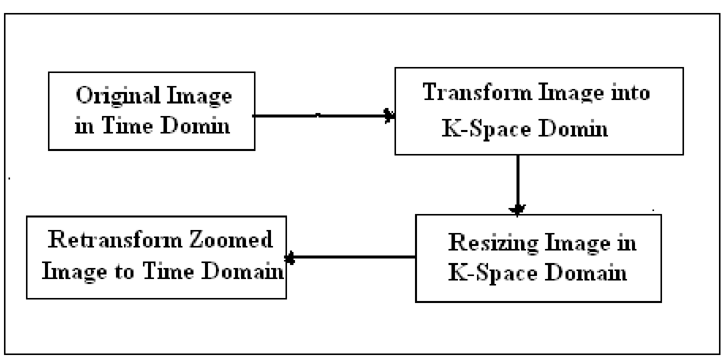

Figure 4. The Proposed Image Zooming Technique

4.2 Zoom in Image

The main advantage of our technique is used in zooming image in an out. This is the main algorithm for zoom in image. First, convert the image into k-space domain using equations (1-4). Then shift zero-frequency component of image in K-space domain to center of spectrum, this is useful to concentrate the zero-frequency component in the middle of the spectrum. In the k-space, each data point in k-space consists of the summation of all signals from all pixels in image space. And general spatial information is concentrated towards the center of "K-Space", so we apply filter on k-space matrix image to select part center of the K-Space with dimension equal to the required zoom in size. For example, suppose original image size is 256x256 and we need zoom in image to 32x32, so k-space matrix dimension is 256x256, we apply filter to select only 32x32 , then take new k-space matrix and retransform it back in image domain which yield rehired zoom in image with new size equal 32x32.

4.3 Zooming the Color Image

The proposed algorithm for zooming digital color images can be easily generalized by the same algorithm for gray-scale ones described above. For each color component R, G and B (Red, Green and Blue) values as a gray-scale. Like common way, first translate each component into k-space domain, then zooming each component, finally re-transform image back to image domain. So the algorithm for gray-scale image zooming can be easily extended to zooming the color images.

5. Image Multiplexing Scheme using K-Space Transformation

In this section, we propose a new image multiplexing technique based on K-Space Transformation. Image multiplexing is the technique involved in sending more than one image over a communication medium as a single image. The receiving end accepts this complex image and reconverts it into its individual images. Image multiplexing provides great cost advantages, since it reduces the need for additional wires and/or communication channels. It reduces time required to transmission and resources. Multiplexing eliminates dedicated wiring connections, hard wiring and manufacturing costs. Also, it is used to compress transmitted or stored image. The main advantage of proposed technique is applicable for any images type, gray, color, medical, text..etc.

The following figure illustrates the proposed image multiplexing technique. The first operation that must be carried out on these images is transforming each image into k-space domain, to zoom in each of these images. Next, we group together these different spectra in a single compound spectrum, referred to as the "multiplexing spectrum", as shown on "Fig. 5". So, the multiplexing spectrum groups together, in a unique spectrum, the data that are necessary for the reconstruction of all the images.

If we want show the new multiplexing image, we do inverse k-space transformation on multiplexing spectrum. Else, we can transmit this multiplexing spectrum as a compressed image containing necessary information from all images. To carry reconstruction, which can be called the decompression, we just have to apply the inverse k-space transformation on this compound spectrum.

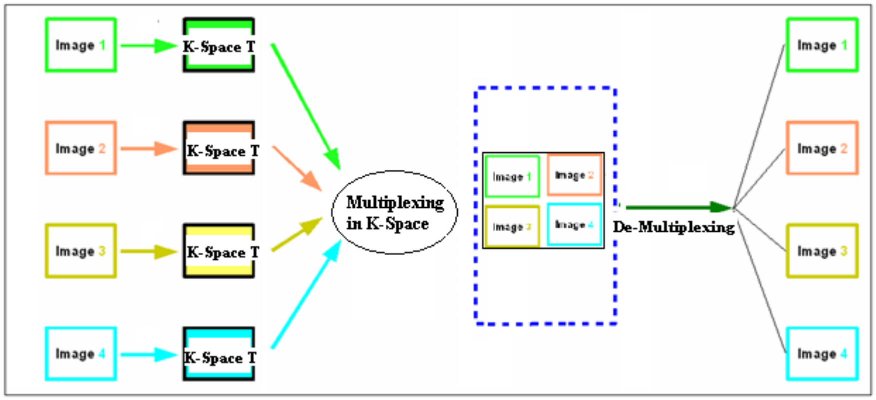

Figure 5. Proposed Image Multiplexing

6. Simulation Results

Several experiments with the proposed image zooming and multiplexing algorithm have been performed. We present a few of them in this section. We used in simulations some standard images in image processing research domain. Then apply the proposed technique for portion of some image (ROI) as MRI image.

6.1 Zoom Out Full Image

In simulation experiments of gray-scale image, the Lena image dimension [64x64] will be magnified to 16 times their original sizes to be [256x256] as shown in Figure 6.

Figure 6. Zooming Gray-scale Image by Factor 16

6.2 Zoom Out Color Image

For color image, the Pepper image with dimension [64x64x3] will be magnified to 16 times their original sizes to be [256x256x3] as shown in Figure 7.

Figure 7. Zooming Out Color Image by Factor 16

6.3 Zoom in Image

For zoom in image, the Cameraman image with dimension [256 256] will be zoomed in to 1/16 times their original sizes to be [64x64] as shown in Figure 8.

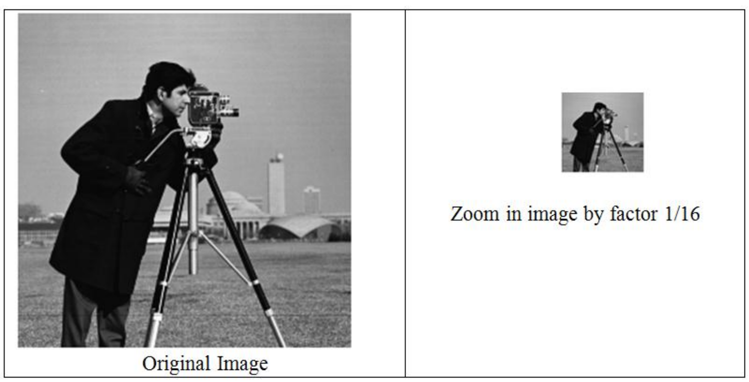

Figure 8. Zooming Cameraman Image By factor 1/16

6.4 Region of Interest (ROI)

In simulation experiments for specific part from image (ROI), the MRI image and papper image with dimension [128x128] will be used. The ROI part dimension [32x32] will be magnified to 4 and 16 times their original sizes to be [64x64] as shown in Figure 9 and simulation results for pepper image shown in Figure 10.

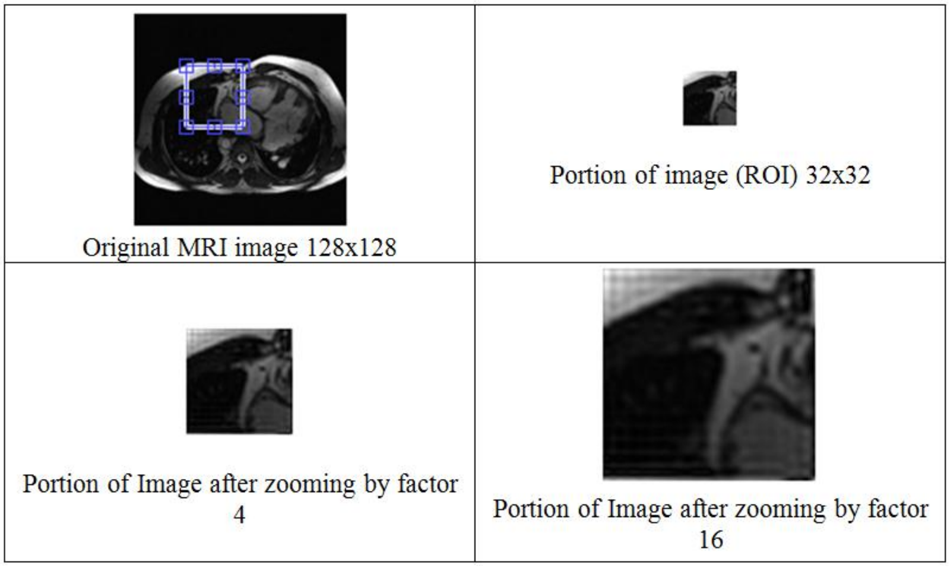

Figure 9. Zooming Portion of MRI Image

6.5 Image Multiplexing

In simulation experiments of image multiplexing we used four standard images, each image dimension [256x256] will be zoomed in to [128x128].Then multiplex these images into single image with the dimension of each original image [256x256] in K-Space domain shown in Figure 10 and in image domain in Figure 11. After transmission the new image (image multiplexing in k-space domain as Figure 10) we reconvert the received image into image domain and apply the proposed de-multiplexing method to retrieve the original images as shown in Figure 11.

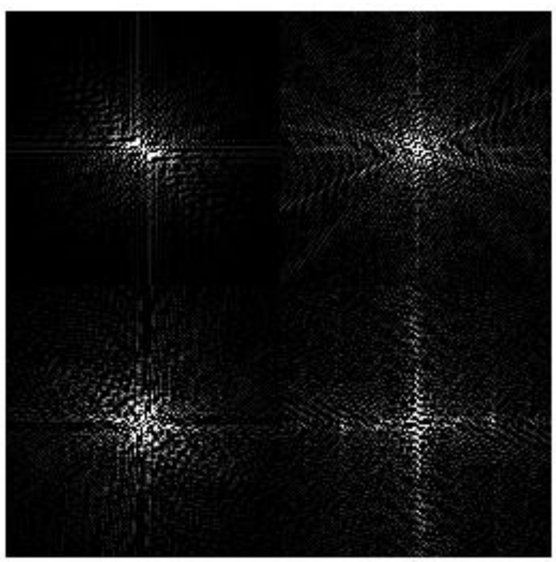

Figure 10. Multiplexing 4 Images in K-Space Domain

Figure 11. De-multiplexing Image

6.6 Visual Comparison

The first qualitative analysis of the proposed method is a series of image comparisons that are presented. It is clear that visually the output of our algorithm better than the other existing techniques. For example, the next figure show comparison zooming image using interpolation method and using proposed technique by factor 16 for portion of pepper image (Fig. 12) and for full color image (Figure 13).

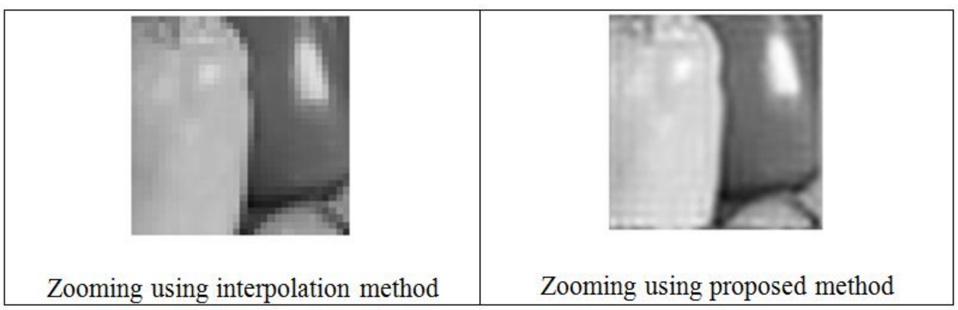

Figure 12. Comparison Results for ROI Image

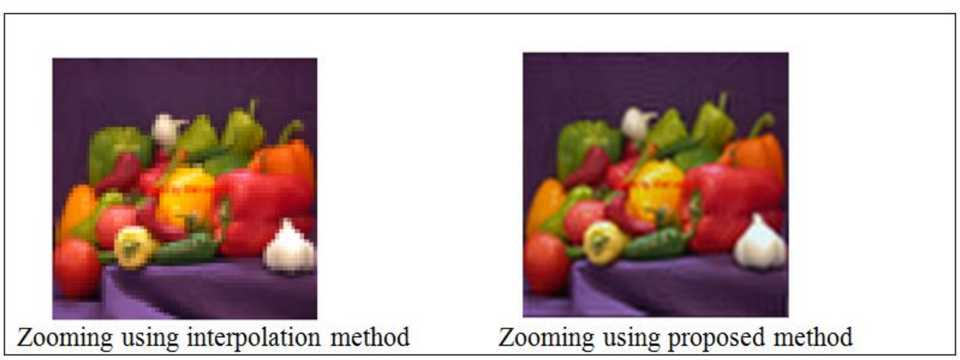

Figure 13. Comparison Results for Color Image

7. Conclusions

In this paper, a new technique is proposed for image zooming depends on known method in the field of medical images, especially in the Magnetic Resonance Imaging (MRI) known as ‘’K-Space. This scheme basically depends on the concept of K-Space transformation technique. The main aim of the proposed scheme is to achieve high zooming factor without much effect on the image quality. We have tested our proposed scheme by many different standard test images, gray, color and medical images at different zooming factors. All the examples indicate that our algorithm is efficient for image zooming and has good subjective quality, both for full images and region of interest images.

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