International Journal of Computer Applications (0975 – 8887)
Volume 93 – No 16, May 2014

Automatic Discrimination between NSR, VT and VF

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ABSTRACT
Ventricular Tachycardia (VT) and Ventricular Fibrillation(VF) are life-threatening arrhythmias and accurate discrimination between them is a hard task for the cardiologists. This paper aims to automatically discriminate between Normal Sinus Rhythm (NSR), VT and VF to help make a timely decision of delivering an electroshock to the patient to save his life. To do this discriminative information is extracted from the trajectories traced by NSR, VT and VF signals in the state space. Time delay method is used to represent the signal in state space which is then converted into image. Onto this image, several masks are applied which classify the signal by counting the number of pixels flagged. The algorithm is tested on signals from MIT-BIH databases and is developed on Python 2.7. Experiments carried out give an accuracy rate of 97%. Also the developed algorithm is computationally less complex and hence can be implemented in real-time applications.

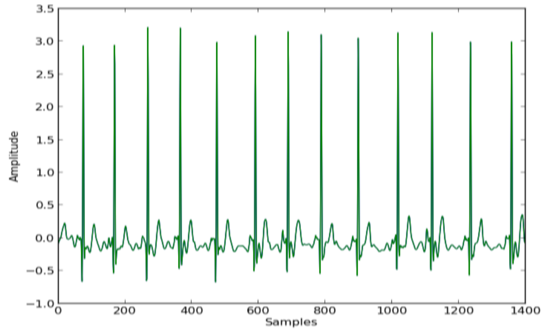
General Terms
Signal Processing, Chaos Theory, Algorithms

Keywords
Normal Sinus Rhythm, Python, State space, Ventricular Fibrillation, Ventricular Tachycardia

1. INTRODUCTION
During emergency situations, it is extremely important to automatically discriminate between the life-threatening arrhythmias-Ventricular Tachycardia (VT) and Ventricular Fibrillation(VF) and the Normal Sinus Rhythm (NSR), wherein the medical personnel can make a timely decision of delivering an electric counter-shock to the patient. VF is the most fatal arrhythmia which may occur after a period of VT and needs to be identified quickly in order to save the patient. VT is a series of three or more ventricular complexes occurring at a rate of 100 to 250 beats/min. A VT ECG will not have normal but wide QRS complexes with rhythm which is usually regular, but occasionally it may be modestly irregular. VF is defined as chaotic depolarization of heart's ventricles, resulting in a failure to pump blood and death within minutes. Figure 1 shows the ECG of the three types of signals that are of interest.

Now, if the combination of an NSR and VT is taken as VF, the patient receives unnecessary shock that could deteriorate the heart functioning. Conversely, a failure in identification of VF is lethal. Hence, the accurate and early detection of VT or VF is of utmost importance which is the aim of this paper.

Othman *et al.*,2012 have described succinctly the various algorithms developed to distinguish between these shockable and non-shockable rhythms. The non-linear analysis technique described in [2] is modified and applied for discriminating all the three signals NSR,VT and VF to achieve a high accuracy. The proposed algorithm is tested onto the MIT 'cudb' (The Creighton University ventricular tachyarrhythmia) [6] database having ECG recordings of patients with sustained ventricular tachycardia and ventricular fibrillation, the MIT 'nsrdb' (normal sinus rhythm)[7] database having ECG recordings of people with normal sinus rhythms only and the MIT 'vfdb' (The MIT-BIH Malignant Ventricular Arrhythmia Database) [8] having ECG of subjects who experienced episodes of sustained ventricular tachycardia, ventricular flutter, and ventricular fibrillation.



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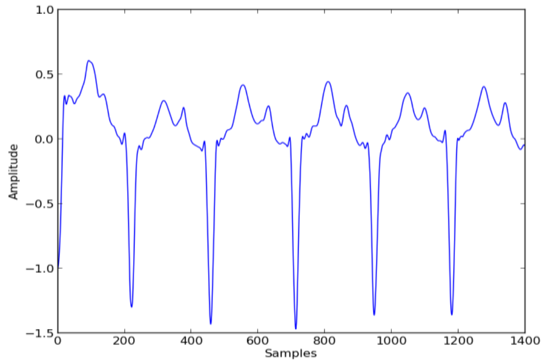

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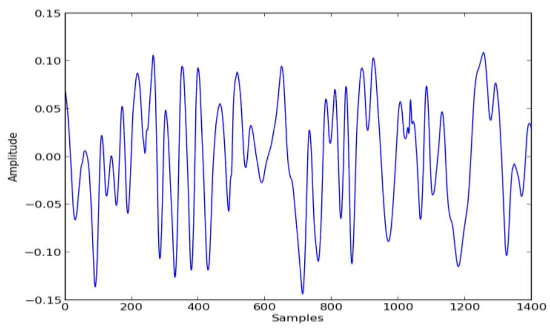

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Figure 1. ECG recordings of (a) NSR (b) VT (c) VF

2. ECG SIGNAL PRE-PROCESSING

ECG signals are usually corrupted by 50 Hz power line interferences and baseline wander. Therefore, the ECG needs to be cleaned before further processing it. Wavelet based denoising and S-golay Filter described in [3] are used for filtering baseline wander and high frequency noise. Raw ECG is first passed through the baseline wander filter, and then wavelet based denoising removes the high frequency noise. S-Golay Filter then smoothens the filtered data. Python v2.7 simulation tool is used to implement all the modules described in this paper.

3. MATERIAL AND METHOD

3.1 Negative-peak Detection

The proposed algorithm exploits an important characteristic of a VT signal i.e. it has a wide QRS complexes that are usually regular in rhythm. Since the waveform follows a pattern, the widths of the wide QRS complexes remains nearly the same. Thus after pre-processing the ECG, negative peaks of the input signal are detected. This is done to check whether all the adjacent peaks lie at almost the same distance from each other. If this is so, then there is a possibility that the input ECG is a VT signal.

3.2 Time Delay Method

The concept of the state of a system refers to a minimum set of variables, known as state variables, that fully describe the system and its response to any given set of inputs. A state space is a space in which all the possible states of a system are represented, with each possible state corresponding to one unique point in the state space. To formulate the dynamics of an ECG cycle by a stochastically driven model, time delay reconstruction method is used. It is a convenient tool to reveal both the regular and the stochastic aspects of an ECG. Here, the state variables of the system represented in state space on the basis of the single lead measurement are reconstructed. This is because in ECG it is not possible to measure the state variables directly. Thus delay reconstruction technique is used to reconstruct the underlying dynamics of ECG in the state space.

After pre-processing the ECG signal, it is mapped into the state space using time-delay method. In this technique, let's say the signal is considered as x(t). This x(t) is depicted in the state space as described in [4] where x(t) is drawn versus x(t + r) and r is the time delay applied. This depiction of the signal is called as trajectory. The trajectories of typical NSR, VT and VF signals in the state space are shown in Figure 2 for a delay of 0.2 seconds. It is evident that the trajectory of VF is irregular, chaotic and spreads throughout the state space whereas that of VT and NSR are restricted to a specific region and regular in shape. Thus this behaviour of the three signals is exploited to discriminate them.

3.3 Proposed Masks for Classification

As can be seen the trajectories traced by all the three signals are different, we differentiate them by first converting the state space plots into images and then applying a combination of the masks to remove the common information and extract the discriminative information. Initially the images are partitioned into 40x40 'boxes' [2] and after the masks are applied, the number of boxes flagged are counted. The resulted count then discriminates the input signal as either NSR, VT or VF. New masks are designed to accentuate the differences and hence to improve the efficiency and the accuracy of the proposed method. The designed masks(A,B) are shown in Figure 3 and are designed heuristically. The size of each mask is the same as the input image.

3.4 Classification

Initially to discriminate VT from the other two, the output of peak detection stage is checked. If the distance between the adjacent negative peaks is nearly same, then the number of flagged boxes after application of Mask C is checked. If it is above a threshold t1, then the input ECG signal is VT else it is then classified as 'other abnormality'. Now, if the distance between the adjacent negative peaks doesn't remain same, then the input signal can be either VF or NSR. To differentiate between NSR and VF, the number of boxes traced by the trajectory (n1) and total number of boxes flagged by Mask A and B (n2) is checked. If n1> threshold t2 or n2> threshold t3, the ECG is VF otherwise it is classified as NSR.

The output after each stage of classification for a VT signal is shown in Figure 4.

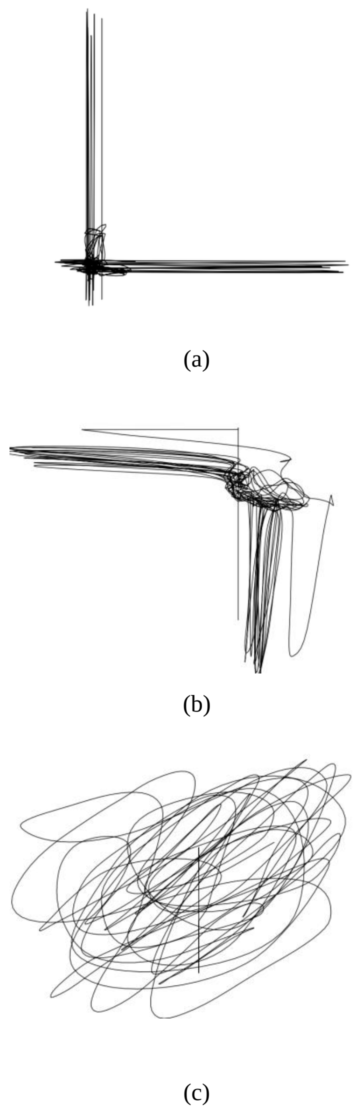


Figure 2. Trajectories of (a) NSR (b) VF (c) VT

4. EXPERIMENTAL RESULTS

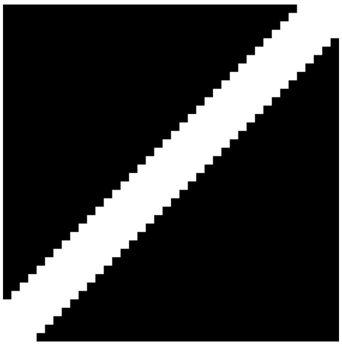
In this paper, ECG episodes of window length of 5.6 seconds are used. The delay used to create the state space plot is of .2 seconds. The values t1, t2 and t3 are determined from the training set which consisted of 80 NSR, 70 VF and 25 VT signals from the nsrdb, cudb and vfdb databases-all of which are sampled at 250 Hz. These determined values t1 and t2 maximized the true positive (TP) and minimized the false positive (FP) for all the training signals. The confusion matrix for the three signals is shown in Table 1. It can be seen from the table that the proposed algorithm gives an overall accuracy of 97% . The algorithm is developed and tested on Python 2.7 simulation tool. The computation time taken by the entire program on intel core i5 machine (Linux OS) is just 1 second. Hence it can be applied to achieve the goal of taking a quick and a timely decision of giving an electric shock to the patient.

Table 1. Confusion Matrix

Actual Signal	Classified As				Sensitivity
	NSR	VT	VF	Other abnormality	
80 NSR	78	0	2	0	97.5%
25 VT	0	23	0	2	92%
70 VF	0	2	68	0	97.14%

5. CONCLUSIONS

This paper presents an efficient , fast and simple discrimination algorithm based on phase space reconstruction phenomenon which is justified by the results. It extracts the discriminative information between the three signals to achieve an overall high accuracy. Due to its simplicity and quick computation it can be a better choice for automatic discrimination of VF, VT and NSR which determines whether the patient is to be delivered a shock or not. Also the use of other parameters like spatial filling index [5] along with the proposed technique can be looked at for making the algorithm robust.



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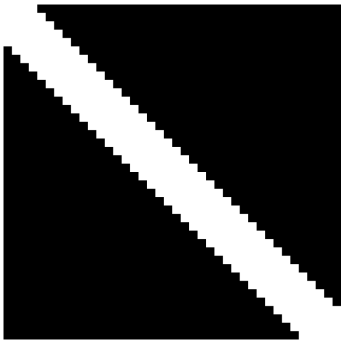

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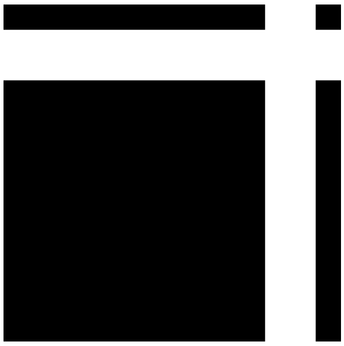

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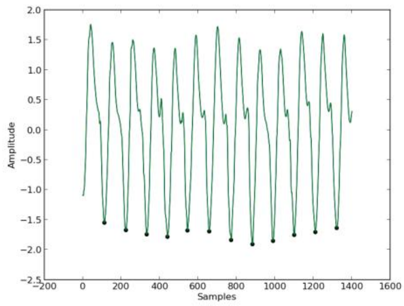
Figure 3. (a) Mask A (b) Mask B (c) Mask C



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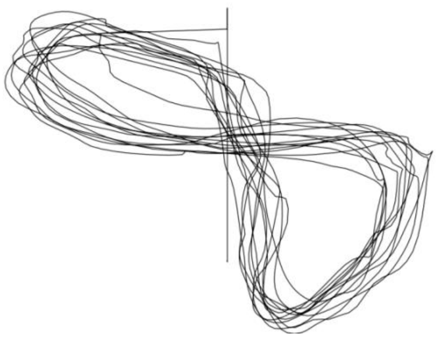

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(d)

(e)

(f)

Figure 4. Output after (a) negative peak detection stage (b) converting the trajectory plot into an image (c) application of Mask A (d) application of Mask B (e) application of Mask C (f) dividing the input image into 40x40 boxes to count the boxes flagged

6. REFERENCES

[1] Othman M A., et al., (2012), "Characterization of Ventricular Tachycardia and Fibrillation Using Semantic Mining." *Computer & Information Science* 5, no. 5.

[2] Sarvestani R., et al., (2009),"VT and VF classification using trajectory analysis." *Nonlinear Analysis: Theory, Methods & Applications*71.12: e55-e61.

[3] Mane R., et al., (2013),"Cardiac Arrhythmia Detection By ECG Feature Extraction." *International Journal of Engineering Research and Applications* 3, no. 2: 327-332.

[4] Anton A., et al., (2007) "Detecting ventricular fibrillation by time-delay methods." *IEEE Trans. Biomed. Eng.* 54 (1) 174_177.

[5] Rocha, T., et al., (2008),"Phase space reconstruction approach for ventricular arrhythmias characterization." In *Engineering in Medicine and Biology Society, 2008. EMBS 2008. 30th Annual International Conference of the IEEE*, pp. 5470-5473. IEEE.

[6] CU Database, Massachusetts Institute of Technology, [online] available : http://www.physionet.org/physiobank/database/cudb

[7] The MIT-BIH Normal Sinus Rhythm Database, [online] available : http://www.physionet.org/physiobank/database/nsrdb

[8] The MIT-BIH Malignant Ventricular Arrhythmia Database, [online] available : http://www.physionet.org/physiobank/database/vfdb