Improving Quality of MR Images Caused by Ghosting and Noise

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Abstract: ***Magnetic resonance (MR) imaging is vulnerable to a variety of artifacts, which potentially degrade the perceived quality of MR Images and, consequently, may cause inefficient and/or inaccurate diagnosis. In general, these artifacts can be classified as structured or unstructured depending on the correlation of the artifact with the original content. In addition, the artifact can be white or colored depending on the flatness of the frequency spectrum of the artifact. In current MR imaging applications, design choices allow one type of artifact to be traded off with another type of artifact. Hence, to support these design choices, the relative impact of structured versus unstructured or colored versus white artifacts on perceived image quality needs to be known. To this end, we conducted two subjective experiments. Clinical application specialists rated the quality of MR images, distorted with different types of artifacts at various levels of degradation. The results demonstrate that unstructured artifacts deteriorate quality less than structured artifacts. White colored artifacts preserve quality better than white artifacts.***

Keywords: Mission - MR, perceived image quality, ghosting, noise, human visual system

1. Introduction

A powerful and widely used clinical imaging modality (MR) magnetic resonance is able to visualize internal structures of the human body [1] [2]. Compared to other imaging technologies, it has some unique advantages namely high spatial resolution and high soft tissue contrast. Ionizing radiation which does not support MR imaging. But it is safer for dynamic imaging, serial examination and screening in asymptomatic subjects. MR images are vulnerable to artifacts compared with other imaging modality, it degrades the quality of images. it impact the efficiency of the clinical specialists, it may affect their workflow and it may cause inefficient or inaccurate diagnosis [13] [14].non-ideal hardware characteristics, poor choice of scanning parameters, intrinsic tissue properties and their possible changes during scanning, assumptions underlying the data acquisition and image reconstruction process are the sources of artifacts in MR imaging [3]-[6]. Improvement of hardware and scanning protocols, scan parameter and pulse sequence optimization, and advanced post-processing algorithms are the correction procedure strategies used to minimize or eliminate these artifacts [7]-[10]. On the user point of view, the existing approaches achieve an optimal image rendering, reducing artifacts in MR imaging is not straightforward [11], [12].

Measuring the image quality in diagnostic performance is not trivial due to the complexity of the human visual system. The errors made in the diagnostic analysis rather than on rating the quality of an image without a direct detection task evaluated with an help of literature studies. ROC (receiver operating characteristics) method , in which images are detected to classify the patients as positive or negative according to an specific disease. The detection task is measured by an ROC: large variety of image contrasts are produced by an MR imaging with an large variety of clinical questions which is linked with an wide variety of an relevant image patterns. The performance of an diagnostic questions are in research of medical imaging [40]-[42]. Artifacts are divided into structured and unstructured artifacts. Hence unstructured artifact is defined as an random noise, and structured artifact is referred as an coherent artifact, which represents the scanning report of an object. (i.e) anisotropy of spectral content of local structure.

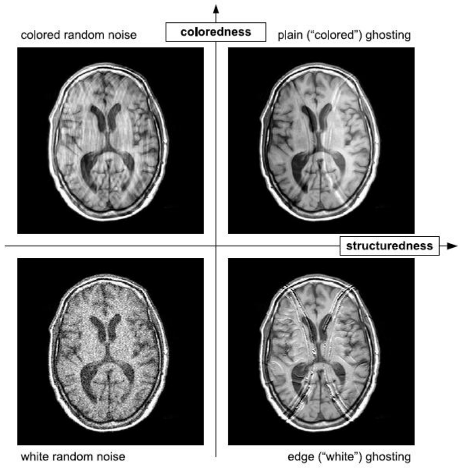

Figure 1: Four types of artifacts in MR image

The illustration of the four types of an artifacts of an exemplary MR image are of high practical relevance. The white random noise is omnipresent in MR imaging. Plain or colored ghosting are occurs during the periodic disturbance in MR data acquisition, which has various frequency than basic acquisition. Echo-planar imaging (EPI) sequence are occurred with an real-world edge ghosting. The horizontal axis denotes the structured-ness of the artifact: the two left quadrants refers random noise (i.e) unstructured artifacts, and the two right quadrants refers ghosting (i.e) structured artifacts. The vertical axis denotes the colored-ness of the artifact: the two top quadrants refers colored artifacts and the two bottom quadrants refers white artifacts.

Illustration of four types of artifacts are shown in fig. 1 the horizontal axis indicates the structured-ness of the artifact.

Two left quadrants refers random noise and two right quadrants refers ghosting. The vertical axis refers colored-ness of the artifact and two top and bottom quadrants indicates the white artifacts. In MR imaging, structured artifact is traded-off with unstructured artifact. In MR, trade-off stands for among many, the change of bandwidth and receiver, which has direct relationship to SNR (signal to noise ratio). SNR is improved by an smaller bandwidth but it causes spatial distortions; it allows faster imaging, but larger bandwidth reduces SNR. Trade-off gets optimize when one knows the relative impact of an artifacts on perceived image quality. Compares the artifacts of one type, different types of artifacts are not compared. Illustration of perceived image quality for an MR image is shown in fig. 2 which degraded by the same amount of energy in ghosting and white noise. The overall control for the occurrence of the artifacts, they get stimulated on top of the original MR image. Illustration of perceived image aim is to measure the relative impact of the artifacts.

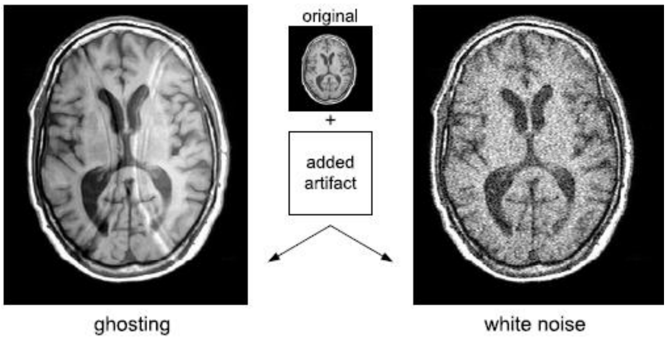

Figure 2: illustration of perceived image quality

In ghosting and white noise, the perceived image quality for an MR image is degraded by the same amount of an energy. MR image degraded by the same energy amount of ghosting had different perceived image quality compared to the same image degraded with white noise to the same energy. The relative annoyance of the artifacts are important to optimize trade-off in terms of perceived image quality. The four types of relative impact of artifacts: white noise, colored noise, edge ghosting and ghosting.

2. System Model

Vary the four types of artifacts in a controlled way, they simulated by means of different levels of energy, and added to the original content of an image. BEL (benchmark energy level) is the energy level. The size of an original image is M × N which means to height and width of the ghosting artifact. Then BEL is described as an:

$$BEL = \sum_{i=1}^{M} \sum_{j=1}^{N} I_g(i, j)^2 \qquad (1)$$

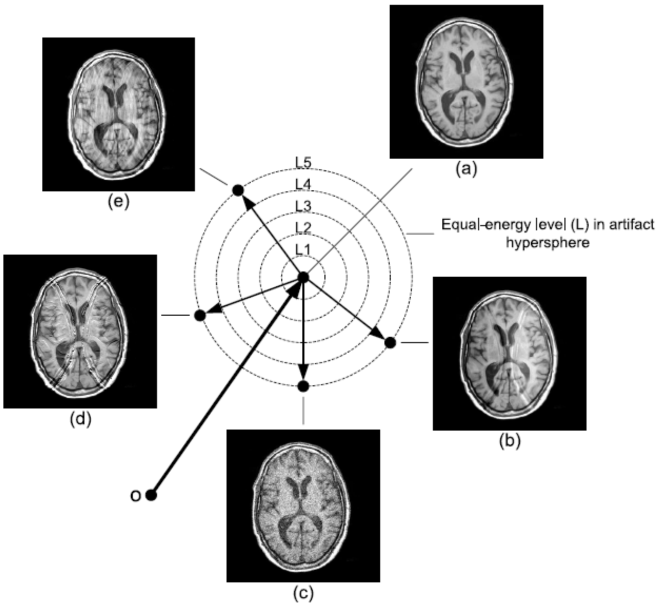

Figure 3: images with same energy level

The BEL is determined for an original image, it was defined by the ghosting artifact by means of energy for that specific content. In simulation process, ghosting artifact is always gets generated first. Images with same level of energy added to the original image constitute a space by means of hypersphere: original image, image with ghosting, image with white noise, image with edge ghosting and image with colored noise. Here different types of energy levels are get used such as L1, L2, L3, L4, L5.

Images with the same level of energy in the artifact are shown in fig. 3 which are added to the original image, it constitutes a hypershere in the image which includes original image, image with ghosting, image with the white noise, image with edge ghosting and image with the colored noise. In this experiment, it consists of an different types of energy levels such L1, L2, L3, L4, L5 are used to select the original image from an MR image. The BEL level is successively reduced to 20% based on the BEL determined for ghosting and the other levels of energy are used to reduce the BEL. The results for levels of energy is defined as: 0.8 × BEL for L4, 0.6 × BEL for L3, 0.4 ×BEL for L2 and 0.2 × BEL for L1.

Here the artifacts are applied only to the area of anatomical object wherein practice they extent to the whole image area. A binary mask MI is applied intentionally to get an viewer's attention for that object, rather than the presence of an artifact are deduced. The artifacts are simulated to ensure high realism. Few experts are judged that the degree of simulation for an realism was subject to serutiny.

3. Modules

A. Ghosting

In MR image, illustration of ghosting is consists of two new images illustrated from the original image. The first one is clinical object represented by an binary MI and the second one, in level L5 version of the original image have 20% intensity while simulating artifacts. The original content of image L1 is shifted with negative and positive intensity values once to the left and right. The distance of the shifting is constant and its width is defined as 1/3 of image. Here this distance 1/3 is selected to form substantial overlap, the procedure of the whole operation resulted in low-intensity image, here clinical object gets doubled.

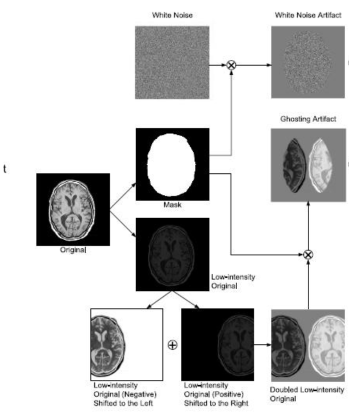

Figure 3: Simulation of ghosting and white noise

The ghosting artifact image is published using pixel-by-pixel multiplication with MI. in energy level L5, original image is added by an ghosting artifacts yields test stimulus. Illustration of the simulation of ghosting and white noise is shown in fig. 4, in practice they often extent to the whole image area of an original MR image. Here we obtained threshold from the original image at the level of 5% to the maximal intensity. The original image contains mask and low intensity original which will added with white noise artifact and ghosting artifact to form white noise and ghosting stimulus at BEL. And finally adds with negative and positive low intensity original to get doubled low intensity original.

B. White Nose

Illustration of white noise also based on two new images: 1) MI (the binary mask image) and 2) an image with flat frequency spectrum consists of white gaussian noise has same size as an original image. The white noise artifact image too generated by an multiplied pixel-by-pixel. Total energy results by an white noise artifact was scaled and it is equal to BEL.

C. Edge Ghosting

Edge ghosting is similar as an ghosting, the original content is shifted with respect to an gradient image. Edge ghosting based on two new images such as 1) binary mask image (MI) and 2) gradient image (GI). Then it is calculated as an:

$$GI(i,j) = |I(i,j+1) - I(i,j)|,\ j \in [1, N-1] \qquad (2)$$

With respect to the original content, GI is shifted to the left and to the right. Then distance of this shift kept constant of width of the image. The clinical object gets doubled, and new GI introduced. Ieg which means to so-called edge ghosting artifact image is gets generated by an pixel by pixel multiplication with the help of mask image. Then the Ieg's intensity of the edge ghosting artifact image was scaled which results its total energy is equal to BEL. The original image I is added Ieg to yield test stimulus at the energy level L5 distorted with edge ghosting. Illustration of simulation of edge ghosting and colored noise is shown in fig. 5, in which it consists of an 2D spectral noise is fourier transform with original image then it splitted into binary mask and gradient image.

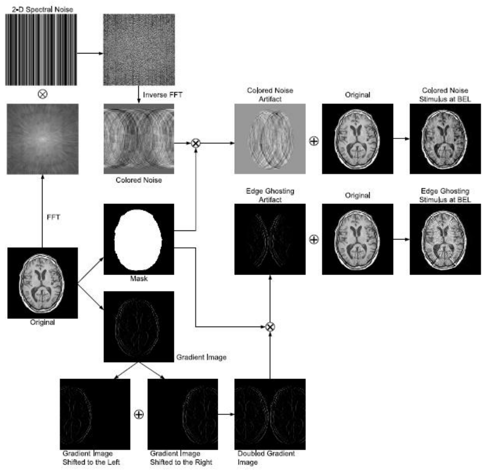

Figure 5: Simulation of edge ghosting and colored noise

Then 2D spectrum connected to inverse FFT (inverse fourier transformation) and colored noise is guassian with colored noise artifact and original to get colored noise stimulus at BEL. Then edge ghosting also combines with original image to get edge ghosting stimulus at BEL. Then finally we gets doubled gradient image by this procedure.

D. Colored Noise

The simulation of colored noise also based on two images such as: binary mask image MI and image with colored noise. In the vertical direction, the colored noise gets generated in an fourier transform domain with 2D spectrum (i.e) complex white gaussian with random values. In the horizontal direction, constant values gets multiplied. It supports inverse fourier transform which results that yielded colored noise that the power spectral density with noise pattern is similar to that of the MR image. The resulted pattern is not unstructured nut it is more unstructured than the plain ghosting. Colored noise artifact (Icn) is produced by an multiplied pixel by pixel with the help of mask image MI. the intensity of an Icn gets scaled then its total energy is equal to BEL.

4. Scope of Research

The aim is to measure the four types of the artifacts which were applied at the same energy level in the distortion affecting the perceived quality of an MR image. The source of MR images are high quality in the means of resolution, artifacts and signal-to-noise ratio.

A. Experiment 1

The main goal is to investigate the relative impact of an artifacts on the perceived quality of the MR images such as the artifacts are structured versus unstructured artifacts. It consists of two parts such as: images degraded with ghosting to white noise and images degraded with edge ghosting to colored noise. Here we uses three original MR images which are two brains and one liver. Brain-1 consists of an: T1-weighted brain, plain spin-echo, TR = 650, TE = 15, RF excitation = 69 degrees, 2 signals averaged, SENSE-head-8 coil, and nominal voxel size = $0.72^{*}0.72^{*}5$mm. the brain-2 consists of an: T@-weighted brain, TR = 4877, TE = 100, 3 signals averaged, echo train length 15, SENSE-head-8 coil and nominal voxel size = 0.47*0.47*5mmand the third image liver consists of an: field echo liver, TR = 117, TE = 4.6, RF excitation = 80 degrees, 2 signals averaged, SENSE-torso-XL coil and nominal voxel size = 1.3*1.3*5mm.

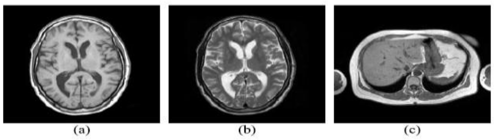

Figure 6: Source Images

Source images are shown in fig.6 which referred to (a) brain-1, (b) brain-2 and (c) liver. Here images are distorted with ghosting with energy level BEL and simultaneously edge ghosting, white and colored noise are applied with the same energy level. Each artifact results with an factors such as 4/5, 3/5, 2/5,1/5 with an help of ghosting edge ghosting colored and white noise with added energy.

B. Experiment 2

The aim is to reduce fatigue effects and to extent the findings of an above experiment for a larger diversity, two energy level is used to limit the total amount of an time. Here we used 5 additional MR source images compared with an above experiment.

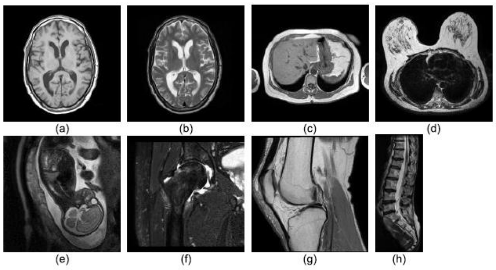

Figure 7: Source MR images

Source MR images are shown in fig.7 consists of an brain-1, brain-2, liver, breast, fetus, hip, knee and spine. Already we have the details of an three sources of an MR images, Breast consists of an T2-weighted mammo, TR = 6107, TE = 120, 2 signals averaged, echo train length 25, 4-elements SENSE-body coil, and nominal voxel size = 0.74*0.74*3mm and the fetus consists of an proton-density-weighted single-shot image, TE = 140, 5-elements SENSE-cardiac coil, and nominal voxel size = 0.9*0.9*4mm and an hip consists of an T2-weighted coronal hip with SPAIR fat-suppression, TR = 2760, TE = 30, 2 signals averaged, echo train length 20, 4-elements SENSE-body coil, and nominal voxel size = 0.31*0.31*3.5mm and the knee consists of an proton-density-weighted image, TR = 5000, TE = 30.2 signals averaged, echo train length 11, 8-elements SENSE-knee coil, and nominal voxel size = 0.3*0.3*2.5mm and spine consists of an T2-weighted sagittal spine, TR = 3255, TE = 120, 6 signals averaged, echo trai length 22, 5-elements SENSE-spine coil, and nominal voxel size = 0.52*0.52*4mm.

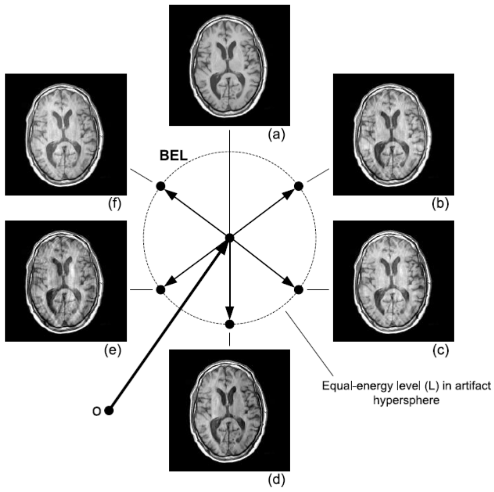

Figure 8: The original image

The same original image is shown in fig. 8 at the same energy level BEL, degraded by colored noise generated differently using randomization procedure which is five times resulted in five different stimuli. It is judged that perceived quality of an image is different. The procedure includes perceived quality using 2 four different versions of colored noise. It consists of an conditions such as low surface reflectance and approximately constant ambient light. The viewing distance achieves approximately 60 cm. here images are not allowed to get adjustment.

5. Experimental Results

For the scoring of ghosting and white noise, one subject gets excluded and remaining scores gets rejected. For the scoring of edge ghosting and colored noise, two subjects were excluded and again 2 gets rejected in an experiment 1. In an experiment 2 as usual one subject gets excluded and 27 gets removed from an additional outliers.

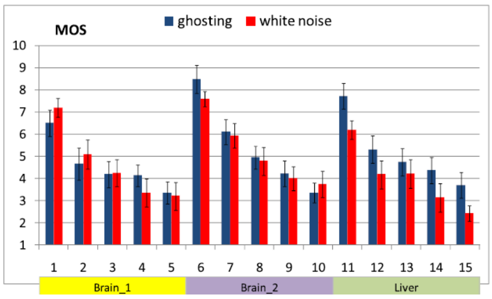

Figure 10: (a) image degraded with ghosting and white noise

The MOS and their error bars are shown in fig.10 (a) in which images degraded with ghosting and white noise affects overall quality trends of the distortion level and image content. The image source liver, in which white noise id added results in lower image quality than the added ghosting. The above consistency is not in two brain image. for comparison, the quality of images degraded by ghosting is compared with an image degraded by an white noise.

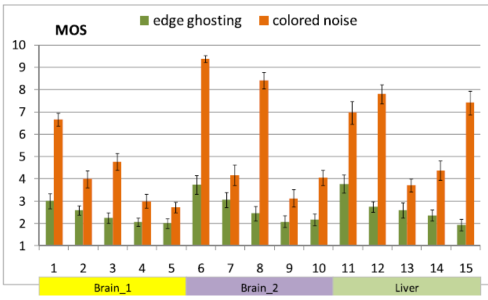

Figure 10: (b) image degraded with edge ghosting and colored noise

Images degraded along with edge ghosting and colored noise is shown in fig. 10 (b) in which the quality of image degraded by an colored noise is higher than the quality of image degraded by an edge ghosting. When the signal changes from the unstructured colored noise to structured edge ghosting largely reduces the perceived quality of an image. The four types of artifacts are added to the source image, the quality of perceived image gets decreases with image distortion. In colored noise, the resulting quality may jumps up and down in the distortion energy level.

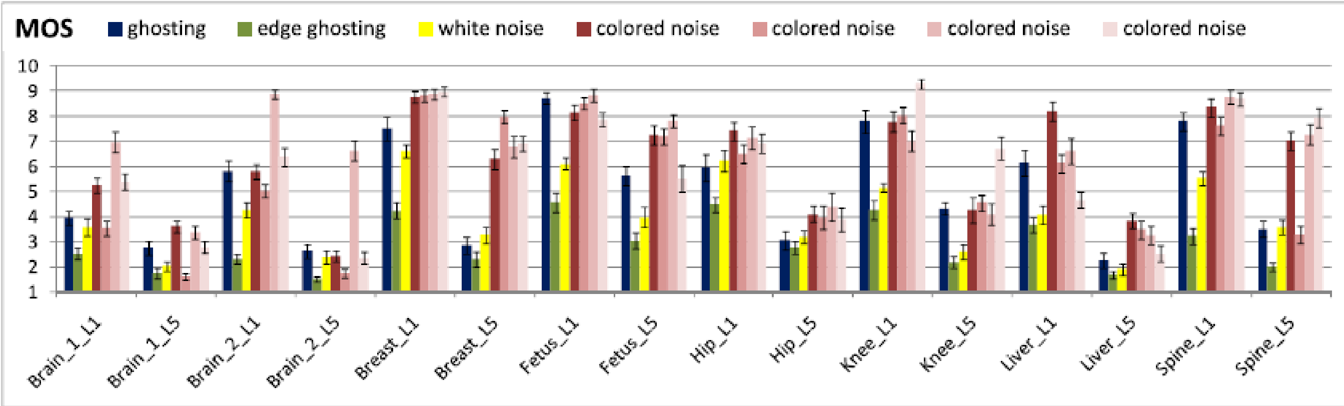

Figure 11: MOS results from an image quality from Exp 1

The MOS resulting from the image quality assessment is shown in fig. 11 which shows that the horizontal axis referred to an 16 sets of stimuli which includes 8 source images and 2 distortion levels, each set response to 7 distorted images: one for ghosting and another one for edge ghosting and one for white noise and finally 4 versions of colored noise. For each case the distortion is applied with an same energy level, and the error bars indicates 95% interval.

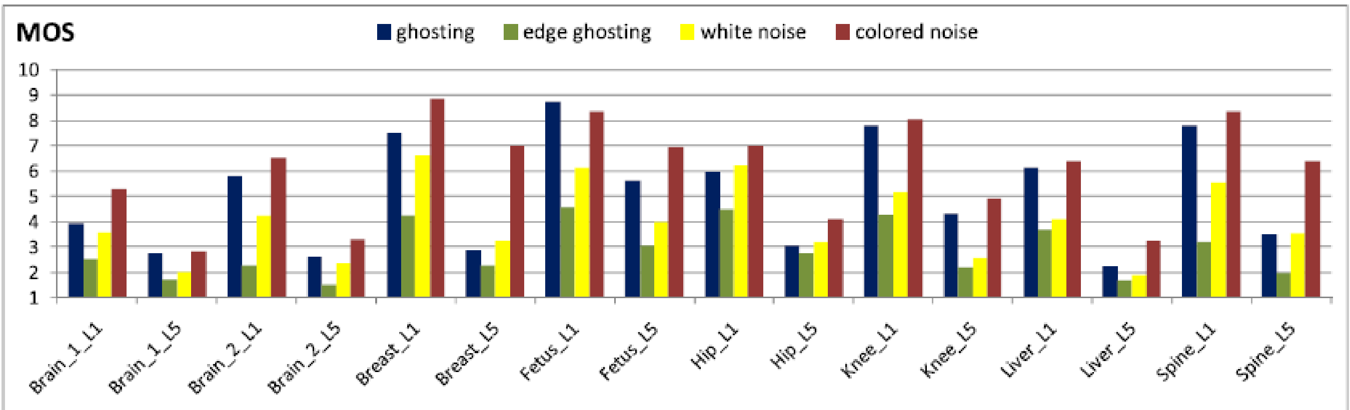

Figure 12: MOS results from image quality from Exp 2

The MOS results from an image quality is shown in fig. 12 in which MOS values of the stimuli degraded with colored noise are averaged for an source image with given energy level. Here the horizontal axis refers 16 sets of stimuli and includes 8 image sources and 2 distortion levels. Each set consists of an 4 distortion versions consists of ghosting, edge ghosting, white and colored noise at the same energy. It consists of an general trends; 1) edge ghosting results lowest image quality at the same energy level, 2) ghosting produces higher image quality than white noise, 3) for ghosting, edge ghosting colored and white noise, the perceived quality at low energy level is higher than at high energy level.

6. Conclusion

The four types of artifacts are occurs in MR images to impact perceived image quality. In MR images, types of artifacts at different levels of energy are assessed and affected different contents. In a given artifact the energy in the frequency spectrum is good to predict perceived quality of an image. Where colored noise may have a bigger impact on quality than the energy using randomization procedure. The artifacts Impact are strongly depends on the content of the MR image . we concludes that the unstructured artifacts deteriorate less quality than the structured artifacts and colored artifacts deteriorate less quality than the white artifacts. And also we found that the energy of unstructured artifact increases its factor to be as annoying in perceived quality as structured artifacts. Similarly the energy of colored artifacts are doubled to become as annoying as white artifacts. It provides new insights in the image quality and the findings are ready to embedded in the real-world MR imaging system.

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