The Research of ECG Signal Automatic Segmentation Algorithm Based on Fractal Dimension Trajectory

Yin-jing GUO[1], Qian Cao[1], Peng Gao[1], Zhi-xin Cheng[1], Wei Xia[2]

(1 . *School of information and electrical engineeringShandong University of Science and Technology Qingdao, China;2 . Shandong Fengyuan Coal Industry & Electric Power CO.,LTDZaozhuang, China)*

***Abstract*—In this paper a kind of ECG signal automatic segmentation algorithm based on ECG fractal dimension trajectory is put forward. First, the ECG signal will be analyzed, then constructing the fractal dimension trajectory of ECG signal according to the fractal dimension trajectory constructing algorithm , finally, obtaining ECG signal feature points and ECG automatic segmentation will be realized by the feature of ECG signal fractal dimension trajectory and the feature of ECG frequency domain characteristics. Through Matlab simulation of the algorithm, the results showed that by constructing the ECG fractal dimension trajectory enables ECG location of each component displayed clearly and obtains high success rate of sub-ECG, providing a basis to identify the various components of ECG signal accurately.**

Keywords* — *ECG; fractal theory; fractal dimension trajectory; automatic segmentation

Manuscript Number: 1674-8042(2010)supp.-0139-04
dio: 10.3969/j.issn1674-8042.2010.supp..38

1 Introduction

The doctors' diagnosis of the changes in cardiac function mainly depends on the ability to detect changes in ECG waveform accurately [1], for various factors, clinical ECG signal showed very complex patterns, which would brought a considerable challenge to position the electricity of heart accurately.Hamid Krimt [2], Kadhim [3] and others put forward a method based on the ECG characteristics and whether their turning points are continuous for ECG segmentation at an early stage; Wang Jianjian [4], MB Shamsollahi [5] and others were made to adjust the sampling interval time and the interpolation value of the signal model and Bayesian model framework to accomplish ECG segmentation; G. de Lannoy [6] and others use limited interpolation method to supervise the partition of electrocardiogram. However, these methods for positioning the ECG accurately are not ideal, and the technique is not perfect. Recent studies of scholars have shown that ECG and EEG signals is not only complex, but also self-similarity [7] .In this paper, fractal is used to the study of ECG, a new algorithm for automatic segmentation of ECG is obtain by constructing the Fractal dimension trajectory. The algorithm is based on the sophisticating fractal technology; it can position the ECG accurately and achieve the purpose of sub-paragraph. The research idea is as shown in Fig. 1.

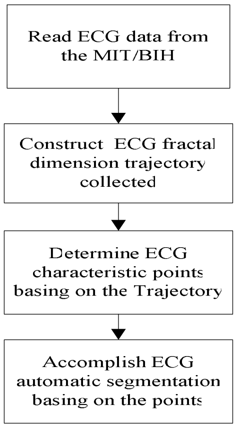

Fig. 1 Research ideas of the segmentation realization

2 Construction of ECG fractal dimension trajectory

2.1 Fractal dimension estimation method

There are many estimation methods of fractal dimension, such as Incremental mean method, Incremental variance method and box dimension method [8] This article focuses on the variance fractal dimension estimation method regarding Incremental variance and box dimension binary estimation method regarding box dimension.

1) Variance fractal dimension estimation method

The estimation of variance fractal dimension mainly depends on the estimation of parameter H, and the main theoretical basis for determine H is the variance of signal amplitude increment and the 2H-th time increment are proportional, that is:

$$Var[\Delta B(t,\Delta t)] = C\Delta t^{2H} \quad (1)$$

Received: 2010-05-25
Corresponding author: Qian Cao huntercq@126.com

C is a constant, H is Hurst Index. Log both sides of the Equation above, and we can get

$$H = \frac{1}{2}\lim_{\Delta t \to 0} \frac{\log Var[\Delta B(t,\Delta t)]}{\log(\Delta t)} \tag{2}$$

From (2-2), we can see, H is the limit as $\Delta t \to 0$

At last, we can get the variance fractal dimension is:

$$D_\delta = E + 1 - H \tag{3}$$

E is the embedded Euclidean space dimension, and E=1 for one-dimensional time series, so:

$$D_\delta = 2 - H \tag{4}$$

2) Binary box dimension estimation method

In R^2 space, box dimension D_B can be defined as:

$$D_B = \lim_{\delta \to 0} \frac{\log N_\delta(F)}{\log(1/\delta)} \tag{5}$$

$N_\delta(F)$ is the least grid number covered by a square with edge length δ.

In the practical application, the fractal characteristics of the signal are all statistically self-similarity, so we can just estimate D_B in a certain range of grid-scale. That is, in an appropriate scale, change Grid-scale in a certain way, calculate $N_\delta(F)$ according to different δ; then linear fitting the collection constituted by point to $(\log(1/\delta), \log N_\delta(F))$ with the least square method [9], and the slope of the fitting line is the estimated value of D_B.

2.2 ECG signals acquisition

In this paper, the ECG signal data is obtained from MIT/BIH standard library in Matlab, as shown in Fig. 2, and the ECG fractal dimension trajectory can be drown by the data.

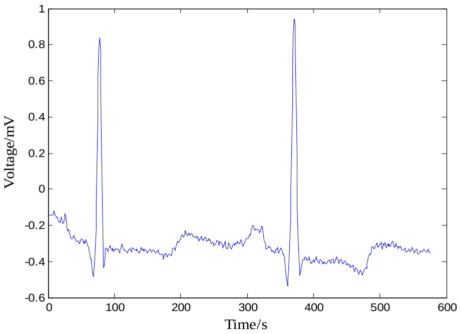

Fig. 2 ECG signal from MIT / BIH standard library

2.3 Construction of the ECG signals fractal dimension trajectory

By the establishment of fractal dimension trajectory through the entire time series, the change characteristics of time series can be more effectively reflected. The construction algorithm of ECG signals fractal dimension trajectory as follows: slide time window along ECG signals time series; calculate the fractal dimension for each window. Assuming that there is an ECG time series with time length T, the construction algorithm flow chart of the ECG signals fractal dimension trajectory is shown in Fig. 3.

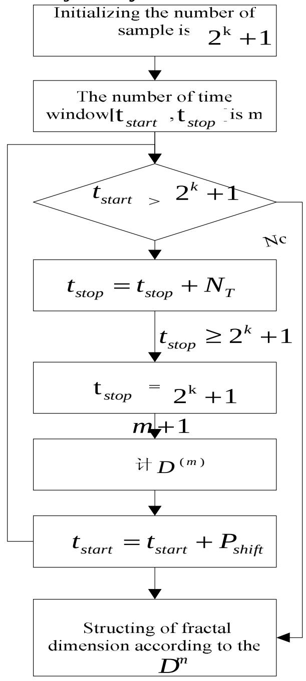

Fig. 3 Flow chart of fractal dimension trajectory constructing algorithm

In the Fig. 3, t_{start} is time window starting point, t_{stop} is time window termination point and m is window number, t_{start} is initialized to 1, m is initialized to 0; N_T is sample points. It is worth noting that, when ECG signals are in the initialization processing to make sample points are 2^k+1, amplitude also should be limited in [0, 2^k]; then record the treated ECG signals samples sequence as { $S(n), n = 1, 2..., 2^k + 1$ },and set the width of time window and move interval with N_T and P_{shift}, $N_T \geq P_{shift}$. The width of time window and move interval affects the shape features of ECG fractal dimension trajectory. In order to more accurately calculate the fractal dimension trajectory, these two parameters must be carefully selected. Usually, we get reasonable value through many experiments .In this article we set the width of time window and move interval with 1024 and 256, and the simulation of ECG signals fractal dimension trajectory is shown in Fig. 4.

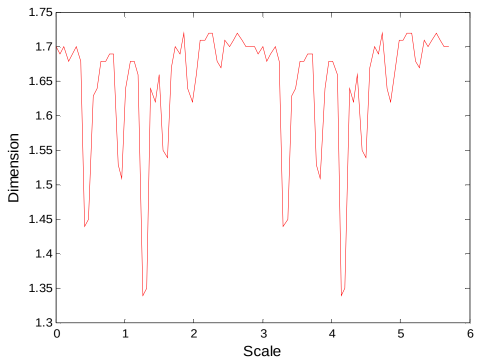

Fig. 4 Simulation diagram of ECG signal fractal dimension trajectory

Characteristics of the fractal dimension trajectory constructed by this method:

1) The ECG signals fractal dimension trajectory directly reflects the features of ECG signals components. These components show relatively stable fractal dimension values because of self-relevance, and the fractal dimension values of adjacent components also have significant difference, which make fractal dimension trajectory generate mutation, so as to provide a basis of various components segmentation.

2) For all ECG, fractal dimension trajectory of P、Q、R、S、T、U shows a clear trough because of little fractal dimension value and short duration. The simulation diagram of ECG signals feature points are shown in Fig. 5.

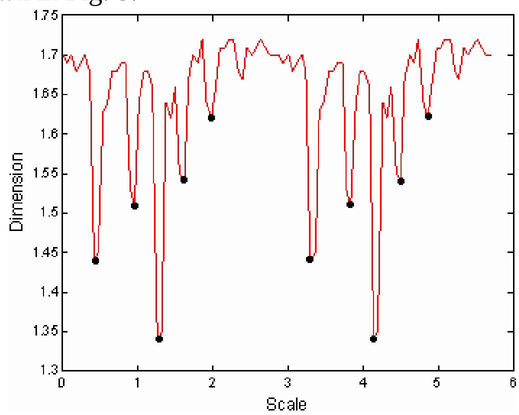

Fig. 5 Simulation diagram of ECG signals feature points

Through the simulation diagram, the location of each ECG component can be obviously displayed, which provides a good basis for the recognition of ECG components. Next we will describe how to construct automatic sub-algorithm through fractal dimension trajectory.

3 Automatic sub-structure based on the fractal dimension trajectory algorithm

The fractal dimension trajectory of ECG directly reflects the complexity and time-domain characteristics of ECG, so we can achieve automatic segmentation and recognition components of ECG based on the fractal dimension trajectory and time-domain characteristics of the ECG [9]. The ECG automatic sub-algorithm is as follows:

1) Identify possible P, Q, R, S, T, U component region

According to the characteristics of Fractal dimension trajectory of ECG, it's known that the fractal dimension of P, Q, R, S, T, U and other components of ECG is smaller than that of other channel noise ,so that The boundary of each component can be shown more obviously.

2) Determine anchor points and boundary points of all characteristics

Identify the minimum value of fractal dimension for each region, that is the trough point, and mark with their position. These are P, Q, R, S, T, U anchor points. Then put the first inflection point found in the track of the fractal dimension from the starting point for the region to the left. Finally put the turning point of the fourth or fifth cardiac cycle found from the end of the region to the right as a point of termination (Specifically, it is the fourth or fifth inflection point depends on if there is any U-wave in the ECG).In this method find all the starting point and termination point of feature points, they are the boundary points of P, Q, R, S, T, U. According to each time point corresponded to boundary points, it can be achieved ECG segmentation of each component.

3) Identify P, Q, R, S, T, U wave

Identify P, Q, R, S, T, U wave in the light of time-domain characteristics of ECG and the distance between trough points. Identification criteria based on the following facts: P, Q, R, S, T, U positioning points (trough points) similarly give P, Q, R, S, T, U position. We can use the time interval of ECG adjacent trough point to identify each feature point: firstly, calculate the distance between marked adjacent trough points, then look for the longest time interval, and locate the corresponding trough points as P, Q, R, S, T, U, respectively, regard it as a basis, move backward respectively to identify the P, Q, R, S, T, U wave.

4 Experimental results

The laboratory data is read from the MIT / BIH database, and figure 6 is a representative sub-result, in this figure, the horizontal axis is shown the numerical sequence of samples of ECG signal, the longitudinal axis is shown the range and fractal dimension values of ECG signal respectively, and the results of the automatic subsection is marked .The results can be seen from the sub-result, all components of ECG signal are separated clearly.

The ECG data used in the experiment includes 200 cases of normal ECG signal and 200 cases of pathological ECG signal.

TABLE. 1 Verification results of ECG signal automatic segmentation

Category	*total number of ECG cycles*	*The method of ECG trajectory fractal dimension*			
		Binary box dimension method		Variance fractal dimension method	
		number of accurate sub	Accuracy rate	number of accurate sub	Accuracy rate
Normal ECG	200	194	97%	196	98%
Abnormal ECG	200	188	94%	184	92%
All ECG	400	382	95.5%	380	95%

Firstly, fractal dimension trajectory of the ECG signal is structured, and then we DIV the 400 ECG cardiac cycle sub-samples include normal and pathological ECG signal by using the above sub-algorithm, and verify the performance of sub-algorithm meanwhile. The verify results are shown in Table 1.

The data in Table 1 is shown that: by using the binary box dimension method, the accurate rate of automatic segmentation of normal ECG signal is 97%, the accurate rate of automatic segmentation of pathological ECG signal is 94%, and the accurate rate of automatic segmentation of all ECG signal is 95.5% ; By using the variance fractal dimension method , the accurate rate of automatic segmentation of normal ECG signal is 98%, the accurate rate of automatic segmentation of pathological ECG signal is 92%, and the accurate rate of automatic segmentation of all ECG signal is 95%. So we can know that: whether it is normal or abnormal ECG, regardless which method is used to generate the fractal dimension-trajectory of ECG signal, the accuracy rates of total are both more than 90% after adopted the method in this paper to divide the ECG signal. Both of the methods showed good effect.

5 Conclusion

This paper studied the method of ECG about the fractal dimension in constructing the track, and submitted the ECG automatic sub-structure algorithm based on this method. The paper also simulated the normal and pathological ECG with the method of two dimension into the box and side-difference fractal dimension finally. The simulation results showed the high accuracy of automatic segmentation algorithm and robustness, and showed the good section results also. It is great significance to determine cardiac function accurately and diagnose and treat cardiovascular disease. At the same time, this research can also be used for the compression of ECG, Based on the superiority of fractal methods, fractal compression will greatly improve the compression ratio of ECG, thus to reconstruct high-quality ECG signal, it is convenient for ECG storage and transmission too.

References

[1]Jiang Deyu,Liu Guangyuan,Long Zhengji. Feature Extraction and Recognition Based on the ECG P - QRS - T Wave [J]. Computer Engineering and Applications,2009-08.

[2]Hamid K and Dana H. B.Feature-Based Segmentation of ECG Signals,1996.

[3]Kadhim K.N, Taha S.M.R, Mahmoud W.A.A new method for filtering and segmentation of the ECG signal,2006-04-10K. Elissa, “Title of paper if known,” unpublished.

[4]Wang Jianjian, Li Zheying. An ECG Segmentation Model Used for Signal Generator, ICICIC,2007.

[5]Sayadi O, Shamsollahi M B. A model-based Bayesian framework for ECG beat segmentation Physiological measurement,2009-01-04,30(3):335-52.

[6]Frénay B, de Lannoy G and Verleysen. M. Emission Modelling for Supervised ECG Segmentation using Finite Differences,2009-02-04.

[7]Ieffrey PM, David SG, Basil AE, et al. Supine low frequencypower of heart rate variability reflects baroreflex function,notcardiac sympathetic innervation[J] ,Heart Rhythm,2007-04-12 :1523-1529.

[8] Sun Yunda, Zhao Yao, Yuan Baozong. A general framework model for fractal coders. IEEE trans. On Image Process,2005.