MRI mimicry of CT

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Abstract

The MRI UTE sequence gives the ability to visualize a signal from bone tissue. The sequence was recently installed on a Phillips Panorama 1T open MR scanner. Through a phantom-based study we have found a set of acquisition parameters that should optimize the contrast between bone and muscle tissue.

Using a Bayesian classifier with Markov Random Fields we segmented the UTE images from a patient into bone and soft tissue regions in order to produce a bulk image that mimics that of a CT.

Introduction

Radiation therapy (RT) is one of the common ways to treat a variety of cancers. Today, all RT planning is based on CT images (Figure 1), because it is geometrically accurate and the fact that CT can be used to calculate the radiation energy deposition in the body.

MRI-based RT would be advantageous in many aspects. The superior soft-tissue contrast over CT allows for better delineation of tumour and organs at risk[1]. However, conventional MRI sequences (Figure 2) are not able to visualize bone, which makes it difficult to translate an MRI into a map of electron densities used for dose calculations.

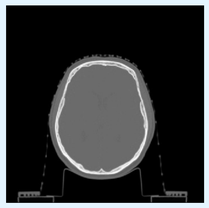


Figure 1: *CT image, transaxial slice of human head*

Figure 2: *MR T2 weighted image, transaxial slice of human head*

Ultrashort Echo Time (UTE) sequences can capture the signal from bone. The sequence was recently installed on the Philips Panorama 1T open MR system situated at the RT centre at Herlev Hospital. Several issues regarding this new sequence needed to be explored:

Which acquisition parameters should be used to optimize bone contrast?

Can bone be automatically segmented from UTE images ?

References

[1] R.C.Krempien et al., Open low-field magnetic resonance imaging in radiation therapy treatment planning, Int. J. Radiation Oncology Biol. Phys., Vol. 53, No. 5, pp. 1350–1360, 2002.

[2] M.D.Robson et al., Magnetic Resonance: An Introduction to Ultrashort TE (UTE) Imaging, J. Comput. Assist. Tomogr., 2003;27:825–846.

UTE Imaging

The bone signal is lost with conventional MRI sequences because the signal is decayed during the time spent to make the excitation, refocusing, build-up spatial gradients etc.

If the acquisition is placed *ultrashortly* after the excitation, a bone signal is recorded along with the signal from all other tissues (Figure 3, left)[2]. In order to make a distinction between bone and other tissues a popular approach is to acquired a second image shortly after the first (Figure 3, middle). Because bone decays much faster than other tissues it will appear bright on the subtraction image (Figure 3, right).

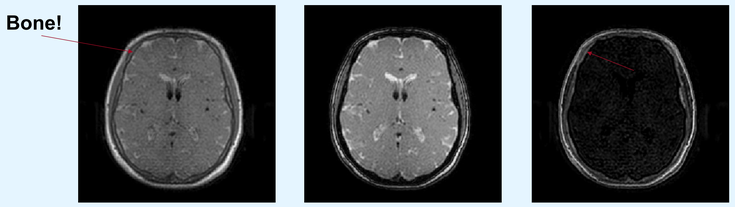


Figure 3: *MR UTE images, transaxial slice of human head.* ***Left:*** *Echo 1, 0.9 ms after excitation.* ***Middle:*** *Echo 2, 3.6 ms after the first.* ***Right:*** *Subtraction image.*

UTE imaging parameters: Being a new and relatively untested sequence, a study investigated which UTE acquisition parameter settings would be optimal for bone segmentation.

Method & Results: A cut-off bovine knee-joint phantom was imaged several times with varying parameters. A Contrast to Noise Ratio (CNR) between two manual annotated regions of muscle and bone tissue was calculated for each acquisition mode. The results are shown in Figure 4. Parameters that maximize the CNR are preferred.

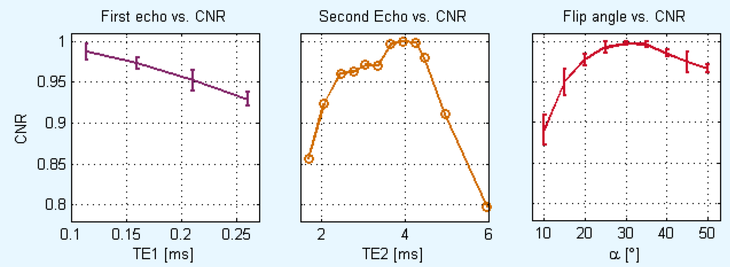


Figure 4: *Normalized CNR results.* ***Left:*** *The first echo time varied, average over 4 repetitions.* ***Middle:*** *The second echo time varied.* ***Right:*** *Varying flip angles, average over 3 repetitions.*

Conclusion on UTE imaging parameters

UTE images should be acquired with the **minimal first echo time**. The lower limit is due to hardware (coils). The **second echo time** should be ***~3.6 ms***, and the best choice for **flip angle** is approximately ***25°***.

Bone Classification

In order to mimic a CT image, the MRI needs to be classified into different tissues representing large differences in Hounsfield Units (HU). Each tissue is assigned a bulk value of either -1000 HU (air), 0 HU (water) or ~600 HU (or something similar high, bone).

Method: Segmentation is done with a voxel-driven approach based on the Bayes classifier and Markov Random Fields. Currently the classification is done using the voxel-intensity from both echoes, but the method can potentially be expanded to include other MRI sequences (for example a T2 weighted sequence).

The classifier training is currently done by manual labelling of four tissue types: Air, brain, bone & other soft-tissue (skin layer).

Results: The true CT and MRI mimic is shown in Figure 5.

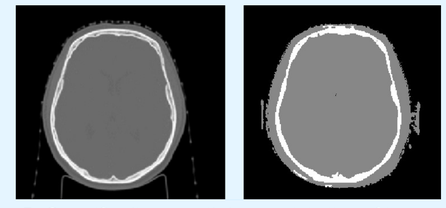
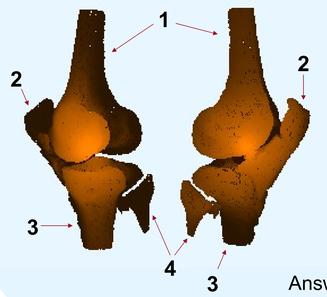


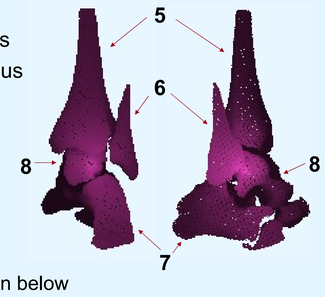
Figure 5: *Classification result, transaxial slice of human head.* ***Left:*** *The true CT.* ***Right:*** *The MR image that mimics CT.*

3D point clouds of the segmented bones from other UTE scans are shown below in order to inspect the classification result visually in the entire volume instead of just a slice-wise result.

Is the bone anatomy recognisable ? Which bones can be seen ?



a. Femur
b. Humerus
c. Calcaneus
d. Fibula
e. Ulna
f. Talus
g. Radius
h. Tibia
i. Patella



Answers are given below

Conclusion on bone classification

The UTE sequence demonstrated that bone segmentation is possible. Several issues remain to be addressed with the current approach. Especially how the method can be automated.

To further improve the results additional image information is needed. This could be extra MRI sequences or the inclusion of CT atlases.

Answers: 1a , 2i , 3h , 4d , 5h , 6d , 7c , 8f.