Contrast Enhancement of MRI Images using AHE and CLAHE Techniques

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Abstract—Medical images require image enhancement, a category of image processing which provides better visualization that make diagnostic more accurate. The most commonly used method for improving the quality of medical image is Contrast enhancement. The main objective is to eliminate the use of contrast dye during the process of MRI scan and to find the parameters MSE, PSNR, AMBE and contrast and compare the result. The histogram equalization (HE) is the widely accepted method which is not productive when the contrast nature differs across the image. Adaptive Histogram Equalization (AHE) overcomes this limitation by considering and developing the mapping for each pixel from the histogram in a neighboring window. Another suitable technique is CLAHE. CLAHE is a refinement of AHE where the enhancement calculation is modified by imposing a user specified level to the height of local histogram. The enhancement is thereby reduced in very uniform areas of the image, which prevents over enhancement of noise and reduces the edge shadowing effect of unlimited AHE. After enhancing the image using AHE and CLAHE the comparison of their parameters is performed.


I. INTRODUCTION

MRI is a medical imaging technique which is widely used to examine the internal organs of the human body. Its uses strong and uniform magnetic field. MRI does not involve ionizing radiation which made it differ from CT and PET scans. If the CT or X-ray does not give clear picture about a patient condition, then the doctor should prescribed MRI. Compared with other scanning procedure, MRI takes longer time and it is louder which generally need the patient to enter a narrow tube. The strong magnetic field produced by it, will align the hydrogen atoms in same direction. It can be used to diagnose brain tumour, stroke, multiple sclerosis, developmental anomalies, evaluate the organs of chest and abdomen. The resultant images can be reviewed on a computer and can be printed or uploaded to a cloud. Image enhancement plays an important role which helps for proper diagnosis by providing very good quality images of the defective parts.

For denoising technique mean and median filter is used based on different pixel values which works better for salt & pepper noise and Gaussian noise. Adaptive histogram equalization is the widely used method of contrast enhancement. In phase-I denoising of MRI image is done which then followed by Enhancement Technique.

By using HE (Histogram Equalization) the MRI brain image enhancement is described in [5]. In [2] comparative study for contrast enhancement of brain tumour is studied.

II. CONTRAST DYE

A. MRI CONTRAST AGENT

Currently, there are two types of MRI procedure. One is with contrast and the other non-contrast. The former involves a contrast dye that is injected into the human body mostly by intravenously before starting the scanning procedure and eliminated from the body through the kidney. It is recommended by medical examiners as it gives the exact and high quality of images for certain conditions. Thus, the dye delivers not only clearer, but sharper result of the image.

Gadolinium, a paramagnetic material is most commonly used in MRI. Roughly 10-20 millilitres of dye will be injected in to the patient’s body. When inject into the body, it enhances and improves the quality of the MRI image. Gadolinium will not be recommended in cases like pregnancy, history of allergic reaction, severe kidney disease. Less often in approximately 1 in 1000 patients, skin rash might appear a few minutes after the injection. Common adverse reaction includes headache, nausea, and dizziness for a long time.

Fig.1. Effect of contrast agent on images

In general, most of the patients are misguided and not aware of the unwanted effects caused by the dye. A survey conducted by Mayo clinic in 2018 by considering over 6, 50,000 dye injections and below is their study outcome.

- Side effects of CT scan – 0.18%
- Side effects of MRI dye - 0.03%
- Significant side effects are nausea and itching
- One patient so far died, which leads to a mortality risk 0.0002

III. DESIGN METHODOLOGY

The proposed methodology involves two methods for image enhancement.

- AHE (Adaptive Histogram Equalization)
- CLAHE (Contrast Limited Histogram Equalization)
Contrast Enhancement of MRI Images using AHE and CLAHE Techniques

A. Block Diagram

![Block Diagram](Image)

B. Filtering

Filtering in image processing is a main function that is used to accomplish interpolation, noise reduction, and resampling etc. Most of the MRI images are affected by impulse noise, due to various factors like faulty switching and environmental conditions. Combination of mean and median filter for different pixel value is used to eliminate the noise in MRI images. Among all the type of filters, the simplest low pass filter is Mean filter. Here, Arithmetic mean filter is used to eliminate the noise. By using median filter, the image details at the edge are preserved while removing noise. It works by go through the picture pixel by pixel and replacing each with the median value of neighbouring pixel.

C. AHE - Adaptive Histogram Equalization

AHE (Adaptive Histogram Equalization) is a digital image processing technique which enhances the contrast of input image. It varies from normal HE by computing numerous histograms and each correlate to a specific region and utilizes them to reconstruct the brightness value of the image. Thus it enhances the local contrast of the input image and results in better quality for visualization.

D. CLAHE - Contrast Limited Adaptive Histogram Equalization

CLAHE is an advanced form of AHE. It prevents the over amplification of noise which results in AHE technique. CLAHE uses contrast amplification limiting procedure that is applied for each neighbouring pixel which then forms a transformation function in order to reduce the noise problem.

E. Parameters Calculated

- **Absolute Mean Brightness Error (AMBE)**
  \[ \text{AMBE} = |E(A) - E(B)| \]
  where \(E(A)\) and \(E(B)\) is the input mean and output mean brightness respectively.
  AMBE is lower which indicates better brightness preservation.

- **Contrast**
  It is the difference in luminance and/or color that makes an object distinguishable.
  \[ \text{Contrast} = \frac{(I_{\text{max}} - I_{\text{min}})}{(I_{\text{max}} + I_{\text{min}})} \]
  where \(I\) is an output image.

- **Mean-Squared Error (MSE)**
  \[ \text{err} = \text{immse}(A, B) \]
  where \(A\) and \(B\) are arrays of any dimension which should be of the same size and class.

- **Peak Signal to Noise Ratio (PSNR)**

  If PSNR is higher, the quality of the resultant image (compressed or reconstructed) is better.

F. Flow Diagram

![Flow Diagram](Image)

G. SOFTWARE TOOL USED

MATLAB (matrix laboratory) Version: 8.1.0.604(R2013a) is used here because of the following advantages.
- Used to de-noise and enhance the medical MRI image
- It saves processing time
- Improves the accuracy of MRI image for easy diagnosis

H. Algorithm for AHE

Step 1: Read the input noise image.
Step 2: Apply mean and median filter
\[ f(a,b) = \frac{1}{mn} \sum_{(s,t) \in S_{ab}} g(s,t) \]
\[ f(a,b) = \text{median}_{(s,t) \in S_{ab}} \{ g(s,t) \} \]
Step 3: Find the frequency counts for each pixel value.
Step 4: Determine the probability of each occurrence using probability function.
\[ \text{probf(value)} = \text{freq(value)} / \text{numofpixels} \]
Step 5: Calculate cumulative distribution probability for each pixel value.
\[ \text{probc}(i) = \text{sum} / \text{numofpixels} \]
Step 6: the enhanced image.

I. Flowchart

![Flowchart](Image)
J. Algorithm for CLAHE
Step 1: Read the input image.
Step 2: Apply mean and median filter.
\[ f(a,b) = \frac{1}{mn} \sum_{(s,t) \in S_{ab}} g(s,t) \]
\[ f(a,b) = \text{median}_{(s,t) \in S_{ab}} \{ g(s,t) \} \]
Step 3: Find the frequency counts for each pixel value.
Step 4: Determine the probability of each occurrence using probability function.
Step 5: Calculate cumulative distribution probability for each pixel value.
Step 6: Perform equalization mapping for all pixels.
\[ p_{val} = \text{img}(i,j) + 1 \]
\[ \text{ieq}(i,j) = \text{ieqhist}(p_{val}) - 1 \]
Step 7: Display the enhanced image.

K. Flowchart

IV. EXPERIMENTAL RESULTS
A. Input Image

B. Enhanced AHE Image

C. Enhanced CLAHE Image

D. Result Analysis
AHE:
- Contrast: 255.0000
- MSE: 12859.02
- PSNR: 55.169529
- Normalized Cross-Correlation: 2.323055
- Average Difference: -100.853745
- SSIM: 0.114144
- Max Difference: 37.0000

CLAHE:
- Contrast: 131.0000
- MSE: 4053.11308
- PSNR: 60.18372
- Normalized Cross-Correlation: 1.887236
- Average Difference: -61.98735
- SSIM: 0.227966
- Max Difference: 0.0000

V. CONCLUSION
The generalized form of adaptive contrast enhancement provides considerable flexibility, largely through the cumulating function. The enhancement using AHE technique produces good results but with the ultimate enhancement of minute background noise present in the image.
However, slow speed and the overenhancementofnoiseisproducedinrelativelyhomogeneousregionstwo problems of AHE. CLAHE overcomes this drawback since it reduces the overamplification of noise which results in AHE technique. In case of enhancement using CLAHE technique, since the contrast of the image is limited, a clear enhanced image without noise is obtained. The calculated parameters AMBE and contrast produces more efficient results for CLAHE than AHE technique. Hence for practice, CLAHE technique gives better and effective results when compared to AHE technique.

REFERENCES

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