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Statistical measurements for Comparison between Mazhar-Eslam Variability Frequency and other old Algorithms for accurate diagnosis of heart diseases

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ABSTRACT: *Variability in the heart rate is a term which refers to the divergence in complex wave in the heart (intervals). It is a reliable indicator for many processing which occur in the body like (psychological, physiological, and environmental factors) which modulating the rhythm of the heart. In fact, the HRV represent a main indicator tool for observation the interaction between the sympathetic and parasympathetic nervous systems.*

In recent works, Rosenstein and Wolf (R&W) had used the Lyapunov exponent (LE) as quantitative method which used for measuring the sensitivity of HRV. However, these methods (R&W) diverge in determining the main features of HRV sensitivity. On the other hand, Mazhar-Eslam introduced a modification algorithm to overcome the Rosenstein and Wolf drawbacks.

The present work give an insight about the most reliable method for analysis the linear and nonlinear behaviour of the heart (especially wave variability), all that aimed to achieving the best result to assess the use of the HRV as a versatile tool for accurate diagnosis of heart disease, with the help of some Statistical measurements for Comparison between the three algorithms.

Keywords:- *Heart Rate Variability (HRV), Mazhar-Eslam Variability Frequency (MVF),Lyapunov exponent (LE), Rosenstein and Wolf (R&W)*

I. INTRODUCTION

The HRV act as auniversal marker which used forneural control analysis of theheart.Also give clear insight about link degree between sympatheticand parasympathetic systems on (HRs). Many pattern explain the linear and non-linear technique in heart rate (HR), which classified into periodical andaperiodicaloscillation. These patterns can be quantified in time domain using statistical measurements, for estimation the RR-fluctuations intervals.

The result of Spectroscopy analysis for HRV reveals that the presence of two bands variations of HR. High and low frequency band in the range vary from (0.16-0.4) Hz and (0.04-0.15) Hz respectively. The higher one represent a marker of vagal modulation, and the lower one give overwhelmingly sympathetic tone and baroreflex activity **[1, 2, 3]**. Time domain and frequency domain were two methods for assuming that, the signal of HRV are linear **[4]**, although it failed as accurate quantification method in heart rate dynamic structure in order to obtaining a highly selective and sensitive method for HR diagnosis.

Now a days several methods have been improved to make the fluctuations in cardiovascular system depends on monitoring with linear techniques, as well as modulating the nonlinear fluctuations. This represent a great work in new drug improvement for patients treatment.

In the present work, introduces an insight about the most selective reliable method for linear and nonlinear techniques analysis of the heart wave variability, which help in improvement the heart disease diagnosis.With introduction of recent algorithm named Mazhar-Eslam algorithm considering whole cases of linear and nonlinear behaviour for the HRV signal. Also verification the importance of using the modified Mazhar-Eslam algorithm as a predicting tool for HRV as a computer aided diagnosis (CAD). As it allows the analysis the linear and nonlinear behaviour of HRV.

II. MAZHAR-ESLAM VARIABILITY FREQUENCY (MVF) ALGORITHM DESCRIPTION

Recently, a novel of new approach titled (Mazhar- Eslam) algorithm clarified **[5-8]**, which used Discrete Wavelet Transform (DWT) considering the merits of DWT over that of FFT. Mazhar-Eslam algorithm act as extention of Rosenstein strategies **[9]** which calculate the lag and mean period, also uses the Wolf algorithm **[10]** for MVF (Ω_M) estimation except the first and second steps, whereas the final steps are taken from Rosenstein's method.As MVF (Ω_M) measures the SED separation degree between infinitesimally close trajectories in phase space. Also MVF (Ω_M) allows determining additional invariants. Consequently, the Mazhar-Eslam algorithm allows to calculate a mean value for the MVF (Ω_M), that is given by:

$$\overline{\boldsymbol{\Omega_M}} = \sum_{i=1}^{j} \frac{\Omega_{M\,i}}{j} \qquad (1)$$

Note: Ω_{M_i}s contain the largest Ω_{ML} and variants Ω_Ms which represent a useful and benifit data used inMazhar-Eslam algorithm for SED prediction quantitative measure.

The application of Mazhar-Eslam algorithm to the HRV, it is found that the mean MVF ($\overline{\Omega_M}$) as 0.4986 Hz, which is more accurate than Wolf (0.505 Hz) and Rosenstein (0.7586 Hz).**Figure 1** flowcharts for calculating Mazhar-Eslam MVF algorithm.

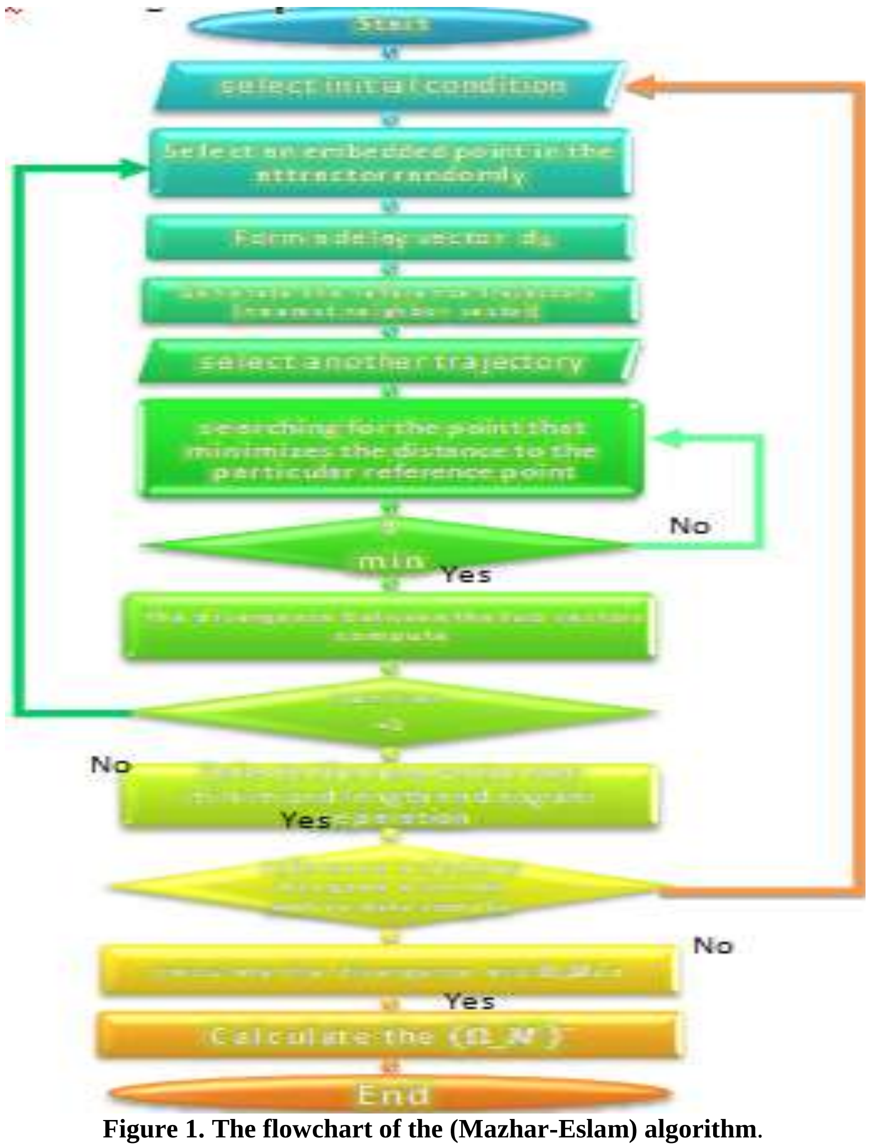

Figure 1. The flowchart of the (Mazhar-Eslam) algorithm.

III. STATISTICAL ANALYSIS AND COMPARISON BETWEEN MVF ALGORITHMS

Table 1 represents bands distribution of three algorithms, and their percentage (Rosenstein, Wolf, and Mazhar-Eslam). It is clear that, the Rosenstein algorithm is inaccurate for HRV as all observation in HF band although the presence of many critical cases. The Wolf algorithm give scores for better accuracy than Rosenstein. Unfortunately, its results are stable in many cases and the HRV needs more sensitive and accurate tool to be predicted. The introduced Mazhar-Eslam algorithm has a sensitive distribution for different cases. The most critical case is **102** as the MVF indicates that by its frequency is 0.053 Hz and it is belong to VLF band. By reference to medical report of MIT-BIH data for case **102**, it is found that, case **102** is the most critical case of the data selection. Thus mean, the algorism of Mazhar-Eslam success to reach the SED more than other algorithms. **Table 1** support the sensitivity and accuracy of Mazhar-Eslam Algorithm.

The median of the three algorithms are presented in **table 2**. It clear that, the three algorithms observations are so closed to each other. But Mazhar-Eslam algorithm is the most logical and effective algorithm for HRV prediction.

Table 3 show statistical measurements of Rosenstein, Wolf, and Mazhar-Eslam algorithms. The deviation, percentage deviation, and variance can be calculated as shown in next equations. The patient case deviation D for normal HRV case is calculated as:

$$\boldsymbol{Deviation}\ (\boldsymbol{D}) = |\Omega_{M_{normal}} - \Omega_{M_{case}}| \qquad (2)$$

the cases percentage deviation is to be calculated as:

$$\boldsymbol{D}\% = \frac{D}{normal} \times 100\% \qquad (3)$$

and, the variance for algorithms should be calculated as

$$\boldsymbol{var} = (\Omega_{M_{normal}} - D)^2 \qquad (4)$$

From **table 3** it is seen that, the Rosenstein algorithm has the lowest SED, while the Wolf algorithm takes a computational place for SED. However, the Mazhar-Eslam algorithm shows more sensitivity than Wolf algorithm as presented in the **table 3**.

The arithmetic mean is introduced in **table 4.** Calculations shown in **table 4** verify the accuracy, sensitivity, and SED of Mazhar-Eslam algorithm. The arithmetic mean can be calculated as:

$$\overline{\Omega_M} = \frac{\sum_{i=1}^{n} \Omega_{Mi}}{n} \qquad (5)$$

It is worth to note that, Mazhar-Eslam algorithm spectral analysis of the given HRV reveals three distinct frequency bands in the modulation of humans HRs. The first band is very low frequency (VLF) band in the range (0.01-0.05 Hz), the second band is low frequency (LF) band in the range (0.06 -0.15 Hz) and the third band is a high frequency (HF) band in the range (0.16-0.50 Hz) as illustrated in **(Fig. 2)**.

Table 1 Percentage band of three algorithms

Parameter		MVF					
Serial	Method / Case	Rosenstein	Bands %	Wolf	Bands %	Mazhar-Eslam	Bands %
1	Normal	0.7586 (HF)		0.505 (HF)		0.4986 (HF)	HF=4.35%
2	101	0.2500 (HF)		0.1700 (HF)		0.0830 (LF)	
3	102	0.1600 (HF)		0.1300 (LF)		0.0530 (VLF)	
4	104	0.2100 (HF)		0.1300 (LF)		0.0700 (LF)	
5	106	0.2300 (HF)		0.1500 (LF)		0.0770 (LF)	
6	107	0.2000 (HF)		0.1300 (LF)		0.0667 (LF)	
7	109	0.2200 (HF)		0.1400 (LF)	HF=47.183%	0.0733 (LF)	
8	111	0.2400 (HF)		0.1600 (HF)		0.0800 (LF)	
9	112	0.2400 (HF)		0.1700 (HF)		0.0800 (LF)	
10	115	0.2800 (HF)		0.1700 (HF)		0.0930 (LF)	
11	117	0.2300 (HF)		0.1600 (HF)		0.0770 (LF)	
12	118	0.2500 (HF)		0.1600 (HF)		0.0833 (LF)	
13	119	0.2700 (HF)	HF = 100%	0.1700 (HF)		0.0900 (LF)	LF = 91.3%
14	121	0.2500 (HF)		0.1600 (HF)		0.0840 (LF)	
15	122	0.2300 (HF)		0.1600 (HF)		0.0770 (LF)	
16	123	0.2300 (HF)		0.1500 (LF)		0.0770 (LF)	
17	124	0.2500 (HF)		0.1700 (HF)		0.0840 (LF)	
18	200	0.2300 (HF)		0.1500 (LF)		0.0770 (LF)	
19	203	0.2300 (HF)		0.1500 (LF)	LF=52.17%	0.0770 (LF)	
20	212	0.2100 (HF)		0.1400 (LF)		0.0700 (LF)	
21	221	0.2100 (HF)		0.1400 (LF)		0.0700 (LF)	
22	230	0.2100 (HF)		0.1400 (LF)		0.0700 (LF)	
23	231	0.2200 (HF)		0.1500 (LF)		0.0740 (LF)	VLF=4.35%

Figure 2 The introduced MVF spectrum bands of HRVs.

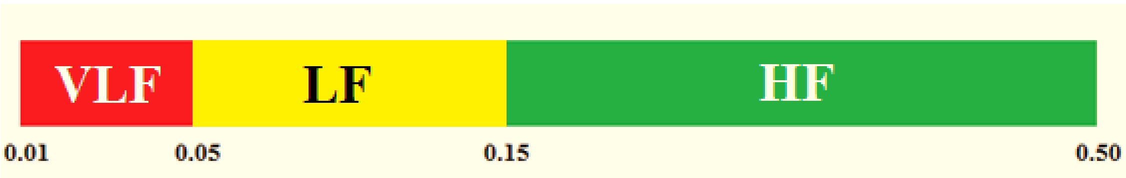

Table 2 Median of the three algorithms

Serial	Parameters	Median		
	Method / Case	Rosenstein	Wolf	Mazhar-Eslam
1	Normal	0.650000	0.494200	0.495800
2	101	0.085000	0.090000	0.080000
3	102	0.070000	0.050000	0.030000
4	104	0.085000	0.070000	0.070000
5	106	0.075000	0.065000	0.070000
6	107	0.045000	0.065000	0.060000
7	109	0.050000	0.050000	0.050000
8	111	0.060000	0.060000	0.060000
9	112	0.100000	0.060000	0.060000
10	115	0.100000	0.085000	0.090000
11	117	0.080000	0.045000	0.050000
12	118	0.090000	0.060000	0.070000
13	119	0.075000	0.088500	0.090000
14	121	0.090000	0.067000	0.070000
15	122	0.060000	0.045000	0.060000
16	123	0.050000	0.040000	0.060000
17	124	0.090000	0.045000	0.060000
18	200	0.060000	0.035000	0.070000
19	203	0.060000	0.056000	0.070000
20	212	0.058000	0.055000	0.060000
21	221	0.047000	0.058000	0.060000
22	230	0.070000	0.047000	0.050000
23	231	0.058000	0.048000	0.060000

Table 3 statistical measurements of the three algorithms

Serial	Parameters	Deviation (D)			PercentageDeviation $(D\%)$			Variance (var)		
	Method / Case	R	W	M-E	R	W	M-E	R	W	M-E
1	Normal	0.258600	0.005000	0.001400	51.720000	1.00000	0.280000	0.058274	0.245025	0.248602
2	101	0.394800	0.330100	0.415600	61.228290	66.0068	83.35339	0.062500	0.028900	0.006889
3	102	0.484800	0.370100	0.445600	75.186100	74.0052	89.37024	0.025600	0.016900	0.002809
4	104	0.434800	0.370100	0.428600	67.431760	74.0052	85.96069	0.044100	0.016900	0.004900
5	106	0.414800	0.350100	0.421600	64.330020	70.006	84.55676	0.052900	0.022500	0.005929
6	107	0.444800	0.370100	0.431900	68.982630	74.0052	86.62254	0.040000	0.016900	0.004449
7	109	0.424800	0.360100	0.425300	65.880890	72.0056	85.29884	0.048400	0.019600	0.005373
8	111	0.404800	0.340100	0.418600	62.779160	68.0064	83.95507	0.057600	0.025600	0.006400
9	112	0.404800	0.330100	0.418600	62.779160	66.0068	83.95507	0.057600	0.028900	0.006400
10	115	0.364800	0.330100	0.405600	56.575680	66.0068	81.34777	0.078400	0.028900	0.008649
11	117	0.414800	0.340100	0.421600	64.330020	68.0064	84.55676	0.052900	0.025600	0.005929
12	118	0.394800	0.340100	0.415300	61.228290	68.0064	83.29322	0.062500	0.025600	0.006939
13	119	0.374800	0.330100	0.408600	58.126550	66.0068	81.94946	0.072900	0.028900	0.008100
14	121	0.394800	0.340100	0.414600	61.228290	68.0064	83.15283	0.062500	0.025600	0.007056
15	122	0.414800	0.340100	0.421600	64.330020	68.0064	84.55676	0.052900	0.025600	0.005929
16	123	0.414800	0.350100	0.421600	64.330020	70.006	84.55676	0.052900	0.022500	0.005929
17	124	0.394800	0.330100	0.414600	61.228290	66.0068	83.15283	0.062500	0.028900	0.007056
18	200	0.414800	0.350100	0.421600	64.330020	70.006	84.55676	0.052900	0.022500	0.005929
19	203	0.414800	0.350100	0.421600	64.330020	70.006	84.55676	0.052900	0.022500	0.005929
20	212	0.434800	0.360100	0.428600	67.431760	72.0056	85.96069	0.044100	0.019600	0.004900
21	221	0.434800	0.360100	0.428600	67.431760	72.0056	85.96069	0.044100	0.019600	0.004900
22	230	0.434800	0.360100	0.428600	67.431760	72.0056	85.96069	0.044100	0.019600	0.004900
23	231	0.424800	0.350100	0.424600	65.880890	70.0060	85.15844	0.048400	0.022500	0.005476

Table 4 Arithmetic mean of the three algorithms

Serial	Parameters: Method / Case	Arithmetic Mean $\overline{\Omega_M}$: Rosenstein	Bands %	Wolf	Bands %	Mazhar-Eslam	Bands %
1	Healthy	0.6448	HF=4.35%	0.5001	HF=4.35%	0.4986	HF=4.35%
2	101	0.1320	LF=95.65%	0.0850	LF=95.65%	0.0830	LF = 91.3%
3	102	0.0790		0.0600		0.0530	
4	104	0.1120		0.0700		0.0700	
5	106	0.1180		0.0750		0.0770	
6	107	0.0950		0.0677		0.0667	
7	109	0.0996		0.0700		0.0733	
8	111	0.1325		0.0815		0.0800	
9	112	0.1288		0.0850		0.0800	
10	115	0.1560		0.0880		0.0930	
11	117	0.1263		0.0750		0.0770	
12	118	0.1420		0.0800		0.0833	
13	119	0.1355		0.0895		0.0900	
14	121	0.1356		0.0820		0.0840	
15	122	0.1125		0.0723		0.0770	
16	123	0.1100		0.0700		0.0770	
17	124	0.1322		0.0780		0.0840	
18	200	0.1025		0.0650		0.0770	
19	203	0.1122		0.0720		0.0770	
20	212	0.0996		0.0720		0.0700	
21	221	0.0998		0.0692		0.0700	
22	230	0.1065		0.0690		0.0700	
23	231	0.1112		0.0730		0.0740	VLF=4.35%

Table 5 Harmonic mean of the three algorithms

Serial	Parameters: Method / Case	Harmonic Mean HM: Rosenstein	Bands %	Wolf	Bands %	Mazhar-Eslam	Bands %
1	Normal	0.630061	HF=4.35%	0.499973	HF=8.7%	0.498542	HF=8.7%
2	101	0.013904	LF=73.91%	0.176538		0.163200	
3	102	0.020613		0.108333	LF=8.7%	0.073125	LF=8.7%
4	104	0.077422		0.136500		0.136500	
5	106	0.079615		0.024580	VLF=82.6%	0.024803	VLF=82.6%
6	107	0.057447		0.024375		0.024124	
7	109	0.049784		0.038889		0.049606	
8	111	0.065455		0.047682		0.041143	
9	112	0.082443		0.047962		0.024480	
10	115	0.121543		0.025500		0.044780	
11	117	0.096359		0.038230		0.039344	
12	118	0.111625		0.041143		0.042532	
13	119	0.089011		0.025601		0.025642	
14	121	0.100614		0.042149		0.042532	
15	122	0.073145		0.023351		0.024407	
16	123	0.067647		0.036735		0.040909	
17	124	0.094406		0.038410		0.041351	
18	200	0.042245		0.022183		0.024803	
19	203	0.073145	VLF=21.74%	0.024092		0.024803	
20	212	0.054214		0.039828		0.024231	
21	221	0.058779		0.024119		0.024231	
22	230	0.068108		0.038256		0.038889	
23	231	0.076867		0.039937		0.024324	

Table 5 shows one of the most powerful measurement called harmonic mean. The harmonic mean shows the Wolf and Mazhar-Eslam algorithms in same frequency band for different cases in **table 5.** The Mazhar-Eslam algorithm success to reach the highest level of SED than Wolf because its harmonic mean is more precise and lower than wolf. The harmonic mean can be calculated as:

$$\boldsymbol{HM} = \frac{\boldsymbol{n}}{\sum_{\boldsymbol{i}=1}^{\boldsymbol{n}} \frac{1}{\Omega_{\boldsymbol{Mi}}}} \tag{6}$$

Thus, Mazhar-Eslam algorithm achieve the most SED than Wolf and Rosenstein algorithms for all statistical measurements as shown in previous tables. The **table 6** presents the comparison of distribution frequency bands for all three algorithms, also when applying arithmetic and harmonic mean on the three algorithms.

Table 6 Frequency bands distribution for three algorithms in different statistics

Ω			***AM***			***HM***		
Rosenstein								
100%	**0%**	**0%**	**4.35%**	**95.65%**	**0%**	**4.35%**	**73.91%**	**21.74%**
Wolf								
47.83%	**52.17%**	**0%**	**4.35%**	**95.65%**	**0%**	**8.7%**	**8.7%**	**82.6%**
Mazhar-Eslam								
4.35%	**91.3%**	**4.35%**	**4.35%**	**91.3%**	**4.35%**	**8.7%**	**8.7%**	**82.6%**

IV. CONCLUSION

HRV has good prediction level in modelling the heart risk. It needs a sensitive tool for accurate analysis Thus, in this work we introduce the most selective and reliable method for achieve this purpose, which concluded in Mazhar-Eslam variability frequency (MVF). Which approved to be the best qualitative method in sensitivity measurements than others. Rosenstein algorithm presented lower sensitive MVF estimates than Wolf algorithm to get variations in local dynamic stability from small data sets. The data confirming that, the idea that latest outcome observations from the inability and ability of the Wolf algorithm and Rosenstein algorithm, respectively, to estimate adequately MVF of attractors with significant of convergence. Therefore, the Mazhar-Eslam algorithm seems to be more suitable to evaluate local dynamic stability for any data sets especially small one like HRV. When the data set size raise, it be preferred to make the observations of the Mazhar-Eslam algorithm more convenient, although other means as raising the sample size might have a same impact. Mazhar-Eslam algorithm takes the same strategy of Rosenstein method for initial step for calculation the lag and mean period, but it uses the merits of Discrete Wavelet Transform (DWT) instead of Fats Fourier Transform (FFT) unlike Rosenstein. After that, it completes steps of calculating Ω_M as Wolf method. Mazhar-Eslam method care of all variants especially the small ones like that are in HRV. These variants may contain many important data to diagnose diseases as R-R interval. Thus, the Mazhar-Eslam algorithm for MVF $\overline{\Omega_M}$ takes all of Ω_Ms. So that makes it to be robust predictor, which appear in different results among (Mazhar-Eslam, Wolf, and Rosenstein) algorithms.

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