Super Resolution in Medical Imaging for An Automated Proficient Process

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Abstract

The responsibility of the physician in cancer screening involves the interpretation of images of the body organ for the identification of potential abnormalities, and their categorization with respect to malignancy. Such images include mammograms, contrast-enhanced Magnetic Resonance Images (MRI) and ultrasound images. We present a wavelet based super resolution algorithm to suit the need of Computer Aided Detection (CAD) in cancer screening for civilizing image excellence and detecting abnormalities in a diversity of modalities associated with. In wavelet technique, the image is decomposed into approximation, vertical details, horizontal details and diagonal details. In multilevel wavelet the image is decomposed into multiple levels and the high frequency components are separated out. High frequency component is used in extrapolation using which high-resolution image is constructed. The objective is the development of an automated process proficient of tagging suspicious regions, supplementing and humanizing the physician's ability to spot abnormalities by showing the suspicious regions in the form of high-resolution image.

Introduction

In the screen-film diagnosis process, film serves as the medium for both image acquisition and display. Screen-film diagnosis has limited detection capability for low-contrast. It is beneficial to enlarge image with increased resolution for display purposes. The duty of the physician in analyzing images for cancer screening and analysis like in digital mammography screening involves the understanding of images of the body organ for the recognition of possible abnormalities, and their classification with respect to melanoma. In manual system, the physician does diagnosis with his knowledge base, which enriches with the experience. If any suspicious patch is observed, then the physician needs the image with more details. Super resolution based medical Imaging can play major role in designing of an automated proficient system for analyzing images for cancer screening and diagnosis. In 2-D multi-slice MRI, the resolution in the slice direction is often lower than the in-plane resolution. For certain diagnostic imaging applications, isotropic resolution is necessary but true 3-D acquisition methods are not practical. In such cases, now if the process is automated and if an image with better resolution and clarity were provided to physician it would surely help in tagging doubtful regions, supplementing and improving the physician's capability to mark abnormalities. We have simulated the manual process by overcoming the drawbacks of the same.

We present a wavelet based super resolution algorithm to suit the need of an automated system. By automated we mean the system spot outs the abnormalities without human involvement. Once the abnormalities are detected by the system, physician plays a vital role for further tagging with respect to malignant cells. Along with processes like cancer screening and detecting abnormalities the system helps in enlightening image excellence for boosting further diagnosis of physician. High frequency component extracted through wavelet decomposition is used in extrapolation using which high-resolution image is constructed. High Resolution (HR) means that pixel density within image is high, and therefore an HR image can offer more details that may be critical in medical imaging. This enhances the image with respect to resolution and makes the image contents rich enough for analysis. Such a resolution enhancement is also called as Super Resolution (SR) image reconstruction [2].

The Proposed System

An automated proficient Computer Aided Detection system has following phases:

1. Capture digital images using image-capturing device.
2. Analyze each image using built-in knowledge base and detect the abnormalities, if any.
3. If any abnormalities are detected, super resolve the suspicious regions that is region of interest for improving image excellence.

The step three helps to humanize the physician's ability to diagnosis and ability to further analyze the size, growth rate etc. If needed the images of specified region may be further captured on physicians demand.

The manual process has few drawbacks. In manual process there are chances of not noticing the suspicious region, especially when it is too tiny to be noticed. In Computer Aided Detection system, this drawback is overcome. For further clarity and to excel the process of physician's ability to further analyze the size, growth rate etc., the suspicious region is displayed with a higher resolution. Physician can control this whole process. The proposed system is interactive as on physicians demand, an image of region of interest can be captured again. The system has three main parts: the image analysis, image enhancement and a third logical component, a database, which we refer as knowledge base. The database maintains information about the patient, his/her previous images, referred as templates in this paper and abnormality identified, if any. This system stores recent details to enable provision of efficient storage and services such as fast look-up of database.

Image Acquisition System

Image acquisition system typically could be an X-ray CT scanner or MRI system or ultra sound imaging system. X-ray CT scanner produces several images of its transaxial projections. A projection is a shadow gram obtained by illuminating an object by penetrating radiation. By rotating the source detector assembly around the object, projection views for several different angles can be obtained. Note that in obtaining projections, we lose resolution along the path of X-rays. CT restores this resolution by using information from multiple projections. For proposed system, all of these images are used for analysis and generating SR image.

Analysis of Image

For lung cancer screening by CT, most of the images handled at the mass-screening level are normal cases, and the rate of detection of lung tumors is no more than a few percent. In order to detect such rare tumors with high accuracy, there must be a technique that can correctly detect small changes in the image. In proposed system, each captured image is analyzed to detect the abnormalities. Aim of this phase is to solve problem of critical significance that is, the detection of change or presence of an abnormalities in an image. In the proposed system, computer analyses the image with the help of knowledge base. The knowledge base is nothing but a database consisting of set of images, which are pre-stored. These are the images having no abnormalities or with abnormalities. These images are used as templates. When the patient undergoes the screening test first time, the default template images are used for matching and diagnosing. Default templates are the one without abnormalities. Then the current image is added into a knowledge base to create that patients own template image to be used during next screening tests. Computer does this automatically by collecting necessary information of the patient. When the patient undergoes the screening second (or further) time, his own template is used for analysis to detect the change or presence of an abnormality. The system keeps updating its own database by storing few recent images as template images. In brief, there is a default template for a new patient and template of every patient's own. This system searches for the template automatically. Now to analyze the image, we can use image matching and detection techniques such as image subtraction, matched filtering etc. One of the most suitable techniques is image subtraction [4]. Once the patient's own template is created, this algorithm is the most appropriate one. Image subtraction helps to observe and detect changes in images observed as u_i (m, n), i = 1, 2, 3, are given by

$$e_i(m,n)= u_i(m, n) - u_{i-1}(m, n) \qquad (1)$$

Although elementary, this image subtraction technique is very much useful for the proposed system. Here u_i represents template image and u_{i-1} is a currently captured image. The microscopic changes that are not visible to human eye can be easily detected by this method. Also change in size which is one of the symptoms, can be noticed without doubt. If any abnormalities (tumor or change in size) are identified, the region of interest can be made strenuous by displaying image with high resolution.

High Resolution Image of The Region of Interest

Interpolation is used extensively in digital medical image processing to magnify images and correct spatial distortions [9]. Image interpolation is used for several different purposes such as resolution enhancement, multi-resolution pyramidal compressing etc. In past years, interpolation techniques such as nearest-neighbor, bilinear, cubic b-spline, cubic convolution etc. is widely used to increase resolution of images [12-14,17-21]. Both the nearest-neighbor and bilinear methods provide the interpolation function with a very small computation time, but they cause conspicuous blocking artifacts [12-21]. The cubic interpolation reduces the blocking effects, but it always blurs the reconstructed image and produces some ringing effects in the edge regions [8]. Because characteristics of the edges in a digital medical image are to be reserved for many scales of resolution and edges are always important for human vision, our wavelet based technique preserves the local edge structure to prevent the blurring and blocking effects in reconstructed high-resolution image.

The Wavelet Based Super Resolution Technique

Wavelets are the functions that satisfy certain mathematical requirements and are used in representing data or other functions. The wavelet transform has been identified as an effective tool for time-frequency representation of signals [[10-12]. It can decompose a digital image into some frequency sub-images, each represented with proportional frequency resolution. The resulting band-pass representation provides that the solution space of many image processing problems and can be decomposed into its lower frequency subspace and higher frequency subspaces. We have developed an excellent method that is well suited for increasing resolution of images based on wavelet transform. Our technique employs both spatial and spectral frequency signals to increase resolution of the medical image. Wavelet analysis represents a windowing technique with variable sized regions.

The idea is wavelet analysis allows the use of long time interval when we want precise low frequency information and short regions when we want high frequency information. We use wavelet to separate frequency components. The technique decomposes image into approximation, vertical details, horizontal details and diagonal details. Using multilevel wavelet, the image is decomposed into multiple levels and the high frequency components are separated out. High frequency component is used in extrapolation using which high-resolution image is constructed. The resolution of approximate component can be improved by using existing image enhanced methods, which are based on interpolation techniques. Existing methods help to improve spatial resolution. But these methods have few limitations. It has limitation to improve the spectral resolution of the image because the high frequency components are absent. The spectral resolution plays an important role in medical image analysis. The high frequency components, which are separated out by wavelet transform are extrapolated in our super resolution technique. Our technique checks the nature of high frequency components: horizontal high frequency components, vertical high frequency components or both. Technique then extrapolates the frequency components accordingly.

Results

The proposed algorithm increases the resolution of a low resolution medical image. The image in figure 1 is a original images and is a image generated during mammography [5,6]. The image has two suspicious patches marked with white colored arrows. The image in figures 2 and 3 are magnified images at upper patch and lower patch of original image respectively. The image in figure 4 is the image with high resolution increased by factor two. Figures 5-6 display the image with region of interest magnified for image in figure 4. All these images are generated as a result of our technique implemented in MatLab7.1. The image in figure 7 is image with high resolution increased by factor four. The images in figure 8-11 are one with region of interest, that is, both the patches magnified once and twice.

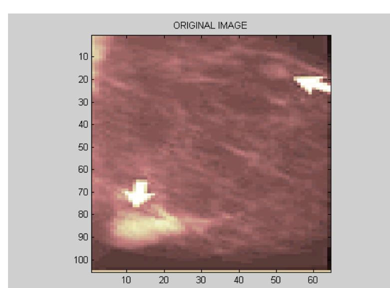

Figure 1 Original Image with two suspicious patches

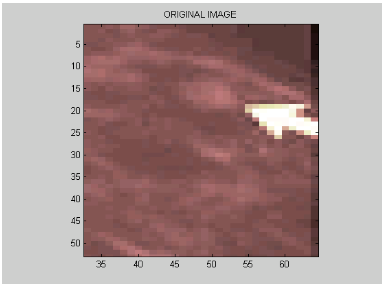

Figure 2 Original Image with upper suspicious patch magnified

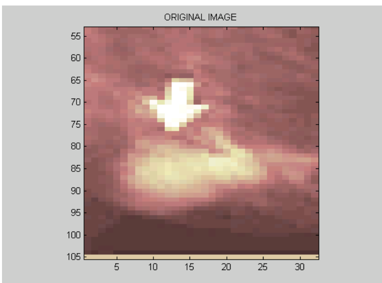

Figure 3 Original Image with lower suspicious patch magnified

From the results, it is found that for the original low resolution image, if we try to magnify the region of interest the blocking effects are observed. With our super resolution algorithm these effects are eliminated. Moreover, the proposed scheme obtains the superior image quality about the edges [16-19]. Also the resolution of a image can be increased up to the resolution till it gives adequate details to the physician. From the experimental results, we found that the proposed technique is useful for medical as well as natural and computer generated images.

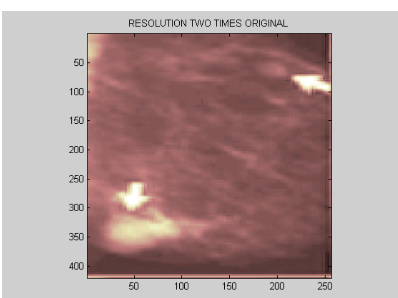

Figure 4 Resolution two times as that of Original Image

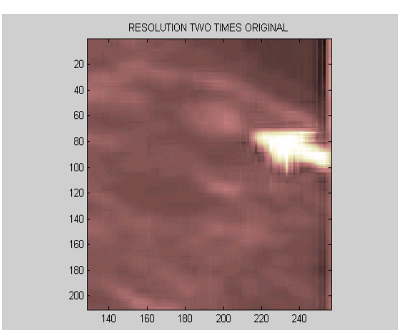

Figure 5 Upper suspicious patch magnified for image in figure4

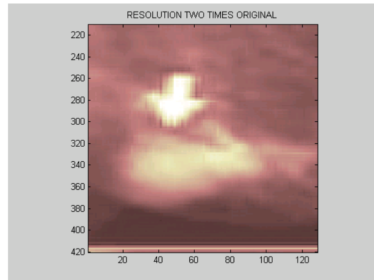

Figure 6 Lower suspicious patch magnified for image in figure4

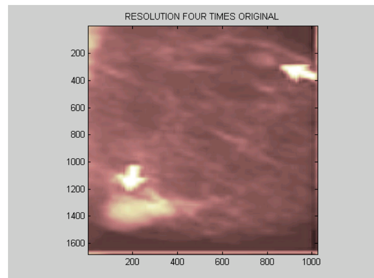

Figure 7 Resolution four times as that of Original Image

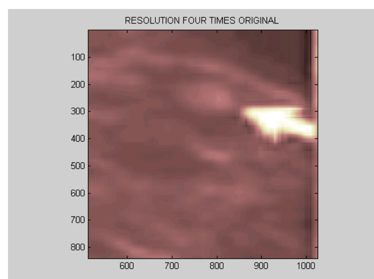

Figure 8 Upper suspicious patch magnified for image in figure7

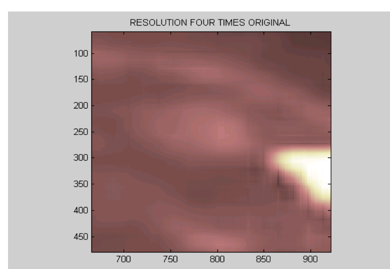

Figure 9 Upper suspicious patch further magnified for image in figure8

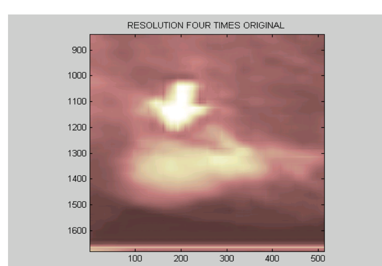

Figure 10 Lower suspicious patch magnified for image in figure7

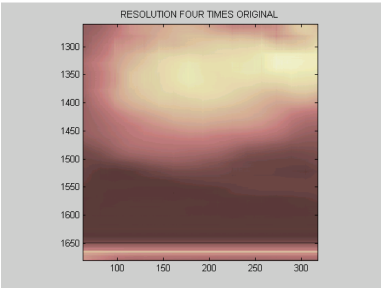

Figure 11 Lower suspicious patch further magnified for image in figure10

Image quality is one of the important factors in image processing applications and it is a critical aspect in medical image processing. For image quality measure there are two commonly used techniques: Objective evaluation and Subjective evaluation. We have used subjective evaluation criteria for image quality. We found it the most suitable for said application. It is based on Human Visual System, which allow a better correlation with the response of the human observer.

Image Quality Measures

- Objective Evaluation of Image Quality

Many objective quality-measuring methods have been developed for image quality evaluation in last few years. And they are based on numerical measures of image quality and computable distortion measures.

- Subjective Evaluation of Image Quality

Subjective evaluation of image quality is measured using Mean Opinion Score (MOS). The MOS values are obtained from an experiment involving experts. Five grade impairment with proper description for each grade: 5-imperceptible, 4-perceptible, 3- slightly annoying, 2-annyoing, 1-Very annoying MOS for each image generated is calculated.

$$MOS = \sum_{i=1}^{5} ip(i) \qquad (2)$$

Where 'i' is the grade and p (i) is the grade probability.

We conducted experiment by taking 20 doctors as observers. The five sets with two images per set were presented to the observers, one original image and second the reconstructed HR image with different increasing factors. They evaluated image quality of both images with grades as 1: Excellent, 2: Good, 3: Fair, 4:Poor, 5: Bad. Grades received were proportional to the increase factor of resolution. For images reconstructed with increasing resolution by factor four received the grade 1, that is, excellent from 90% of the observers.

Conclusion

In this paper, we have proposed an automated proficient Computer Aided Detection system for cancer screening. We emphasize that this system surely can detect very early tumors, even when they are too small to be felt. As per proposed system the subtraction of two images should detect the abnormalities and then the region of interest or the whole image should be used to generate the super resolution image. But we faced difficulty in getting the image with and without cancerous patch. Hence the cancerous image is used for testing the algorithm and presenting the results. Here the original image and the abnormalities, which is region of interest, are shown with different resolutions so that the results of algorithm are compared to show the improved quality of image. This automated computer based system is online and interactive, hence is faster and accurate than manual process. This system would surely assist a physician for faster and accurate diagnosis. The system uses super resolution technique to display the image with more details for boosting the physician's diagnosis.

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