R wave peak detection using wavelet decomposition and multi-level thresholding for ECGs acquired in MR scanner

Manivannan Jayapalan[1], Bhargav Bhatt[2], and Vijikumar N[3]

[1]MR PSD & Applications, GE Healthcare, Bangalore, Karnataka, India, [2]MR Systems, GE Healthcare, Bangalore, Karnataka, India, [3]MR Applications, GE Healthcare, Bangalore, Karnataka, India

Introduction: Cardiac Magnetic Resonance Imaging (MRI) requires synchronization of electrocardiogram (ECG) signal with the acquisition. As the complete acquisition might not be acquired in one heart cycle, its successive acquisitions have to be accurately combined with the cardiac phase motion. Such requirements depends on a reliable detection of the R-wave of the ECG to guarantee that consecutive image data collections always start at the same point of the cardiac cycle. However the interaction of blood flow with static magnetic field, known as Magnetohydrodynamic (MHD) effect, introduces special kind of artifact in ECG which is known as MHD artifact or flow artifact. The effect of MHD is directly proportional the field strength and complicates the detection of R wave peak from ECG acquired during MR acquisition especially at higher field strengths. This work presents a method to remove noises and to identify R wave peaks which is contaminated with MHD artifact using multilevel wavelet decomposition and multi-level thresholding.

Method: In this method ECG were acquired from subject when they undergo a regular cardiac scan in a GE Signa 3T MRI Scanner (GE Healthcare, Milwaukee, WI, USA). A standard ECG waveform was recorded outside the MR room that is free from MHD effects for comparison. Before starting the scan, ECG was recorded that has only the impact of B0 field, not gradients. Various cardiac applications were scanned and recorded ECG at a sampling rate of 1 KHz. Complete workflow of the method discussed in this abstract and ECG recorded are shown in figure 1.

The ECG recorded during the pulse sequences was first preprocessed to remove the baseline drift and power line noise. Then they were decomposed into 8 frequency sub-bands using 'db4' wavelet. Most of the QRS energy lies in the 4–17 Hz band [1]. After reconstruction of the detail signals, the reference signal is obtained by averaging the details d6 and d7 resulting in a [3.91–15.63] Hz sub-band. This reference signal is treated with a two level thresholding process to get the R wave peaks. First level of thresholding is coarse, where the number of false positives is more. Second level of thresholding is fine and minimizes these false positives. These two thresholds values were derived based on the cumulative differentiated reference signal and the signal obtained after first level thresholding respectively.

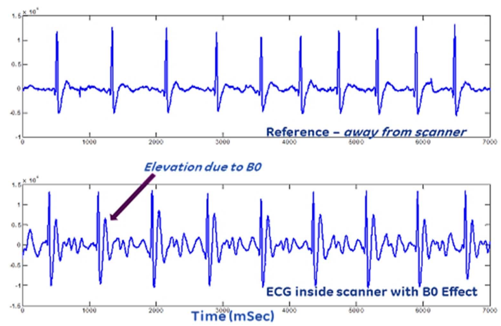

Figure 1.a Acquired ECG signal reference signal and one away from scanner

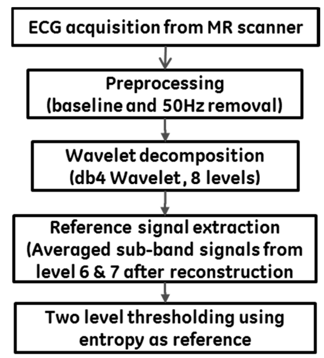

Fig 1.b Workflow of the method

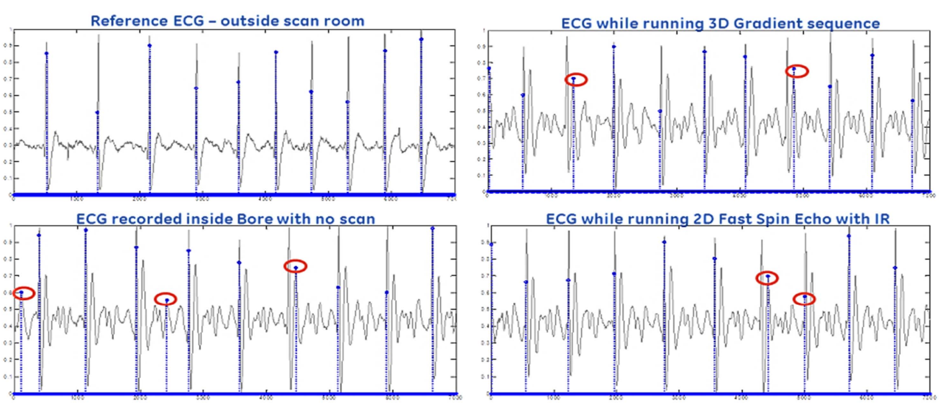

Figure 2. ECG signals along with the R peaks detected with the proposed method

Results & Discussion:

Figure 2 shows the ECGs processed using the proposed algorithm. For the sake of clarity in visualization, only 10 cardiac cycles were shown in fig 2, 100 cardiac cycles in each case were included for analysis. Algorithm is tested with the reference ECG acquired outside MRI scanner and ECG acquired from subject inside the scanner while scanning cardiac applications, Fast spin echo and gradient echo pulse sequence. As seen in fig 3a, gating becomes tedious with regular algorithm in terms of fixing the electrode and subject condition.

The proposed algorithm that applies threshold based on the reference signal obtained after wavelet decomposition worked well with ECG contaminated with MHD artifacts as shown in figure 2. Sensitivity [1] of the algorithm as described in fig 3.b is better for the cases considered here: reference ECG-98.33%, ECG with no scan- 95.36%, ECG during 3DGRE-93.21% and ECG during FSE –94.89%.

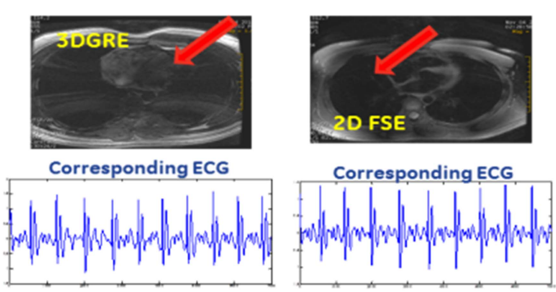

Figure 3a. Impact of MHD on image quality

$$Se = \frac{TP}{TP + FN}$$

Se *Algorithm sensitivity*
TP *True positive*
FN *False Negative*

Fig 3b QRS detection algorithm sensitivity

Conclusion: The results of this proposed algorithm shows that this could be used to detect R wave peaks for the ECGs acquired inside MRI. As the MR is evolving towards the high field strength scanner (7T), this would be beneficial as MHD effects will be high with higher field strengths.

Reference: [1]Abi-Abdallah,et.al., BioMed-ical Engineering OnLine, 5(1), 11. ISSN 1475-925X. (2006) [2] Bhargav et.al., IEEE TENCON, Singapore, 23-26 November 2009, pp.1-4.