West Indian Journal of Engineering Vol. 24, No. 1, (July 2001) Technical Paper (Alam, Aleem Islam & Hoque) 42 - 54

A Methodology for Evaluating Physical System Performance using Digital Technique

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This paper represents a methodology for evaluating the physical system performance. Auto-correlation and cross-correlation phenomena are the basis for the development of this methodology. With a view to develop this methodology, a computer model was designed. This methodology was validated with different ECG signal analysis. This validation leads to conclude that the proposed methodology may be accepted as a method for analysing the system performance.

1. Introduction

Auto-correlation and cross-correlation phenomena are many of the preferable techniques to evaluate the accuracy level of a physical system. The evaluation will be made by determining the similarities or dissimilarities of the state variable(s) of the test system with the state variable(s) of the reference system. Auto-correlation measures the similarity or coherence between the state variable(s) of the given system with the replica of those state variable(s) delayed by a variable amount of time. Cross-correleation measures the similarity between the state variable(s) of a system with the time delayed version of state variable(s) of other systems [1]. Yarlagadda and Hershey [2] used auto-correlation phenomenon to develop a new robust synchronisation method and simulated its behaviour over a highly degraded binary symmetric channel. Samite and Pursley [3] used cross-correlation phenomenon for efficient implementation of LPT and code book searching. Pinto and Childers [4] used the modified auto-correlation method for the detection of pitch of a voice signal. In this paper, an attempt has been made to develop a methodology based on auto-correlation and cross-correlation phenomena for evaluating the performance of a physical system. In this research, the ECG system was taken as the physical system to validate the proposed methodology.

2. Objective

With a view to characterise the physical system, the state variable(s) will be transformed into electrical signal(s). Therefore, the electrical signal(s) will have to be quantitatively analysed based on auto-correlation and cross-correlation phenomena to assess the system performance.

3. Methodology

To fulfill the objective of this paper, the following steps were to be taken:

(a) To formulate a mathematical model for the auto-correlation and cross-correlation sequence and then programme the model with an appropriate computer language.

(b) State variable(s) of a reference system as well as the test system will be collected by converting from its original state into electrical signal(s) through an appropriate transducer and storing them with memory/storage oscilloscope.

(c) Then the signal(s) was converted from analog to digital form with the A/D converter.

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Pertinent discussion will be published in July, 2002 West Indian Journal of Engineering if received by May, 2002.

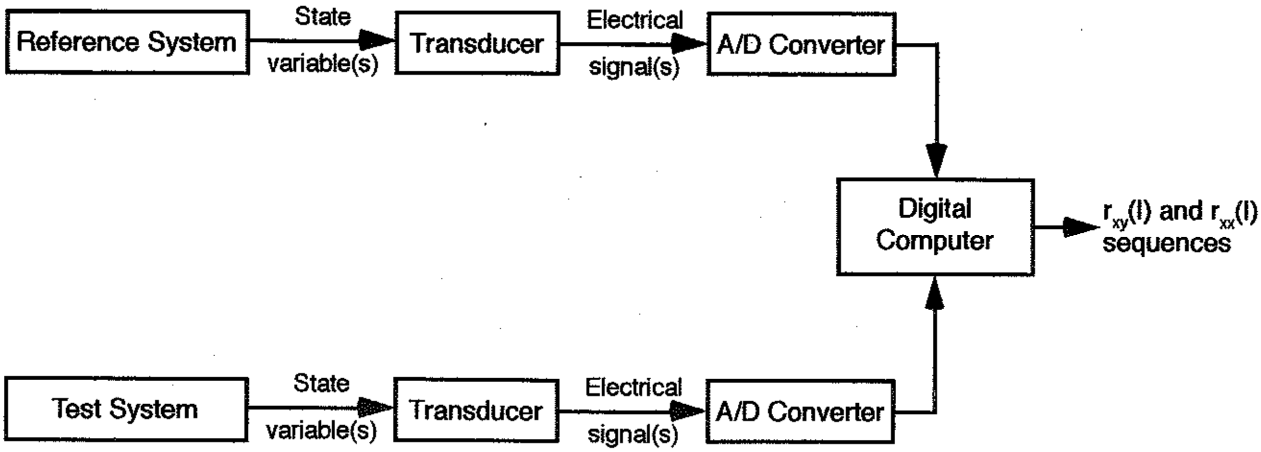

FIGURE 1: *Model for Evaluation of Physical System Response*

(d) Then with the designed model, auto-correlation and cross-correlation coefficients were computed from these digital signals.

(e) Finally, the curves showing the lag parameter versus auto-correlation normalised value and lag parameter versus cross-correlation normalised value were drawn to assess/characterise the system performance/response.

4. Model Formulation

Figure 1 represents the model of the proposed methodology. The performance of the system is tested with respect to a reference system which has been characterised by the state variable(s). This variable(s) has been converted into analog electrical signal by analog to digital converter. Similarly, the state variable(s) of the reference system is converted into digital signal. A computer programme is developed with a Fortran-90 high level language based on the algorithm shown in **Figure 2** for the computation of the auto-correlation and cross-correlation sequences. The numerical values for the said sequence for the corresponding lag parameter has been considered for the prediction of the accuracy level of the test system. The state variable(s)/ vector(s) of the reference system and test system are represented by the following state equations [5].

For reference system:

$$Y(t) = \begin{bmatrix} y_1(t) \\ y_2(t) \\ \cdot \\ \cdot \\ y_k(t) \end{bmatrix} \qquad \text{.......} \quad (1)$$

For the test system:

$$X(t) = \begin{bmatrix} x_1(t) \\ x_2(t) \\ \cdot \\ \cdot \\ x_k(t) \end{bmatrix} \qquad \text{.......} \quad (2)$$

When the state vector(s) signal(s) is converted into digital form, the state equations may be written in the following form:

For the reference system:

$$Y(n) = \begin{bmatrix} y_1(n) \\ y_2(n) \\ \cdot \\ \cdot \\ y_k(n) \end{bmatrix} \qquad \text{.......} \quad (3)$$

For the test system:

$$X(n) = \begin{bmatrix} x_1(n) \\ x_2(n) \\ \cdot \\ \cdot \\ x_k(n) \end{bmatrix} \qquad \text{.......} \quad (4)$$

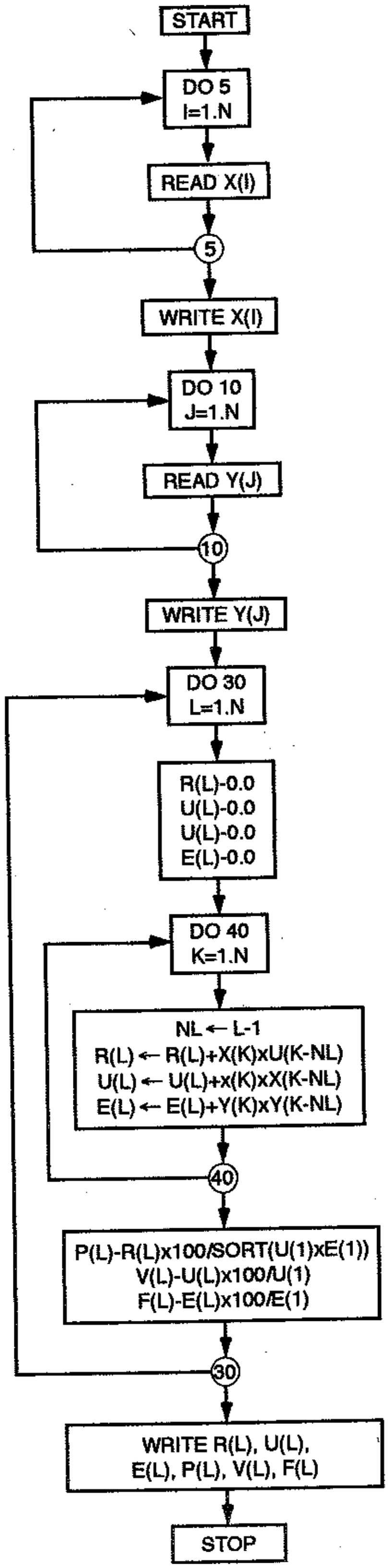

FIGURE 2: *Flow Chart Representation of the Algorithm used in the Computation of $r_{xx}(1)$ and $r_{xy}(1)$*

The cross-correlation for y(n) and x(n) is a sequence $r_{xy}(e)$ is defined in the following equations:

$$r_{xy}(e) = \sum_{n=-\infty}^{n=+\infty} x(n)y(n-e)$$

where $e = 0, \pm 1, \pm 2$ ....(5)

or equivalently,

$$r_{xy}(e) = \sum_{n=-\infty}^{n=+\infty} x(n+e)y(n)$$

where $e = 0, \pm 1, \pm 2$ ....(6)

The index e in the above relations is the time shift (or lag) parameter and the subscripts xy on the cross-correlation sequences $r_{xy}(e)$ indicates the sequences being correlated. The order of the subscripts as with x preceding y means the direction in which one sequence is being shifted relative to another. In Eqn. (5), the sequence x(n) is left unshifted where y(n) is shifted by e units in time, to the right for e being positive, and to left for e being negative. Similarly, in the case of Eqn. (6), y(n) is left unshifted and x(n) is shifted by e units in time, to the left for e being positive and to the right for e being negative, but shifting x(n) to the left by e units relative to the y(n) is equivalent to shifting of y(n) to the right by 1 unit relative to x(n). Hence, both of the computations yield identical cross-correlation sequence.

If we reverse the role to the x(n) and y(n) in Eqn. (6) and hence reverse the order of the indices xy, we obtain the cross-correlation sequence as

$$r_{yx}(e) = \sum_{n=-\infty}^{n=+\infty} y(n)x(n-e) \quad \text{.......................... (7)}$$

equivalently,

$$r_{yx}(e) = \sum_{n=-\infty}^{n=+\infty} y(n+e)\,x(n) \quad \text{.......................... (8)}$$

So, it can be concluded that

$$r_{xy}(e) = r_{yx}(-e) \quad \text{.. (9)}$$

Where x(n) = y(n), we have the auto-correlation of x(n), which is then defined as by the sequence

$$r_{xx}(e) = \sum_{n=-\infty}^{n=+\infty} x(n)x(n-e) \quad \text{..........................(10)}$$

equivalently,

$$r_{xx}(e) = \sum_{n=-\infty}^{n=+\infty} x(n+e)\,x(n) \quad \text{........................(11)}$$

It can also be shown that

$$r_{xx}(0) \geq r_{xx}(e) \text{ for any } e \neq 0 \quad \text{....................(12)}$$

This means that the auto-correlation sequence of a signal has its maximum value at zero lag. Since scaling of amplitude is not important, it is often desirable in practice to normalise the auto-correlation and auto-correlation sequences to the range from -1 to 1. In the case of the auto-correlation sequence, we may simply divide $r_{xx}(e)$ by $r_{xx}(0)$. Thus, the normalised auto-correlation [1] can be defined by

$$\rho_{xx}(e) = \frac{r_{xx}(e)}{r_{xx}(0)} \quad \text{.. (13)}$$

Similarly, the normalised cross-correlation sequence can be defined by

$$\rho_{xy}(e) = \frac{r_{xy}(e)}{\sqrt{r_{xx}(0)r_{yy}(0)}} \quad \text{.......................... (14)}$$

It may be demonstrated that the cross-correlation sequence satisfies the following property

$$r_{xy}(e) = r_{yx}(-e) \quad \text{.. (15)}$$

With y(n) = x(n), this relation results the auto-correlation sequence of

$$r_{xx}(e) = r_{xx}(-e) \quad \text{(16)}$$

Hence the cross-correlation and auto-correlation functions are even functions. Consequently, it suffices to compute $r_{xx}(e)$ or $r_{xy}(e)$ for $e \geq 0$. Therefore, the computer programmes were developed for the computing $r_{xx}(e)$ or $r_{xy}(e)$ sequences for different state vectors in accordance with the algorithm shown in **Figure 2**.

5. Experimental Model

An experimental model as shown in **Figure 1** was set up in the laboratory. The physical signals used in this experiment were stored in the form of analog electrical signal. For this purpose, the physical signal was first converted into analog electrical signals by suitable devices/transducers. Then, a digitiser machine with a built-in computer system which acts as an A/D converter was used for conversion of analog signals to digital signal. It consists of a computer, computer system oscilloscope CSO, preamplifier and a power unit. The electrical signal is fed directly from a memory storage oscilloscope. Since the strength of the signal is not sufficient, the amplitude of the signal is amplified by a preamplifier stage. In the computer system oscilloscope, the signal is levelled as required. The model was calibrated with the known electrical signals obtained from signal generator.

Therefore, the two ECG signals known as test signals were taken from Myocardial Infarction patients. Then using this model, $r_{xx}(e)$ and $r_{xy}(e)$ for those ECG signals were calculated to evaluate the test ECG signals with respect to a known standard ECG signal of a normal heart, which was taken as reference. It is noted that the digitised value of those ECG signals were collected at the rate of 50 sample/sec. from the said model [6].

6. Result

It is experimentally observed that when the frequency of the two signals is equal, the similarity between the two signals is the highest considering $r_{xx}(e)$ and $r_{xy}(e)$, irrespective of the shape of the signals. It indicates that the similarity depends upon frequency.

Computation of $r_{xy}(e)$ for two test ECG signals with respect to reference ECG and $r_{xx}(e)$ were made at all the leads. These leads of ECG are commonly known as i.e. I-III, avf, avl, avr, V_1, V_2, V_3, V_4, V_5 and V_6, respectively [7]. The $r_{xx}(e)$ and $r_{xy}(e)$ Vs. lag parameters (e) were tabulated for corresponding leads which are shown in **Tables 1 - 12**, respectively. The degree of dissimilarity between test signal and reference signal is to be considered significant when max $r_{xx}(e)$ and/or $r_{xy}(e)$ for $e \geq 0$ is lower than 80%. The concluding results were shown in **Table 13**.

Therefore, **Table 13** shows that the significant changes were at leads V_5, V_6, II, III, avf of ECG for 1st test case and at leads V_4, V_5, V_6, I, II, III, avf & avl for 2nd test case.

7. Discussion and Conclusion

The diagnosis of the various heart disease can be generally obtained by investigating the chart shown in **Table 14** [8]. The different disease of Myocardial Infarction can be predicted with respect to various changes at different leads.

ECG consists of 12 leads with 3 sections. Section 1 consists of six leads such as V_1 - V_6 known as pericardial or chest leads. Section 2 consists of three leads such as I - III. These are known as standard limb leads, and Section 3 consists of another three leads such as avR, avL and AvF. Those are known as augmented limb leads.

Various heart disease can be predicated for a test case in comparison with a reference case observing the changing pattern in V_1 - V_6, I - III, avr, avl and avf on ECG plot with the help of **Table 14**.

Therefore, the significant changes at different Tables were obtained from the model shown in **Table 13**. The first test case indicates that there are infarction, namely:

(i) Lateral infarct and
(ii) Infarction in two walls which is known as Interio-lateral

In the second test case, there are the presence of infarctions in two walls, which is known as Extensive Circular Apical Infarction.

Now, it can be concluded that this methodology can also be applied for the diagnosis of the different types of infarction for human hearts by analysing the ECG signal.

TABLE 1: *Maximum Percentage of Normalised Cross-Correlation and Corresponding Auto-Correlation Coefficients for ECG Signal of Chest Lead (V_1)*

	Auto-Correlation Coefficients			Cross-Correlation Coefficients	
Lag Parameter (l)	AA	BB	CC	AB	AC
0	100	100	100	97.17	97.64
10	90.07	89.31	88.56	90.65	90.15
20	83.31	82.50	82.18	83.29	83.97
30	75.23	72.56	73.61	74.60	76.07
40	67.56	69.22	69.19	67.61	69.27
50	59.57	59.44	59.02	59.80	60.48
60	51.84	52.77	52.49	52.36	53.66
70	45.15	42.62	43.93	44.14	45.98
80	37.12	37.09	38.31	36.90	39.21
90	29.21	29.16	29.44	29.45	30.59
100	21.42	22.74	22.77	22.79	23.96
110	13.79	13.15	14.27	13.50	15.14
120	06.51	06.16	07.76	06.85	07.74
129	00.56	00.80	00.79	00.88	00.77

TABLE 2: *Maximum Percentage of Normalised Cross-Correlation and Corresponding Auto-Correlation Coefficients for ECG Signal of Chest Lead (V_2)*

	Auto-Correlation Coefficients			Cross-Correlation Coefficients	
Lag Parameter (l)	AA	BB	CC	AB	AC
0	100	100	100	94.63	95.98
10	87.30	86.41	89.09	87.07	88.46
20	79.72	78.88	80.69	78.87	80.30
30	72.35	69.02	73.20	70.08	73.21
40	65.56	66.94	65.46	63.82	66.51
50	58.65	57.16	58.18	57.45	59.48
60	52.09	51.35	52.30	50.11	51.66
70	42.95	42.12	44.37	40.39	43.18
80	36.34	37.79	37.56	35.28	37.51
90	29.52	30.32	30.34	29.28	30.43
100	22.61	24.58	23.05	22.47	23.54
110	15.22	14.72	15.08	14.05	15.42
120	07.34	07.45	06.81	06.79	07.76
129	00.76	00.80	.00.98	00.79	00.93

TABLE 3: *Maximum Percentage of Normalised Cross-Correlation and Corresponding Auto-Correlation Coefficients for ECG Signal of Chest Lead (V_3)*

	Auto-Correlation Coefficients			Cross-Correlation Coefficients	
Lag Parameter (l)	AA	BB	CC	AB	AC
0	100	100	100	93.71	94.61
10	88.35	82.26	86.43	85.94	88.90
20	79.78	75.79	79.90	78.46	80.98
30	72.85	70.41	73.03	72.45	72.62
40	66.26	70.33	64.28	66.10	64.95
50	58.73	54.88	56.36	56.82	57.11
60	50.66	48.62	50.82	49.76	49.64
70	43.89	43.22	44.51	43.86	44.13
80	35.36	40.12	37.75	36.05	34.87
90	28.40	26.95	29.02	27.99	26.85
100	22.08	21.28	21.45	21.91	22.39
110	14.77	15.91	13.68	15.94	14.71
120	06.15	10.48	07.29	08.46	07.48
129	00.59	00.69	00.88	00.64	00.75

TABLE 4: *Maximum Percentage of Normalised Cross-Correlation and Corresponding Auto-Correlation Coefficients for ECG Signal of Chest Lead (V_4)*

	Auto-Correlation Coefficients			Cross-Correlation Coefficients	
Lag Parameter (l)	AA	BB	CC	AB	AC
0	100	100	100	93.75	90.18
10	88.03	84.26	82.58	86.73	87.65
20	78.89	77.51	70.41	78.15	79.56
30	71.97	69.97	62.60	72.48	70.68
40	65.14	67.58	58.45	67.87	67.83
50	58.58	56.32	55.36	60.95	64.54
60	50.76	49.37	48.06	54.41	59.71
70	41.77	41.66	38.63	46.00	51.47
80	34.72	35.58	33.85	39.41	42.32
90	28.11	28.10	30.83	31.08	35.83
100	21.72	20.78	25.52	22.60	31.20
110	15.30	13.43	15.73	15.21	22.18
120	06.53	07.03	06.02	08.02	11.26
129	00.69	00.56	01.09	00.64	02.19

TABLE 5: *Maximum Percentage of Normalised Cross-Correlation and Corresponding Auto-Correlation Coefficients for ECG Signal of Chest Lead (V_5)*

Lag Parameter (l)	Auto-Correlation Coefficients			Cross-Correlation Coefficients	
	AA	BB	CC	AB	AC
0	100	100	100	90.10	79.56
10	76.84	81.03	79.34	80.23	73.36
20	65.90	74.90	72.46	72.15	69.31
30	59.45	66.91	66.77	64.37	68.88
40	55.80	64.34	61.97	60.28	64.15
50	51.25	54.85	52.75	57.52	56.18
60	44.86	47.72	42.54	49.42	48.75
70	35.89	39.76	35.73	41.34	42.97
80	30.62	33.04	28.90	34.25	36.53
90	27.54	26.83	21.51	27.74	28.16
100	21.47	20.37	13.92	22.47	18.26
110	15.37	12.85	07.28	15.32	10.53
120	06.15	06.44	05.14	07.29	05.59
129	00.56	00.61	00.44	00.61	00.52

TABLE 6: *Maximum Percentage of Normalised Cross-Correlation and Corresponding Auto-Correlation Coefficients for ECG Signal of Chest Lead (V_6)*

Lag Parameter (l)	Auto-Correlation Coefficients			Cross-Correlation Coefficients	
	AA	BB	CC	AB	AC
0	100	100	100	60.10	64.23
10	52.42	68.24	72.73	57.93	57.59
20	39.85	63.07	65.52	52.68	54.79
30	34.90	54.42	61.51	46.68	51.51
40	34.59	50.00	57.02	42.78	46.21
50	48.18	44.74	50.31	38.85	38.81
60	32.49	40.49	39.46	33.30	31.94
70	22.02	32.82	36.69	26.74	27.83
80	17.86	29.75	31.20	24.03	25.83
90	16.14	23.51	26.03	21.03	21.24
100	14.11	18.49	16.15	17.56	13.98
110	10.54	10.50	11.14	11.12	09.23
120	02.76	05.24	07.21	03.85	03.61
129	00.19	00.53	00.63	00.40	00.42

TABLE 7: *Maximum Percentage of Normalised Cross-Correlation and Corresponding Auto-Correlation Coefficients for ECG Signal of Limb Lead I*

	Auto-Correlation Coefficients			Cross-Correlation Coefficients	
Lag Parameter (l)	AA	BB	CC	AB	AC
0	100	100	100	93.64	88.41
10	82.05	88.14	80.49	85.63	80.38
20	72.35	81.67	74.55	79.82	75.59
30	66.25	74.93	69.60	73.44	70.33
40	61.33	70.15	63.19	67.41	62.91
50	55.06	58.79	53.44	59.92	54.00
60	49.05	51.70	45.15	54.19	47.98
70	40.41	44.47	41.51	46.29	42.03
80	34.09	38.61	35.64	39.06	36.07
90	28.82	28.28	26.15	31.47	28.23
100	23.26	21.29	18.15	25.08	21.17
110	16.55	14.76	13.28	19.10	16.84
120	08.19	08.58	08.41	09.45	07.94
129	00.43	00.75	00.50	00.68	00.65

TABLE 8: *Maximum Percentage of Normalised Cross-Correlation and Corresponding Auto-Correlation Coefficients for ECG Signal of Limb Lead II*

	Auto-Correlation Coefficients			Cross-Correlation Coefficients	
Lag Parameter (l)	AA	BB	CC	AB	AC
0	100	100	100	67.75	69.75
10	61.86	66.75	75.18	67.67	67.62
20	53.06	59.92	63.75	61.56	63.71
30	47.74	55.28	55.98	51.24	52.92
40	46.07	69.68	52.28	46.73	48.62
50	47.32	43.76	48.41	43.24	46.22
60	36.24	36.52	42.94	40.44	39.29
70	25.97	31.05	35.77	29.36	31.39
80	19.18	35.28	29.22	22.25	22.29
90	17.87	19.41	30.08	17.01	19.00
100	12.04	13.54	22.04	13.99	15.48
110	07.62	08.13	13.85	10.16	12.23
120	03.45	04.48	40.91	05.85	06.02
129	00.17	00.29	00.52	00.26	00.40

TABLE 9: *Maximum Percentage of Normalised Cross-Correlation and Corresponding Auto-Correlation Coefficients for ECG Signal of Limb Lead III*

	Auto-Correlation Coefficients			Cross-Correlation Coefficients	
Lag Parameter (l)	AA	BB	CC	AB	AC
0	100	100	100	81.11	79.26
10	67.58	80.73	75.15	74.40	68.68
20	58.29	75.52	69.10	69.02	66.76
30	51.87	65.53	67.71	61.48	64.09
40	50.27	64.39	62.33	60.99	58.91
50	48.61	52.73	49.00	60.73	53.82
60	39.23	48.32	42.41	49.00	47.50
70	32.10	39.98	39.61	43.07	43.46
80	26.20	35.55	31.30	38.51	36.73
90	24.07	27.89	25.51	33.61	32.24
100	20.16	22.99	16.69	26.60	22.67
110	13.99	12.58	12.66	16.84	15.93
120	07.79	06.94	07.98	10.93	08.53
129	00.49	00.68	00.39	00.73	00.74

TABLE 10: *Maximum Percentage of Normalised Cross-Correlation and Corresponding Auto-Correlation Coefficients for ECG Signal of Limb Lead avR*

	Auto-Correlation Coefficients			Cross-Correlation Coefficients	
Lag Parameter (l)	AA	BB	CC	AB	AC
0	100	100	100	97.13	96.95
10	90.36	89.95	90.02	90.22	90.99
20	82.73	82.98	82.88	82.70	82.66
30	75.13	74.65	74.95	74.71	74.42
40	67.33	69.08	67.42	65.36	67.06
50	59.18	59.82	59.58	57.83	59.87
60	51.61	53.00	52.47	51.25	51.35
70	45.45	44.61	44.43	43.97	44.20
80	37.87	38.36	37.45	35.94	37.36
90	30.15	29.88	29.52	28.23	29.57
100	21.82	22.99	22.10	21.47	21.21
110	14.12	14.67	14.68	14.09	14.05
120	06.86	07.63	07.17	07.54	08.03
129	00.78	00.69	00.72	00.69	00.76

TABLE 11: *Maximum Percentage of Normalised Cross-Correlation and Corresponding Auto-Correlation Coefficients for ECG Signal of Limb Lead avL*

	Auto-Correlation Coefficients			Cross-Correlation Coefficients	
Lag Parameter (l)	AA	BB	CC	AB	AC
0	100	100	100	96.96	94.12
10	90.65	89.44	84.78	89.95	86.47
20	83.56	82.42	78.32	83.56	78.28
30	75.81	73.25	68.85	74.02	68.75
40	67.86	68.40	69.02	66.54	63.24
50	59.55	59.81	56.67	59.39	55.62
60	51.76	52.96	49.81	52.65	47.33
70	45.58	43.53	39.90	44.67	39.41
80	37.85	37.32	36.47	36.85	33.47
90	29.79	30.01	27.14	29.43	26.06
100	21.55	23.27	21.34	22.33	18.49
110	13.71	14.10	11.66	14.07	10.77
120	06.92	06.99	06.45	06.72	05.75
129	00.78	00.71	00.63	00.75	00.69

TABLE 12: *Maximum Percentage of Normalised Cross-Correlation and Corresponding Auto-Correlation Coefficients for ECG Signal of Limb Lead avF*

	Auto-Correlation Coefficients			Cross-Correlation Coefficients	
Lag Parameter (l)	AA	BB	CC	AB	AC
0	100	100	100	70.01	69.88
10	57.05	75.15	76.25	66.04	69.34
20	47.74	67.87	66.30	61.75	67.10
30	42.03	64.77	57.64	55.50	52.09
40	43.70	66.83	60.19	49.57	49.04
50	40.89	50.67	50.14	46.70	49.76
60	35.44	42.54	42.26	42.25	47.65
70	26.08	38.69	35.51	36.71	38.63
80	21.30	34.14	32.12	27.72	29.11
90	20.60	24.59	28.06	23.81	26.58
100	19.27	16.74	21.88	19.68	23.12
110	11.68	13.49	13.91	14.43	18.06
120	06.03	06.30	07.11	08.29	07.51
129	00.32	00.66	01.26	00.49	00.48

Note: Explanation of the various terms used in different tables (1 - 12).

A → Refers to normal heart (reference) ECG signal
B → Refers to first test heart ECG signal
C → Refers to second test heart ECG signal
AA → Indicates auto-correlation of A
BB → Indicates auto-correlation of B
CC → Indicates auto-correlation of C
AB → Indicates cross-correlation between A & B
AC → Indicates cross-correlation between A & C

TABLE 13: *Change in Different ECG Leads for Various Two Test Case with respect to Reference*

Name of Leads	Comparing of the Test ECG Signal with Reference				
	Auto-Correlation		Cross-Correlation Dissimilarity		
Chest Leads	1st Test ECG Signal	2nd Test ECG Signal	1st Test ECG Signal	2nd Test ECG Signal	Remarks
V_1	-	-	-	-	For 1st test case
V_2	-	-	-	-	change at V_5, V_6.
V_3	-	-	-	-	For 2nd test case
V_4	-	Significant	-	-	major change at
V_5	Significant	Significant	-	Significant	V_4, V_5, V_6
V_6	Significant	Significant	Significant	Significant	
Limb Leads	1st test case	2nd test case	1st test case	2nd test case	
I	Significant	-	-	Significant	For 1st test case
II	Significant	Significant	Significant	Significant	major change at
III	Significant	Significant	Significant	Significant	I, II, III & avf.
avr	-	-	-	-	For 2nd test case
avl	-	Significant	-	-	major change
avf	Significant	Significant	Significant	Significant	I, II, III, avl & avf

Note for Table (13): Changes occur at following leads:

For 1st Test ECG: V_5, V_6, I, II, III, avF

For 2nd Test ECG: V_4, V_5, V_6 & I, II, III, avl, avf.

TABLE 14: *Localisation of Myocardial Infarction*

Area of Infarction	Changes in the ECG	
1. Anterior infarction:	Limb leads	Chest leads
(a) Antero-septal		V_{1-3}
(b) Antero-apical		V_{3-5}
2. Lateral infarct	I, avl	V_{5-6}
3. High lateral infarct	avl	
4. Inferior (Posterior) infarct:		
Postero-diaphragmatic or Inferior infarct	II, III, avf	V_1, V_2 or V_3
5. Infarction in two walls:		
a) Antero-lateral	I, avl	V_{1-6}
b) Intero-lateral	II, III, avf	V_{5-6}
c) Antero-interior	II, III, avf	V_{1-4}
d) Extensive circular apical infarction	I, II, III, avl, avf	V_{1-6}
6. Right ventricular infarction	Occasional II, III	$V_{2-4}R$ Occasional V_{1-3}

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