Impact Factor (SJIF): 3.632

International Journal of Advance Research in Engineering, Science & Technology

e-ISSN: 2393-9877, p-ISSN: 2394-2444

Volume 3, Issue 2, February-2016

Mark out of Qrs Complexes in Ecg Signal Using Fuzzy C-Means Algorithm

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Abstract — ***This paper implements a simple method using simple fuzzy c mean clustering algorithm for the detection of QRS complexes in ECG signal. QRS Complex is the most striking waveform within electrocardiogram (ECG), which provides much information about the current state of the heart. This paper proposes a novel QRS complex and non QRS Complexes detector using fuzzy c means algorithm. The performance of the algorithm is validated using MIT-BIH Database. The efficiency of QRS detection is evaluated based on two parameters namely sensitivity and detection rate.***

Keywords-ECG, MIT-BIH database, Fuzzy C -Means algorithm, QRS detection, Butterworth;

I. INTRODUCTION

The Electrocardiogram provides the valuable information regarding the cardiovascular diseases. Any abnormality in rhythm can provide useful information about the type of disease. in ecg QRS complex is a dominant of electrocardiographic signal, Fig. 1. Its amplitude and time analysis, shape and appearance time of adjacent rhythms estimation can be used to diagnose a wide range of heart diseases. QRS complex is necessary for the determination of the heart rate, and as reference for beat alignment.Thus, the obvious problem is the precise definition of the occurrence time and other various parameters of QRS-complex.

Various methods for classification of arrhythmias have been developed by researchers and clustering technique is one of them. Although it is an unsupervised type of technique, it is advisable technique for analysis and interpretation of long term ECG Holter records. In this paper, Ascending Fuzzy C-Means clustering has been used for analysis. Different types of linkages have been used for analysis.

The MITBIH arrhythmia data base has been used and on the proposed approach data is classified into five arrhythmia beats type i.e. Normal(N), Premature ventricular contraction (PVC), Paced beats(P), Left Bundle Branch Block(LBBB) and Right Bundle Branch Block. The data is preclustered and then analysis is done using different linkages. It has been seen that 'ward' linkage has got maximum success rate for arrhythmia classification.

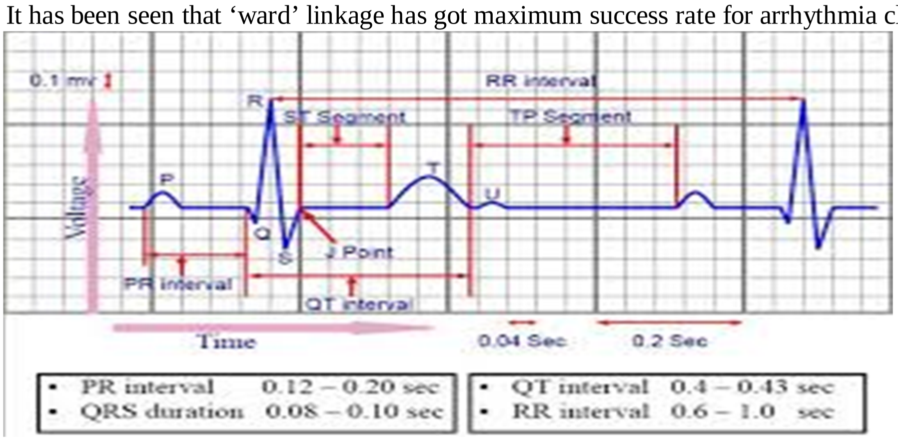

Figure 1: An ECG Signal with its intervals

II. FUZZY C-MEANS ALGORITHM

This section describes an outline of Fuzzy C-Means algorithm used for the generation of feature signal. Fuzzy c-means (FCM) is a method of clustering which allows one piece of data to belong to two or more clusters. This method (developed by Dunn in 1973 and improved by Bezdek in 1981) is frequently used in pattern recognition. Straightly speaking, this algorithm works by assigning membership to each data point correspoinding to each cluster center on the basis of distance between the cluster and the data point. More the data is near to the cluster center more is its membership towards the particular cluster center. Clearly, summation of membership of each data point should be equal to one. The algorithm is based on minimization of the following objective function:

$$J_m = \sum_{i=1}^{N} \sum_{j=1}^{C} u_{ij}^m \left\| x_i - c_j \right\|^2 \quad , \quad 1 \le m < \infty$$

where *m* (the Fuzziness Exponent) is any real number greater than 1, *N* is the number of data, *C* is the number of clusters, u_{ij} is the degree of membership of x_i in the cluster *j*, x_i is the *i*th of d-dimensional measured data, c_j is the d-dimension center of the cluster, and ||*|| is any norm expressing the similarity between any measured data and the center. Fuzzy partitioning is carried out through an iterative optimization of the objective function shown above, with the update of membership u_{ij} and the cluster centers c_j by:

$$u_{ij} = \frac{1}{\sum_{k=1}^{C} \left(\frac{\left\| x_i - c_j \right\|}{\left\| x_i - c_k \right\|} \right)^{\frac{2}{m-1}}}$$

$$= \frac{1}{\left(\frac{\|x_i - c_j\|}{\|x_i - c_1\|}\right)^{2/(m-1)} + \left(\frac{\|x_i - c_j\|}{\|x_i - c_2\|}\right)^{2/(m-1)} + \dots + \left(\frac{\|x_i - c_j\|}{\|x_i - c_k\|}\right)^{2/(m-1)}}$$

where $\|x_i - c_j\|$ is the Distance from point *i* to current cluster centre *j*, $\|x_i - c_k\|$ is the Distance from point *i* to other cluster centers *k*.

$$c_j = \frac{\sum_{i=1}^{N} u_{ij}^m \cdot x_i}{\sum_{i=1}^{N} u_{ij}^m}$$

The iteration will stop when $\max_{ij} \left\{ \left| u_{ij}^{(k+1)} - u_{ij}^{(k)} \right| \right\} < \varepsilon$, where ε is a termination criterion between 0 and 1, whereas *k* are the iteration steps. This procedure converges to a local minimum or a saddle point J_m.

The algorithm is composed of the following steps:

1. Randomly select cluster centre
2. Initialize U=[u_{ij}] matrix, $U^{(0)}$
   Calculate the the u_{ij} using:

$$u_{ij} = \frac{1}{\sum_{k=1}^{C} \left(\frac{\left\| x_i - c_j \right\|}{\left\| x_i - c_k \right\|} \right)^{\frac{2}{m-1}}}$$

3. At k-step: calculate the centres vectors $C^{(k)}=[c_j]$ with $U^{(k)}$

$$c_j = \frac{\sum_{i=1}^{N} u_{ij}^m \cdot x_i}{\sum_{i=1}^{N} u_{ij}^m}$$

4. Update $U^{(k)}$, $U^{(k+1)}$

$$u_{ij} = \frac{1}{\sum_{k=1}^{C}\left(\frac{\left\|x_i - c_j\right\|}{\left\|x_i - c_k\right\|}\right)^{\frac{2}{m-1}}}$$

5. If $\| U^{(k+1)} - U^{(k)}\| < \varepsilon$ or the minimum J is achieved, then STOP; otherwise return to step 2.

III. MIT-BIH ARRHYTHMIA DATABASE

In this paper, ECG signals are taken from MIT-BIH database for QRS detection and arrhythmia classification. MIT (Massachusetts Institute of Technology) and Beth Israel Hospital (now the Beth Israel Deaconess Medical Center) have combined and put forward this database. This was developed from 48 half an hour excerpts of two-channel ambulatory ECG recordings, taken from 47 subjects studied at the laboratories of Beth Israel Hospital. The 360 samples per second digitized recordings have 11-bit resolution over a 10 mV range. In this paper recordings of 10 seconds duration have taken.

The analog outputs of the playback unit were filtered to limit analog-to-digital converter (ADC) saturation and for anti-aliasing, using a passband from 0.1 to 100 Hz relative to real time, well beyond the lowest and highest frequencies recoverable from the recordings. The bandpass-filtered signals were digitized at 360 Hz per signal relative to real time using hardware constructed at the MIT Biomedical Engineering Center and at the BIH Biomedical Engineering Laboratory. The sampling frequency was chosen to facilitate implementations of 60 Hz (mains frequency) digital notch filters in arrhythmia detectors. Since the recorders were battery-powered, most of the 60 Hz noise present in the database arose during playback. In those records that were digitized at twice real time, this noise appears at 30 Hz (and multiples of 30 Hz) relative to real time.

IV. PRE PROCESSING OF ECG SIGNAL

In Diagnosing of ECG Signal, Signal acquisition must be noise free. Experienced physicians are able to make an informed medical diagnosis on heart condition by observing the ECG signal. In This we implemented the digital IIR Butterworth filter on the raw ECG signal for pre processing.

V. IMPLEMENTATION OF FUZZY C-MEANS ALGORITHM

This section implements an algorithm developed for the detection and delineation of QRS-complexes in single lead ECG signal in MATLAB programming Language. MATLAB (matrix laboratory) is a multi-paradigm numerical computing environment. MATLAB allows matrix manipulations, calculations, plotting of functions and data, implementation of algorithms, creation of user interfaces.

Step1: The absolute slope i.e. absolute value of the difference between two consecutive samples is calculated to enhance the signal in the region of QRS-complex. The absolute value of slope of the ECG signal is used as an important discriminating feature because absolute slope of the signal is much more in the QRS-region than in the rest of the region. Fig. shows the absolute slope of the filtered ECG signal. To enhance this absolute slope this paper uses moving average criteria. Due to this it is observed that the smoother version of QRS complex is obtained, which is shown in Fig. These absolute slope values are then normalized to reduce the burden of the classifier to form the complicated decision boundary.

Step 2: 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 3: After finding two cluster centers using Fuzzy C-Means algorithm, the slope curve shown in Fig. 2(e) is scanned. The membership of slope, at a given sampling instant, is found. An output is 1 if a sample belongs to a QRS-cluster and output is 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. Fig. 3 shows the output of Fuzzy C-Means algorithm. It is seen that, Fuzzy C-Means algorithm not only detects the QRS complexes of ECG, but also delineate them accurately.

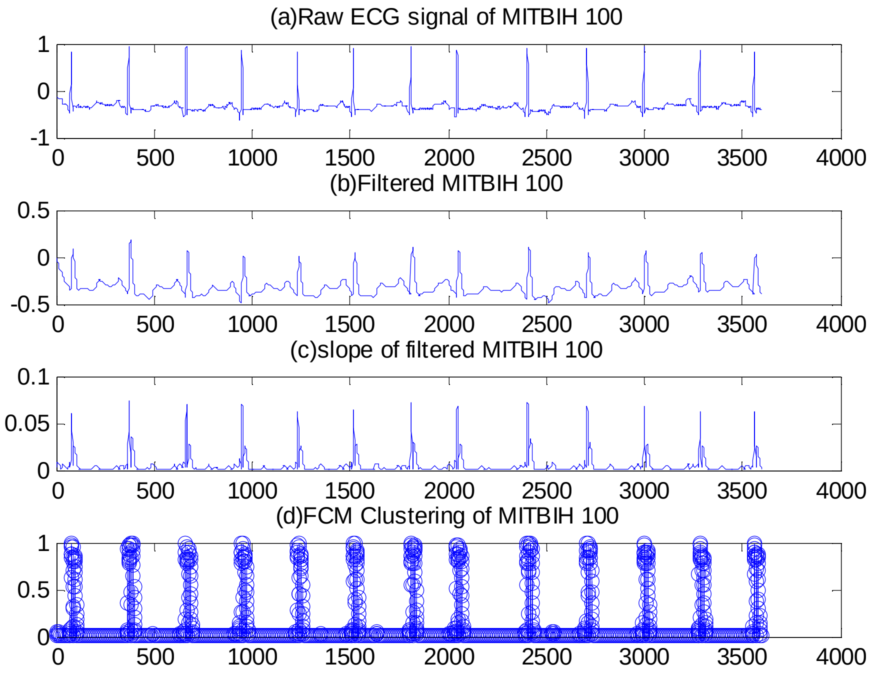

Figure 2: An Implementation of FCM Clustering (a)Raw ECG Signal, (b)Filtered ECG Signal, (c)Slope of the ECG Signal, (d)FCM Clustered Signal

IV. RESULTS

Detection is said to be true positive (TP) if the algorithm correctly discerns 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. The ECG signals used for analysis and detection in this work are a part of MIT-BIH Arrhythmia Database given on the website of MIT-BIH.

The said algorithm is applied on total of 48 records from database. It is observed that, in the case of normal beats(i.e.for recordnumber100,101,102,103,104,105,106,107,112,113,115,117,119,121,122,123,201,202,209,212,213,215,217,219,220,221,222,223,228,230,231,232,234) and right bundle branch block (i.e. for record numbers118,124), the results are encouraging and almost all the beats were detected successfully. Similarly, in the case of left bundle branch block also (i.e. for record numbers 111,207, 214), the total number of complexes detected are accurate and percentage range of *Se* and *P+* is satisfactory.

As the algorithm has been implemented in MATLAB working environment, therefore the part ofthe whole signal of each data set has been operated. In order to evaluate the accuracy of detection of QRS complex, two essential parameters: sensitivity *Se* and the positive predictivity P+(detection rate), are used.

These parameters describe the overall performance of the detector and their values are calculated as follows

$$Se = TP / (TP + FN)$$

$$P+ = TP / (TP + FP)$$

Using the above formula, the average detection rate is 96.39% obtained for all 48 MIT-BIH Records. Also the percentage of false positive detection and false negative detection for all records are very less, as listed in Table 1.

S NO	RECORD NO	TOTAL BEATS	TRUE +VE	TRUE -VE	FALSE +VE	FALSE -VE	SENSITIVITY	PREDICTIVITY
1	100	13	13	0	0	0	100	100%
2	101	11	11	0	0	0	100	100%
3	102	12	12	0	0	0	100	100%
4	103	11	11	0	0	0	100	100%
5	104	13	11	2	0	0	100	100%
6	105	14	14	0	0	0	100	100%
7	106	10	10	0	0	0	100	100%
8	107	11	11	0	0	0	100	100%
9	108	11	11	0	0	0	100	100%

10	109	16	16	0	0	0	100	100%
11	111	12	12	0	0	0	100	100%
12	112	14	14	0	1	0	100	93%
13	113	9	9	0	9	0	100	50%
14	114	9	9	0	0	0	100	100%
15	115	10	10	0	0	0	100	100%
16	116	14	14	0	0	0	100	100%
17	117	9	9	0	8	0	100	56%
18	118	12	12	0	0	0	100	100%
19	119	10	10	0	1	0	100	90%
20	121	10	10	0	1	0	100	90%
21	122	15	15	0	1	0	100	93%
22	123	8	8	0	0	0	100	100%
23	124	8	8	0	1	0	100	88%
24	200	15	15	0	0	0	100	100%
25	201	14	14	0	0	0	100	100%
26	202	9	9	0	0	0	100	100%
27	203	19	19	0	0	0	100	100%
28	205	15	15	0	1	0	100	93%
29	207	10	10	0	0	0	100	100%
30	208	16	16	0	1	0	100	94%
31	209	15	15	0	0	0	100	100%
32	210	16	16	0	0	0	100	100%
33	212	15	15	0	0	0	100	100%
34	213	18	18	0	0	0	100	100%
35	214	12	12	0	0	0	100	100%
36	215	18	18	0	0	0	100	100%
37	217	12	12	0	0	0	100	100%
38	219	13	13	0	0	0	100	100%
39	220	12	12	0	0	0	100	100%
40	221	13	13	0	0	0	100	100%
41	222	13	13	0	0	0	100	100%
42	223	13	13	0	1	0	100	92%
43	228	12	12	0	0	0	100	100%
44	230	14	14	0	0	0	100	100%
45	231	10	10	0	0	0	100	100%
46	232	8	8	0	1	0	100	88%
47	233	17	17	0	0	0	100	100%
48	234	15	15	0	0	0	100	100%
0	**TOTAL**	**606**	**604**	**2**	**26**	**0**	**100**	**96.39%**

Table 1: Different MIT-BIH Records Sensitivity and Predictivity

V. CONCLUSION

This paper represents new method implemented for the mark out of QRS complex detection in ECG signal using Fuzzy C-Means algorithm. The method has been comprehensively tested using the MIT-BIH ECG database covering wide variety of QRS complexes. A considerable detection rate 96.39% is obtained. It is observed that the information obtained through this algorithm is very useful for ECG classification and diagnosis. It is also possible to extend this method for automatic ECG signal analysis and diagnosis.

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