Development of derivative based algorithm for the detection of QRS-complexes in Single lead Electrocardiogram using FCM

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ABSTRACT
FCM algorithm is used to divide the ECG signal into QRS and non-QRS region. This paper presents a simple technique for automatic detection of cardiac beat (QRS-complex) in Electrocardiogram (ECG) using Fuzzy C-Means (FCM) clustering algorithm. The power line interference and baseline wander present in the ECG signal is removed using digital filtering techniques. Absolute derivative of the filtered ECG signal is calculated to enhance the QRS-complexes in the ECG signal. Algorithm performance is validated using original single lead ECG recordings from the CSE ECG database. Detection rate of 98.32% with 1.68% of false negative (FN) and 0.08% of false positive (FP) has been achieved.

Keywords
ECG, QRS-complex, ECG detection, FCM.

1. INTRODUCTION
An Electrocardiogram (ECG) is a bioelectrical signal which has important correlation with mechanical activity of the heart. An Electrocardiogram (ECG) is one of the most widely used diagnostic tools for the assessment of various cardiac diseases. Most of the abnormality of the heart can be found out by looking at the various features of the ECG. In these days, computer based ECG analysis plays an important role in assisting physicians in the treatment of cardiac diseases. Significant amount of research has focused on the development of algorithms for the accurate diagnosis of cardiac diseases. Fig.1 shows a typical ECG signal. One of the most important ECG components is the QRS-complex, which is associated with electrical ventricular activation. QRS complex is the most striking waveform within the electrocardiogram. Once the locations of the QRS-complexes are demarcated, the locations of other components like P-wave, T-wave, ST-segment etc. can be easily found out. Many automatic QRS-detection algorithms have been developed and reported in literature. The overview of the various approaches is given in [1-4]. In this paper, a new approach using FCM algorithm is investigated in order to detect the position of the QRS-complexes in single lead ECG signal. The detection performance of the algorithm is validated using 50 single lead ECG of the CSE database.

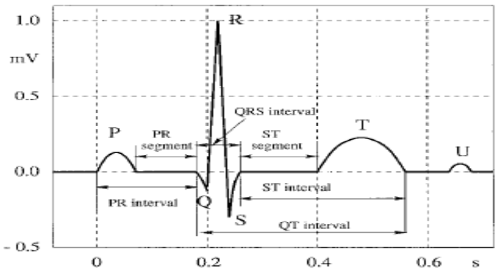

Fig. 1 Typical ECG Signal

2. FUZZY C-MEANS ALGORITHM
The fuzzy c-means algorithm was initially developed by Dunn [14] in 1973 and later generalized by Bezdek [15] in 1981. Fuzzy clustering plays an important role in solving problems in the areas of pattern recognition and fuzzy model identification. FCM is a method of clustering which allows one piece of data to belong to two or more clusters. Fuzzy c-means clustering (FCM) is also known as Fuzzy Isodata, is a clustering technique, which is different from hard k-means that employs hard partitioning. The main difference between traditional hard clustering and fuzzy clustering can be stated as follows. While in hard clustering an entity belongs only to one cluster, in fuzzy clustering entities are allowed to belong to more than one clusters with different degrees of membership. Usually, membership functions are defined based on a distance function such that membership degrees express proximities of entities to cluster centers. By choosing a suitable distance function different cluster shapes can be identified. It is the most popular objective function based clustering technique. The FCM employs fuzzy partitioning such that a data point can belong to many groups with different membership grades between 0 and 1. FCM is an iterative algorithm. The aim of the FCM is to find cluster centers that minimize a dissimilarity function. The steps for FCM clustering are as follows:

Step 1: Randomly initialize the membership matrix (u) to accommodate the introduction of fuzzy partitioning subject to the constraints in Eq. (1)

$$\sum_{i=1}^{p} u_{ij} = 1, \quad \forall\ j = 1,..n \qquad (1)$$

where, u_{ij} is between 0 and 1

p is the number of clusters

Step 2: Calculate the centroids (ci) by using the following equation:

$$c_i = \frac{\sum_{j=1}^{n} u_{ij}{}^{m} x_j}{\sum_{j=1}^{n} u_{ij}{}^{m}} \qquad (2)$$

where, c_i is the centroid of i^{th} cluster,
m is a weighting component and $m \in [1, \infty)$

Step 3: Compute dissimilarity between centroids and data points using dissimilarity function given in (3). Stop if its improvement over previous iteration is below a threshold

$$J(u, c_1, c_2, .., c_p) = \sum_{i=1}^{p} J_i = \sum_{i=1}^{p}\sum_{j=1}^{n} u_{ij}{}^{m}\, d_{ij}^{2} \qquad (3)$$

Where,

d_{ij} is the Euclidian distance between i^{th} centroid (c_i) and j^{th} data point.

Step 4: Compute a new (**u**) using the following equation and go to step 2.

$$u_{ij} = \frac{1}{\sum_{k=1}^{p}\left(\frac{d_{ij}}{d_{kj}}\right)^{2/(m-1)}} \qquad (4)$$

By iteratively updating the cluster centers and the membership grades for each data points, FCM iteratively moves the cluster centers to the correct location within a dataset. FCM does not insure that it converges to an optimal solution because cluster centers are initialized using U which is randomly initialized.

3. QRS DETECTION ALGORITHM

This section describes an algorithm for the detection of QRS-complexes in single lead ECG signal. Fig. 2 displays the result obtained at each step of the algorithm for certain record of the CSE database.

Step 1: A raw ECG signal of a subject is acquired. Fig.2 (a) shows raw ECG signal.

Step 2: Raw ECG signal is often contaminated by disturbances such as power line interference and baseline wander. The finite impulse response (FIR) notch filter proposed by Van Alste and Schilder [17] is used to remove baseline wander. Frequencies in the range 0-0.5Hz are removed to reduce the baseline drift. The filter proposed by Furno and Tompkins is used to remove 50Hz power line interference. Fig. 2(b) displays the filtered ECG signal after removal of power line interference and baseline wander.

Step 3: The absolute value of derivative of the ECG signal is used as an important discriminating feature because absolute derivative of the signal is much more in the QRS-region than in the region other than QRS as depicted in Fig. 2(c). The absolute derivative i.e. absolute value of the difference between two consecutive samples is calculated to enhance the signal in the region of QRS-complex. These absolute derivative values are then normalized to reduce the burden of the classifier to form the complicated decision boundary.

Step 4: The various steps of fuzzy c-means algorithm as described in section 2 are followed in order to find the two cluster centers namely the QRS-cluster center and the non-QRS-cluster center.

Step 5: After finding two cluster centers using FCM algorithm, the absolute derivative curve shown in Fig. 2 (c) is scanned. The membership of absolute derivative, at a given sampling instant, is found. An output of 1 is marked if a sample belongs to a QRS-cluster and 0 if it belongs to a non-QRS-cluster. Thus, a continuous train of 1's is obtained in the QRS-region and 0's is obtained in the non-QRS region.

Step 6: Continues train of 1's are picked and using their duration, average pulse duration of 1's is evaluated. Those trains of 1's, whose duration turns out to be more than a certain fraction of the average pulse duration are detected as QRS-complex and the other ones are discarded.

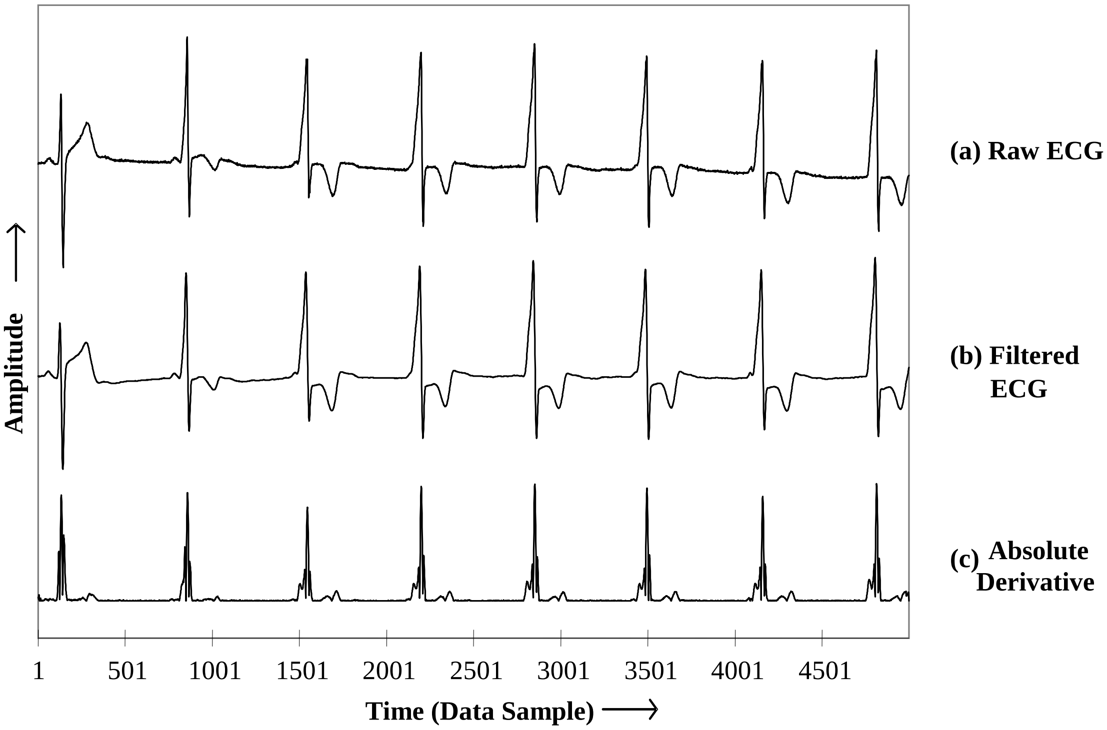

Fig. 2 Results obtained during each step of the algorithm

4. RESULTS

The performance of the proposed FCM based algorithm for QRS-detection is evaluated using 50, single lead ECG recordings from the dataset-3 of the CSE database [16]. Detection is said to be true positive (TP) if the algorithm correctly identifies the QRS-complex and it is said to be false negative (FN) if the algorithm fails to detect the QRS-complex. False positive (FP) detections are obtained if non-QRS-wave is detected as a QRS-complex. Detection rate (DR) of 98.32% is obtained with 0.08% percentage of false positive and 1.68%

percentage of false negative. Since the detection rate is found to be reasonably good the proposed simple statistical method gives a new direction in the area of ECG signal processing.

5. DISCUSSIONS

The following representative case demonstrates the effectiveness of the proposed FCM based algorithm for the detection of QRS-complexes.

Fig. 3 shows the ECG QRS detection in record MO1_085 where T-waves are prominent in nature. It is observed from fig. 3(c) that though the amplitude of T-wave is large but its absolute derivative is very small in comparison to that QRS region. This is because the T-wave though tall amplitude but are wider in nature. Hence the algorithm distinctly picked all the QRS complexes present in the ECG signal.

Fig.4. shows ECG QRS detection in record MO1_012 where it can be seen that though the P and T-waves are prominent but the absolute value of derivative in P and T-wave region are very small as compared to QRS-complex. Therefore, FCM algorithm has correctly identified all the QRS- complexes preset in the record.

Fig. 5 displays QRS detection in record MO1_065. Here the P wave is not prominent but the T-wave are quite tall in nature. Their absolute value of derivative is very small as depicted in fig 3. Hence these T-waves have rightly not picked as QRS complexes by the FCM algorithm.

The absolute values of derivative of second and ninth QRS complex are feeble in nature as compared to the other QRS complexes as seen in fig 5(c). Hence these two QRS complexes could not be detected by the algorithm.

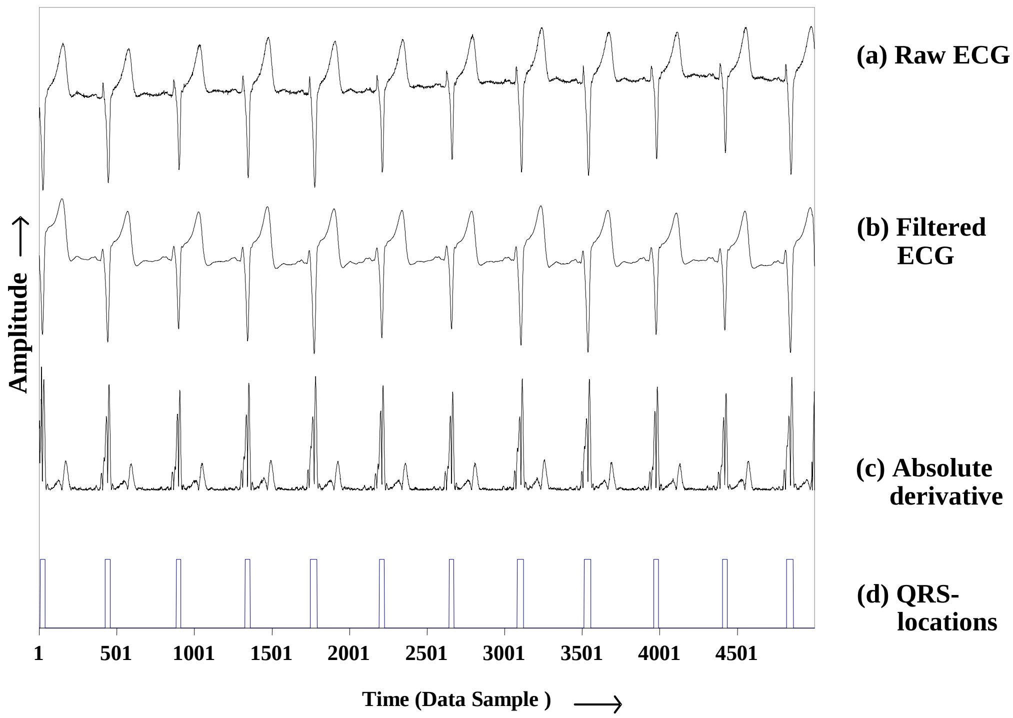

Fig.3 QRS-detection in Record MO1_085

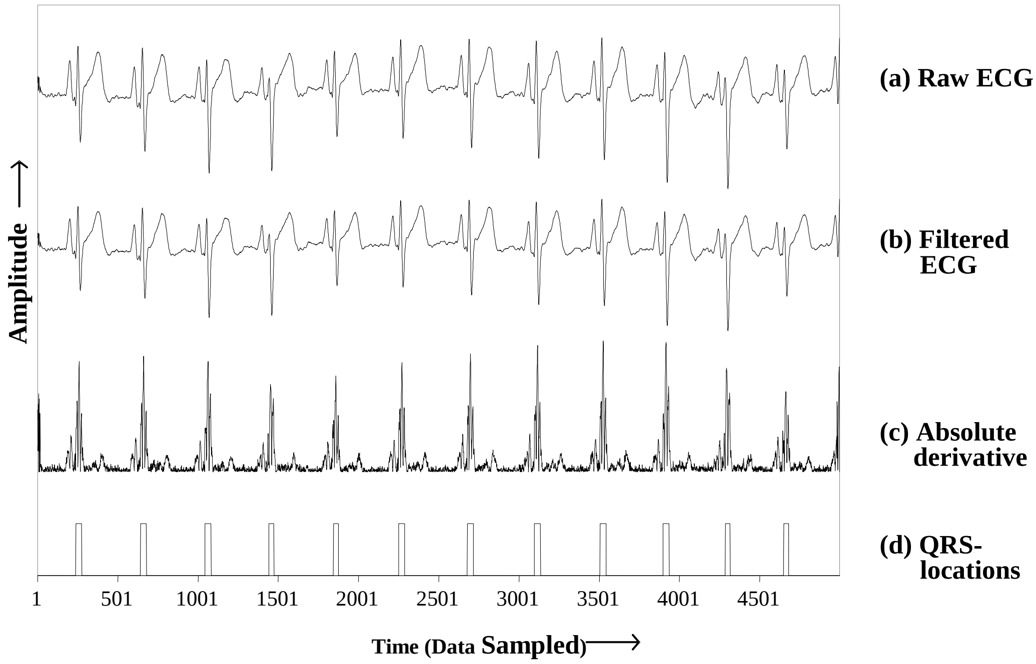

Fig. 4 QRS-detection in Record MO1_012

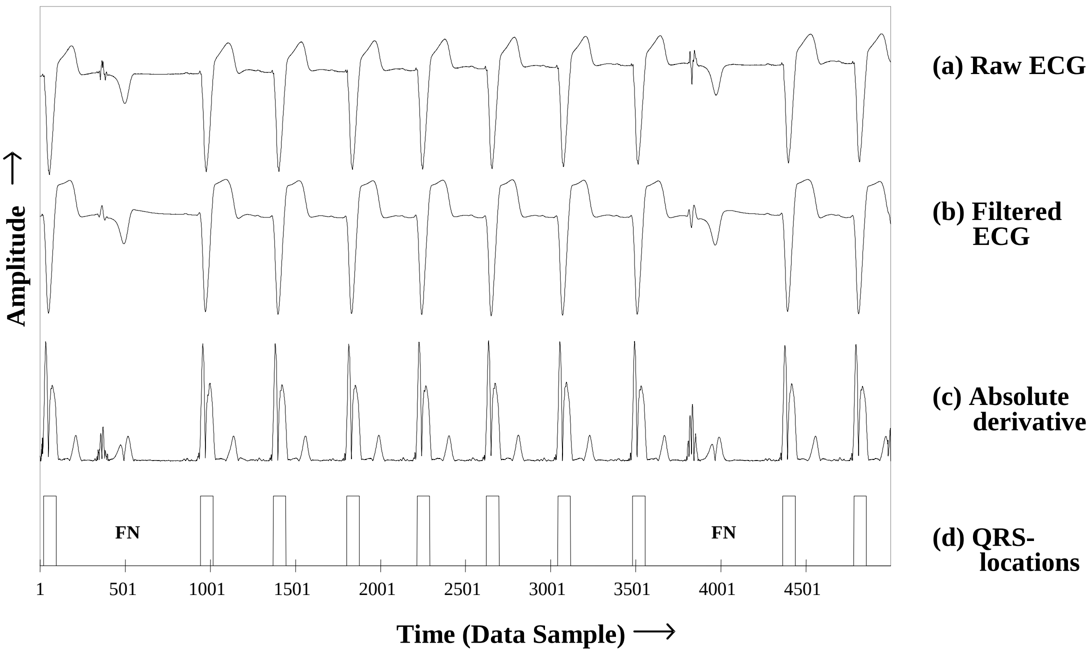

Fig. 5 QRS-detection in Record MO1_065

6. CONCLUSION

A simple but effective method using FCM clustering algorithm is presented in this paper for the detection of the QRS-complexes in Electrocardiogram. Digital filtering techniques effectively remove the noise and power line interference present in the ECG signal. A significant detection rate of 98.32% is obtained. The proposed algorithm detects the QRS-complexes efficiently. The information obtained by this method is very useful for ECG classification and diagnosis and can readily be used for automatic ECG analysis and diagnosis.

7. REFERENCES

[1] B. U. Kohler, C. Henning, and R. Orglmeister, "The principles of software QRS detection," IEEE Eng. in Med. and Bio., vol. 21, pp. 42-47, 2002.

[2] F. Gritzali, "Towards a generalized scheme for QRS Detection in ECG waveforms," in Signal Processing, vol. 15, 1988, pp. 183-192.

[3] O. Pahlm and L. Sornmo, “Software QRS detection in ambulatory monitoring- A review,” Med. Biol. Eng. Comp., vol. 22, pp. 289-297, 1984.

[4] G. M. Friesen, T. C. Jannett, M. A. Jadallah, S. L. Yates, S. R. Quint, and H. T. Nagle, “ A Comparison of noise sensitivity of nine QRS detection algorithms”, IEEE trans on Biomed. Engg., vol. 37, pp. 85-98, 1990.

[5] P. J. M. Fard, M. H. Moradi, and M. R. Tajvidi, “A novel approach in R peak detection using Hybrid Complex Wavelet,” Int. J. Card., 2007, doi:10.1016/j.ijcard.2006. 11.136.

[6] M. B. Messaoud, “On the algorithm for QRS complex localization in Electrocardiogram”, I. J. of Computer Science and Network Security, vol. 7, pp. 28-33, 2007.

[7] M. P. S. Chawla, H. K. Verma, V. Kumar, “A new statistical PCA-ICA algorithm for location of R-peaks in ECG,” Int. J. Card., 2007.

[8] A. Ghaffari, H. Golbayni, and M. Ghasemi, “A new mathematical based QRS detectorsusing continous wavelet transform,” Computers and Electrical Engg. 2007.

[9] F. Zhang and Y. Lian, “Electrocardiogram QRS detectionusing multiscale filtering using wavelet transform,” Proc. 29th Annual Int. Conf. of the IEEE EMBS, Lyon, France, pp. 3196-3199, Aug. 2007.

[10] S. S. Mehta and N. S. Lingayat, “Development of Entropy based algorithm for cardiac beat detection in 12-lead electrocardiogram,” Sig. Proc., vol. 87, pp. 3190-3201, 2007.

[11] S. S. Mehta and N. S. Lingayat, “Combined Entropy based method for detection of QRS complexes in 12-lead electrocardiogram using SVM,” Comp. in Biol. and Med, vol. 38, pp. 138-145, 2008.

[12] S. S. Mehta and N. S. Lingayat “SVM-based algorithm for recognition of QRS complexes in Electrocardiogram,” ITBM-RBM, vol. 29, pp 310-317, (2008).

[13] V. S. Chouhan and S. S. Mehta, “Detection of QRS-complexes in 12-lead ECG using adaptive quantized threshold,” IJCSNS International Journal of Computer Science and Network Security, vol.8, no.1, pp. 155-163, 2008

[14] J. C. Dunn, “A fuzzy relative of the ISODATA process and its use in detecting compact well-separated clusters,” J. Cybernet., vol. 3, pp. 32-57, 1974.

[15] J. C. Bezdek, “Pattern Recognition with fuzzy objective function algorithms,” Plenum Press, New York, 1981.

[16] J. L. Willems, P. Arnaud, J. H. Van Bemmel, P. J. Bourdillon, R. Degani, B. Denis, I. Graham, F. M. A. Harms, P. W. Macfarlane, G. Mazzocca, J. Meyer, and C. Zywietz, “A reference database for multilead electrocardiographic computer measurement programs,” J. Amer. Coll. Cardiol., vol. 10, pp. 1313-1321, 1987.

[17] J. A. Van Alste, and T.S. Schilder, “Removal of base-line wander and power line interference from the ECG by an efficient FIR filter with a reduced number of taps,” IEEE Trans. Biomed. Eng., vol. 32, pp.1052- 1059, 1985.