

Smart QRS detection using wavelet transform for ECGs acquired inside MR scanner

Manivannan Jayapalan¹ and Bhargav Bhatt¹

¹MR Software and 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 identify R wave peaks which is contaminated with MHD artifact by smart thresholding using multilevel wavelet decomposition.

Method: In this method ECG were acquired from subject when they undergo the scan in a GE Signa 3T MRI Scanner (GE Medical Systems, Milwaukee, WI, USA). Two pulse sequences were played, one from fast spin echo family and other from gradient echo family. Also took a standard ECG waveform obtained outside the MR room that is free from MHD effects for comparison. ECG data were first preprocessed to remove the baseline drift and 50Hz noise. The contaminated ECG signals, sampled at 1200Hz were decomposed into 8 frequency sub-bands using 'db4' wavelet. For each level, detail signals were then reconstructed, using lowpass and high-pass reconstruction filters with up-sampling. 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 [3.5–14] Hz sub-band as shown in figure 1.a This reference ECG signal is then used to determine the R peaks. The reference ECG is then differentiated twice to get the cumulative differentiated signal in which the threshold is applied. To determine the desired threshold, entropy of the signal is used, higher the entropy, greater is the threshold as the profile would be uniform with less noise in this case. R wave peak is then obtained by applying this threshold on the reference ECG. The above workflow is given the figure 1.b

Results & Discussion:

Figure 2 shows the ECGs processed using the proposed algorithm. Algorithm is tested with a standard ECG acquired outside MRI scanner and ECG acquired from subject inside the scanner while scanning a Fast spin echo and gradient echo pulse sequence. Regular algorithm that includes simple threshold failed with ECG with MHD artifacts. The proposed algorithm that applies threshold based on the entropy of the reference signal obtained after wavelet decomposition worked well with ECG contaminated with MHD artifacts as shown in figure 2. Algorithm fails to detect peaks at two instants due to very high noise at that instants, however this is very low (<10%) when compared with other advantages. Marked in red color are the artifacts due to MHD effect.

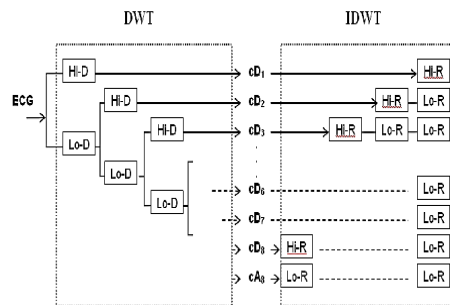


Figure 1.a Reference ECG extraction using wavelet transform

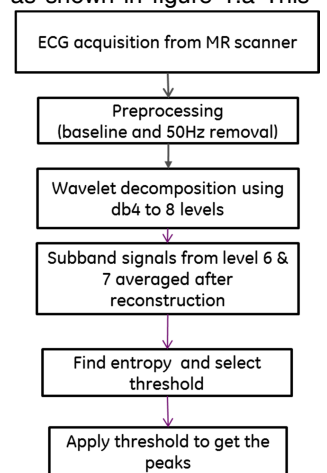


Figure 1.b Work Flow of proposed method

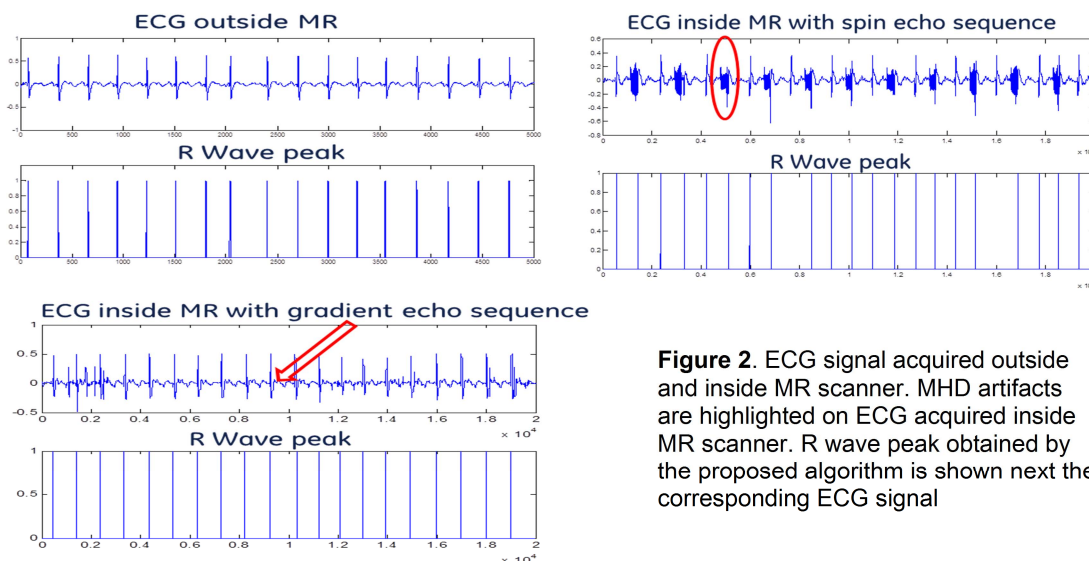


Figure 2. ECG signal acquired outside and inside MR scanner. MHD artifacts are highlighted on ECG acquired inside MR scanner. R wave peak obtained by the proposed algorithm is shown next the corresponding ECG signal

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.