Representation Techniques for 4-Dimensional MR Images

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ABSTRACT

Metabolic analysis of biological tissues, the interventional radiology in MRT (Magnetic Resonance Treatment) and for clinical diagnoses, representation of 4-Dimensional (4D) structural information (x,y,z,t) of biological tissues is required. This paper discusses image representation techniques for those 4D MR Images. We have proposed an image reconstruction method for ultra-fast 3D MRI. It is based on image interpolation and prediction of un-acquired pictorial data in both of the real and the k-space (the acquisition domain in MRI). A 4D MR image is reconstructed from only two 3D MR images and acquired a few echo signals that are optimized by prediction of the tissue motion. This prediction can be done by the phase of acquired echo signal is proportioned to the tissue motion. On the other hand, reconstructed 4D MR images are represented as a 3D-movie by using computer graphics techniques. Rendered tissue surfaces and/or ROIs are displayed on a CRT monitor. It is represented in an arbitrary plane and/or rendered surface with their motion. As examples of the proposed representation techniques, the finger and the lung motion of healthy volunteers are demonstrated.

Keywords: 3D MRI, 4D medical image, Image Processing, Image representation

1. INTRODUCTION

Medical imaging and medical image processing by MRI, XCT, US and others equipments are extremely important in clinical diagnosis and interventional Radiology (IVR), diagnostic imaging of geometrical and functional characteristics of tissues. In recent years, some functional imaging for metabolic changes and blood flow are actively studied. On the other hand, 3D image processing for clinical diagnosis and IVR are very actively studying now. The purpose of these studies is to use these image information, or quantitative analysis of extracted features and 3D display of surface or volume rendered images are terribly useful in those clinical diagnosis and IVR. This paper describes a new direction of the noninvasive functional MR imaging. A proposed ultra-fast MRI can provide 3D geometrical motion (x,y,z,t) of the tissue. From experimental results of phantom (deformation of a cubic water phantom) and human studies (finger motion and lung motion), quantitative representation and display techniques of 4D geometrical information are also discussed.

2. MATERIALS AND METHODS

2.1 An Ultra-fast 3D MR imaging

To acquire 4D image information (x,y,z,t), it need to develop an ultra-fast 3D MRI. Figure 1 shows basic concept[1] of a proposed 3D MRI, it is an example of 3D MRI for six images. Those six images are sequentially acquired in time domain. The first and the last imaging (the 6th imaging) are acquired under full or half phase encoding by using 3D-GRE (gradient recalled echo), 3D-spiral MRI and other 3D MRI, and reconstructed with 128 by 128 by 128 voxels. For the other four images, only a few voxels are needed to acquire for evaluation of the phase change of the magnetized spins. For those imaging, a new MRI technique is developed which is base on the 3D-spiral MRI with a dynamic keyhole technique. Those techniques are well known, the Spiral MRI[2] is as one of the fast-MRI, and the keyhole technique[3,4] to reduce the number of acquisition. In the proposed MRI, sampling of echo signals in k-space, trajectory of spiral scan is changed in each imaging. In other word, the k-space trajectory is optimized by estimation of tissue motion. In the proposed MR imaging, some constructions are required. These are --- subjects are not deforming drastically, and motion of the imaging subjects is limited within the FOV area and can be estimated.

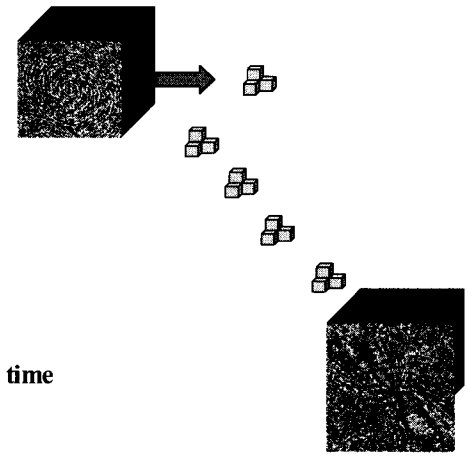


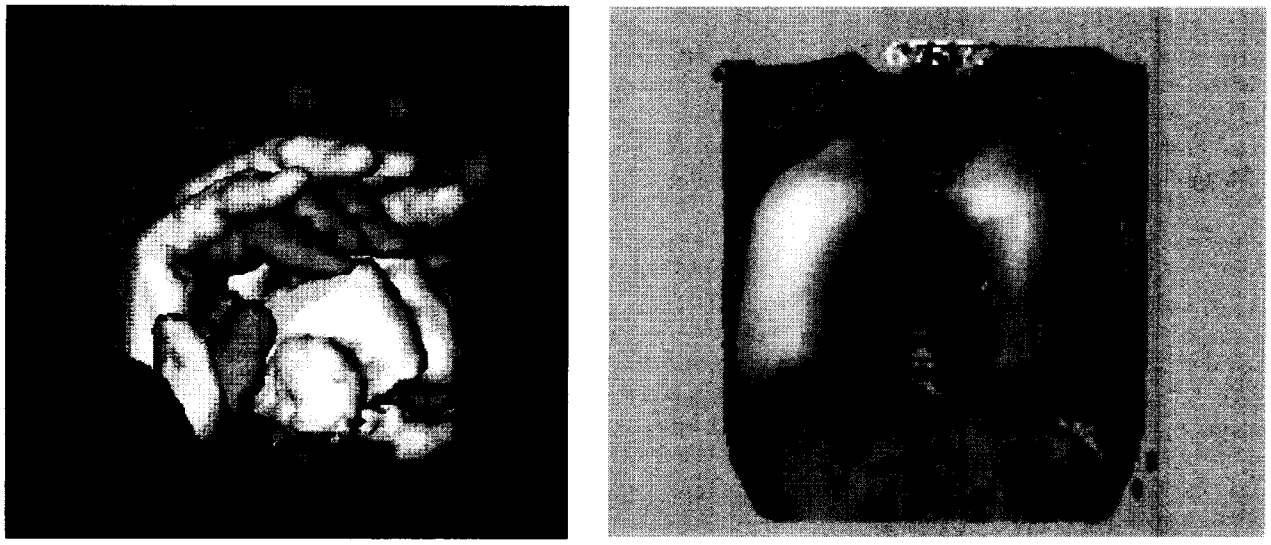
Fig.1 A proposed ultra-fast 3D MR imaging

2.1 Estimation and interpolation of un-acquired MR data

The keyhole technique in MRI interpolates unacquired data from acquired data. In the proposed MRI, unacquired data from 2nd to 5th imaging is estimated and interpolated in both of the k and the real space from image data acquired at the first and the last 3D imaging.

3. RESULTS

Some phantom and human studies had been examined for evaluation of the proposed MRI and to develop some image processing and representation techniques. Figure 2 shows two examples of 4D image representation of MR images. One of the most important role of the 4D image representation is how to show quantitatively geometrical motion of the tissue. A volume rendered image of human finger (a) is superimposed four 3D MR images acquired with finger gripping motion in different timing. It also can represent some motion characteristics in graphically and/or numerically such as coordinates of the finger joints and their displacement. Another example, human lung motion (b), can show surface rendered lung with inner and outer surface of the body. From this result, volume of the lung and displacement in each point are calculated. Unacquired image data is interpolated by the results of estimation of geometrical characteristics of the tissue.



(a) Finger motion (b) Lung motion

Fig.2 Examples of 4D image representation

4. DISCUSSIONS

4.1 Ultra-fast MR imaging

For decreasing the acquisition time, new MRI techniques such as the parallel imaging[5,6], the single-shot MRI[7] including EPI (Echo Planar Imaging)[8] are actively studying now. In this paper, a new 3D MRI based on a new dynamic keyhole technique is discussed. It is very important to calculate the optimum trajectory of data sampling in the k space from the estimation of the tissue motion, and required put some constraints for increasing the accuracy in imaging. The data acquisition will be much faster if this MRI technique can be done with parallel data acquisition and processing.

4.2 Representation techniques for 4D MR images

One of the major roles of the image representation of 4D geometrical information (x,y,z,t) is to enhance the tissue function extracted from the irregularity of the tissue motion. Therefore, image processing is how to extract correctly the tissue structure and show its 3D motion. In other words, to detection and extraction of contour lines and surfaces of the tissue is the most important image processing. On the other hand, quantitative analysis is also very useful for the clinical diagnosis. In this paper, displacement, volume and other characteristics of tissue motion are represented with a 4D image. These numerical values are IVR (Interventional Radiology) such as MRT (Magnetic resonance Treatment), which can be used for some treatments such as radiotherapy, chemotherapy and surgical operation by using the fiberscope in the MR magnet, because 3D coordinate of the tissue is very important for the treatment.

5. CONCLUSION

This paper proposed and discussed an ultra-fast MRI that is a 3D spiral MRI with dynamic keyhole interpolation technique and basic concepts for 4-dimensional image processing and representation techniques. From the represented features in the reconstructed 4D MRI, some geometrical characteristics especially the tissue motion is enhanced. Proposed representation techniques are applicable to the noninvasive clinical studies, especially, some functional analysis of the tissues from 3D motion irregularity.

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