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Review of medical image quality assessment

Li Sze Chow*, Raveendran Paramesran

Department of Electrical, Faculty of Engineering, University of Malaya, Lembah Pantai, 50603 Kuala Lumpur, Malaysia

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ABSTRACT

Image Quality Assessment (IQA) plays an important role in assessing any new hardware, software, image acquisition techniques, image reconstruction or post-processing algorithms, etc. In the past decade, there have been various IQA methods designed to evaluate natural images. Some were used for the medical images but the use was limited. This paper reviews the recent advancement on IQA for medical images, mainly for Magnetic Resonance Imaging (MRI), Computed Tomography (CT), and ultrasonic imaging. Thus far, there is no gold standard of IQA for medical images due to various difficulties in designing a suitable IQA for medical images, and there are many different image characteristics and contents across various imaging modalities. No reference-IQA (NR-IQA) is recommended for assessing medical images because there is no perfect reference image in the real world medical imaging. We will discuss and comment on some useful and interesting IQA methods, and then suggest several important factors to be considered in designing a new IQA method for medical images. There is still great potential for research in this area.

Contents

1. Introduction

Medical imaging is an important branch of medicine. It is especially useful in assisting diagnosis and treatment. Among the most common imaging modalities are Magnetic Resonance Imaging (MRI), Computed Tomography (CT), ultrasonic imaging, X-ray, nuclear magnetic imaging with Single Photon Emission Computed Tomography (SPECT) and Positron Emission Tomography (PET) [1]. Each of them has its own specific features and each is chosen according to the requirement of image types, physical and/or physiological study, patient's condition and availability. There are a lot of researches conducted to improve the quality of the medical images, either during acquisition or post-processing. The majority of the researches and development in medical imaging aim to speed up the acquisition time and/or improve the image signal-to-noise ratio (SNR). Therefore, there is a need for a good standard of Image

* Corresponding author. Tel.: +60 122748362.
E-mail addresses: lschow@um.edu.my, lisze.chow@gmail.com (L.S. Chow).

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Quality Assessment (IQA) to assess any newly developed hardware, software, higher field strength (in MRI) or radiation (in CT, X-ray or PET), image reconstruction techniques and image processing algorithm, etc. In the past few decades, there has been a huge advancement in the research and development of MRI compared to other imaging modalities. Naturally, the majority of the published IQA studies on medical images were performed on MRI. Therefore, we would also focus this review more on MRI.

There are two paramount problems in the IQA of medical images: the measure of image quality is not a reliable measure of diagnostic accuracy and it does not indicate any abnormality in the scanned areas. Usually a specific imaging technique is used to acquire the signal or image of a single focal lesion, but it may not have the best image quality overall; Yet, it is still serving its purpose and is considered good enough for a specific diagnosis. In other words, IQA is not necessarily equal to diagnostic quality assessment [2]. Nevertheless, radiologists and medical consultants would prefer high quality images for accurate diagnosis. A high quality image will increase the confidence in diagnosing and subsequently lead to the right treatment.

There are various image artifacts in medical images that are not seen in natural images. The artifacts can generally be categorized as hardware-related and human-related artifacts. The hardware-related artifacts are related to the technology of the imaging system. For example, in MRI, it could be due to B_0 field inhomogeneity, RF noise or irregularities, chemical shift, ghosting, electromagnetic interference, etc [3]. The common artifacts in CT include beam hardening, scattering, pseudo enhancement, cone beam, helical, Zebra, ring, and metal artifacts [4]. In ultrasound, there are grayscale and Doppler ultrasound artifacts [5]. Refer to Figs. 1–3 for some examples of artifacts in MRI, CT and ultrasound respectively. There were many researches conducted to improve the imaging modality. Subsequently, there are various proposed quality assurance (QA) protocols and methodologies to test machine-related artifacts [6,7]. The main human-related artifact is motion of the scanned subjects, which leads to blurred images. The majority of the patients find it difficult to keep still during a long period of scanning. Hence, many researches were conducted to reduce the imaging time without compromising on image quality. There are other typical artifacts in a particular imaging modality. For example, in MRI, Gibbs ringing artifacts are seen if there is insufficient acquisition matrix, chemical shift artifacts due to the different Larmor frequency of fat and water, susceptibility artifacts due to the variations in the magnetic field strength at tissues with different magnetic susceptibilities; wrap-around artifacts, partial volume artifacts, zebra stripes, Radio Frequency (RF) flow, flowing spin artifacts, zipper artifacts, cross-excitation, shading artifacts, etc. [8] Patients with metallic orthopedic implant would also produce artifacts on the scanned images, in both MRI and CT [9]. However, ultrasound is not limited by the metallic artifacts [10]. The various types of artifacts in medical images could impinge on the effectiveness of the state-of-the-art NR-IQA designed for natural images. Therefore, modification of the natural image NR-IQA model is recommended for a more accurate IQA on medical images.

IQA is divided into two categories: (i) subjective assessment, which is judged by human beings, and (ii) objective assessment, which is computed with mathematical algorithms [11]. The objective assessment can be further divided into three categories: (i) full reference (FR-IQA), where there is a perfect reference image for comparison with the test image; (ii) reduced reference (RR-IQA),

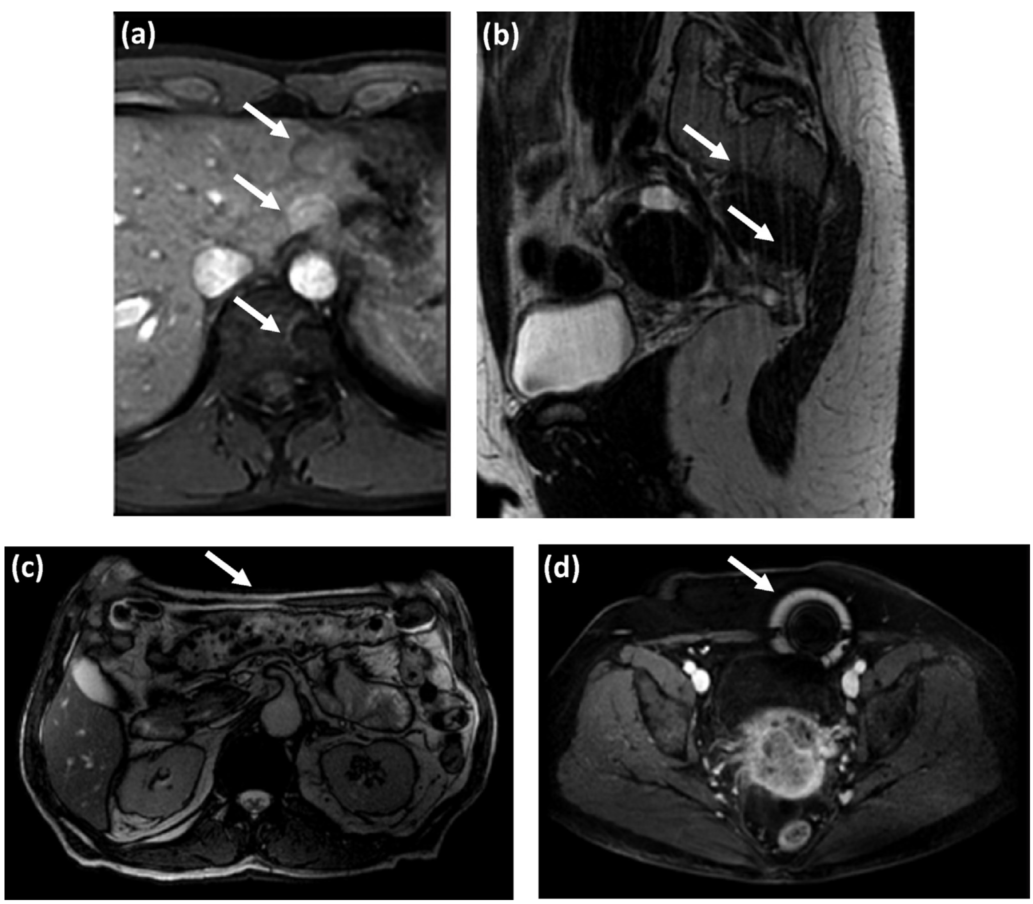

Fig. 1. Examples of artifacts in MR images [3]: (a) ghosting artifact due to aortal pulsation, (b) motion artifact caused by breathing, (c) chemical shift artifacts, (d) artifacts due to metallic surgical clip implant.