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Identification of ST Segment ECG Signal Using Degestseg Wavelet Detection

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***Abstract*– Chest pain is an early sign of a person experiencing cardiac function abnormalities. Characteristic changes in ST segment elevation of ST segments which can be followed by T wave inversion is an early sign of heart dysfunction. In this paper, the ST segment of the electrocardiogram signal will be identified using new wavelet methods. Specific form of the electrocardiogram signal which gives angle, amplitude, phase and certain frequency is used as the basis of new wavelet DeGeSTSeg formation. The first thing to do is to detect the R peak of the electrocardiogram signal. Furthermore, the Q signal and the S signal is detected after the R signal is determined. ST segment was detected after all components of the signal are identified. The Basis of DeGeSTSeg is a new wavelet to detect the ST segment of the electrocardiogram signal. The originality of this study is applied to the electrocardiogram signal ST segment, with varying leads and was analyzed for each component Q, R, S and ST segment of the electrocardiogram signal. The results show the effectiveness of the utility DeGeSTSeg wavelet algorithm to detect the wave of the electrocardiogram STSegmen 6-lead electrocardiogram. With the sensitivity = 93% by using Receiver Operating characteristics of the community (ROC) curve.**

***Index Terms*– DeGeSTSeg, Electrordiogram, ST Segment and Wavelet Detection**

I. INTRODUCTION

COMPUTERIZED techniques in the identification of the electrocardiogram itself have been made since the last four decades. Several algorithms have been used in its development. The purpose of these algorithms is to improve the accuracy and makes identification of these have the same ability as a cardiologist. Research on the electrocardiogram signal and its classification is mostly just detect the QRS complex, these techniques have drawbacks for some of the electrocardiogram to detect, especially in detecting ST Segment as well as natural changes in the electrocardiogram signal. One model that is used to identify abnormalities in the electrocardiogram signal with Wavelet detection. Wavelet is a wave in smaller and shorter size when compared with sinusoidal signals in general, where the energy is concentrated at certain time intervals which are used as a tool for analyzing transient, non-stationarity, and time variant phenomena. Methods for analyzing signal wave that being localized may use wavelet detection. Wavelet detection, giving techniques at the electrocardiogram signal processing, divides electrocardiogram signal into several scales, making it easier to analyze signals at specific frequencies.

II. FUNDAMENTAL THEORY

A. ST Segment

ST segment connects the QRS complex and T wave and a duration of 80-120 ms. This segment begins at the J point, that is a junction between the QRS complex and ST segment and ends at the beginning of the T wave However, since it is usually difficult to determine exactly where the ST segment ends and the T wave begins, the relationship between ST segment and T wave should be examined together. Typical ST segment duration is usually around 80 ms, which is essentially equivalent to the level of PR and TP segment. ST segment changes as shown in Fig. 1.

Fig. 1: *ST Segment changes with Chest pain (Shirley, 2005); A) Flatening ST Segment, B) T wave planar, C)ST Segment Depression (D) downsloping ST Segmen*

Normal ST segment slightly concave upward. ST segment flat, slightly sloping, or may indicate coronary ischemia. ST segment elevation can indicate myocardial infarction. Normal ST segment is usually coupled with a smooth T wave, making it difficult to determine where the ST segment ends and the T wave begins. One of the changes of the first and the most refined in the ST segment is leveling the segment, and this produces a more obvious angle between the ST segment and T wave.

B. Wavelet

A wave is usually defined as an oscillatory function of time or space, for example, a sinusoidal wave. A wavelet is a short wave or small wave whose energy is concentrated in a time interval to provide transient analysis capabilities, non stationer, or the phenomenon of time-varying. Wavelet can be used as a tool to perform mathematical decomposition of a signal into components of different frequencies, so that each component can be studied using the appropriate scale of resolution. Therefore, the wavelet is known as a tool to perform analysis based on the scale.

Short waves have the advantage when compared to Fourier style shift methods in analyzing non-stationary signals.

A wave is normally defined as an oscillation function of time such as sinusoidal waves. Fourier analysis is a wave analysis where this analysis expands signals or function of a sinusoidal wave having a periodic phenomenon, not changing time (time invariant), and stationary.

In the short wave range over used term translation and scale, because the term of time and frequency is already used in the Fourier style shift. Translation is the location of the modulation window when it is slide along the signal, associated with timing information. Scale is related with frequency, high scale (low frequency) associated with the global information of a signal, while the low scale (high frequency) associated with the detail information. Continuous Wavelet Transform (CWT):

$$\gamma(s,\tau) = \int f(t)\psi^*_{s,\tau}(t)dt \quad (1)$$

Explanation:

$\gamma(s,\tau)$	: Signal Function,
s	: Scale
τ	:(translastion) as new dimension.
$f(t)$	: Input Signal.
$\psi^*_{s,\tau}(t)$	: Basic Function Wavelet,
*	:Complex Conjugate.

III. NEW FORM WAVELET DETECTION

In this study testing a new Wavelet detection by performing cross-correlation between ST Segment electrocardiogram signal with a new type of wavelet that has been obtained under the appropriate signal pattern of ST Segment electrocardiogram signal.

The equation used for the cross-correlation is as follows:

$$R_{yx}(m) = \frac{1}{N}\sum_{n=1}^{N-m+1} y(n)x(n+m-1) \quad (2)$$

Where, m = 1,2,3,…,N+1

Explanation:

R_{yx}	: Correlation result
N	: Amount of Sample.
$y(n)$	: New Wavelet Function, Length n
$x(n+m-1)$	: Premature Ventricular Contraction ECG Signal

If the value R_{yx} (m) = 0 then it can be said that the two signals x (n) and y (n) are not correlated or statistically independent otherwise, assumed with zero average value. This new wavelet includes Wavelet for ST Segment electrocardiogram. Electrocardiogram signal corresponding to the type of the new wavelet will give a higher correlation score than other electrocardiogram signal. The new wavelet is determined by calculating the highest correlation values that appear in each of the ST Segment electrocardiogram signal. Seen from the group, function that obtained by shifting and making the scale of the parent mother waveletΨ (t) $\in L_2 (R)$,

$$\Psi_{a,b}(t) = \frac{1}{\sqrt{|a|}}\Psi\left(\frac{t-b}{a}\right), \quad (3)$$

With$a, b \in R\ (a \neq 0)$and normalization is performed in order to make norm:

$$\left\|\Psi_{a,b}(t)\right\| = \left\|\Psi\ (t)\right\|$$

(For now assumed a can be positive or negative). Furthermore, it is assumed that this wavelet is able to fulfill acceptance requirement (admissibility condition).

$$C_\Psi \int_{-\infty}^{\infty} \frac{|\Psi(\omega)|^2}{|\omega|} d\omega \langle\infty \quad (4)$$

$$\text{Where } \Psi(\omega) = \int_{-\infty}^{\infty} \Psi\ (t)e^{j\omega t}\,dt$$

With Ψ (ω) is the FT function of Ψ (t). In practice, Ψ (ω) will always decrease (decay), in order to make acceptance decrease and fulfill Ψ (0) = 0:

$$\int_{-\infty}^{\infty} \Psi(t)dt = \Psi(0) = 0$$

Because the FT is zero at the beginning and spectrum decreases at higher frequencies, Wavelet shows field-escape behavior (band-pass). This Wavelet further normalized so it has energy unit, or

$$\|\Psi(t)\|^2 = \int_{-\infty}^{\infty} |\Psi(t)|^2\,dt$$
$$= \frac{1}{2\pi}\int_{-\infty}^{\infty} |\Psi(\omega)|^2 d\omega = 1$$

IV. EXPERIMENTAL RESULTS

A. Wavelet DeGeSTSeg$_1$

This research creates first equation, named Wavelet DeGeSTSeg$_1$ as written in the following equation 5:

$$\psi_{DeGeSTSeg_1} = e^{-x^2/2}[(cos3x) - (sin5x)] \quad (5)$$

Now we know the equation of the Wavelet DeGePVC$_1$ that will be simulated by taylor tools into equation 6 as follows:

exp(-x^2/2)*(cos(3*x)-sin(5*x)) (6)

As shown in Figure 2 Wavelet DeGeSTSeg$_1$ it is expected to have high enough correlation value to be able to determine the shape of a ST Segment electrocardiogram signal with inverted P component amplitude and without repetition.

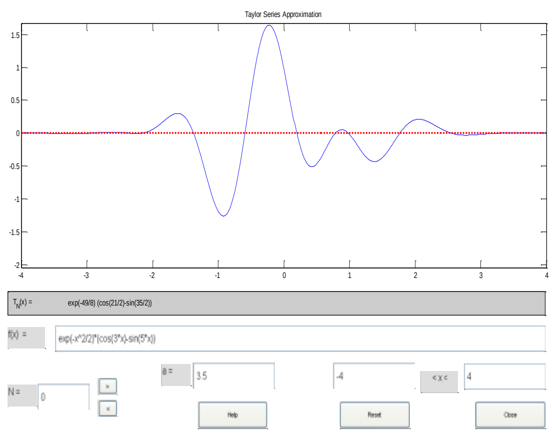

Fig. 2: Wavelet DeGeSTSeg$_1$ are simulated in the Taylor series

The test phase is done by not sifting electrocardiogram signal noise, so that the input signal of its electrocardiogram still has electrocardiogram signal noise as shown in Fig. 3.

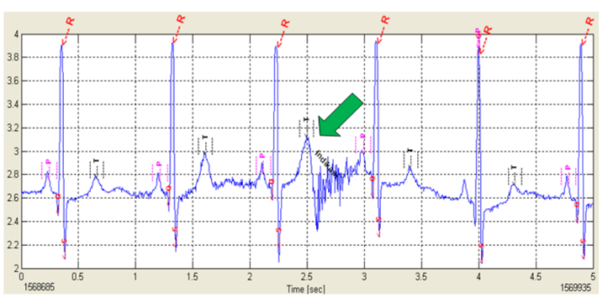

Fig. 3: Wavelet DeGeSTSeg1$_1$ testing on Second Lead with noise

Table 1: The sensitivity result of detection of the PVC component with DeGePVC$_1$

	Lead 1	Lead 2	Lead 3	avr	avl	avf
Total Components ST	43	43	43	43	43	43
Detected ST Segment	38	39	40	41	42	42
True Positive	38	39	40	41	42	42
False Negative	5	4	3	2	1	2
False Positive	0	1	1	4	1	1
Sensitivity (%)	88	90	93	95	97	97

From the result of Table 1 above it appears that the average program sensitivity is 93% to be able to detect ST Segment with detection of DeGeSTSeg$_1$ Wavelet.

B. Wavelet DeGeSTSeg$_2$

This research makes the second equation, named Wavelet DeGeSTSeg$_2$ as written in the following equation 7:

$$\psi_{DeGeSTSeg_2} = e^{-x^2/2} * \left\{ [\boldsymbol{sin2x}] * \left[\mathbf{cos}\left(3x - \frac{1\pi}{4} \right) \right] \right\} \quad (7)$$

Now we know the equation of the Wavelet DeGeSTSeg$_2$ which will be simulated by taylor tools into equation 8 as follows:

exp(-x^2/2)*(sin(2*x)*cos(3*x-(1*pi/4))) (8)

As shown in Fig. 4, this Wavelet DeGeSTSeg$_2$ has a detection of ST segment components with amplitudes exceeding 0.5 component of the R amplitude. Short wave is expected to detect ST components with high amplitude so it is not considered a component of the normal QRS.

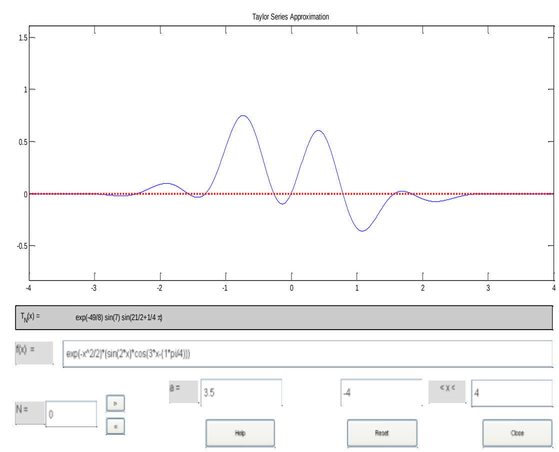

Fig. 4: Wavelet DeGeSTSeg$_2$ are simulated in the Taylor series

Wavelet DeGeSTSeg$_2$ are designed to detect the S and T components with amplitudes close to the top of the R component. This wavelet design is expected to be able to detect ST-segment abnormalities with an indication of the component is located at T.

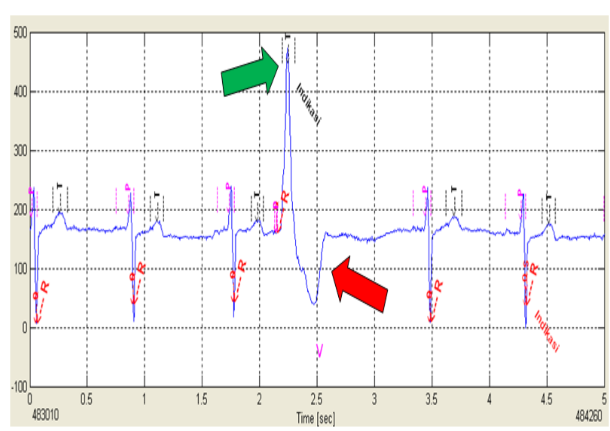

Fig. 5: *Wavelet Test DeGeSTSeg$_2$ on aVR Lead*

Testing for Wavelet $DeGeSTSeg_2$ detection can be seen in Table 2 below:

Table 2: Sensitivity result of detection of the QRS component with $DeGeSTSeg_2$

	Lead 1	Lead 2	Lead 3	avr	avl	avf
Total Components ST	43	43	43	43	43	43
Detected ST Segment	34	36	29	31	34	35
True Positive	34	36	29	31	34	35
False Negative	9	7	14	12	9	8
False Positive	3	2	4	6	3	1
Sensitivity (%)	79	83	67	72	79	81

From the above results it appears that average program sensitivity is 76,8% to be able to detect the components of the ST Segment with $DeGeSTSeg_2$.

C. Wavelet $DeGeSTSeg_3$

This research made the third equation, named Wavelet $DeGeSTSeg_3$ as written in the following equation 9.

$$\psi_{DeGeSTSeg_3} = e^{-x^2/2} * \left\{\left[\cos\left(3x - \frac{3\pi}{4}\right)\right] * \left[\sin\left(5x - \frac{1\pi}{4}\right)\right]\right\} \qquad (9)$$

Now we know the equation of the Wavelet $DeGeSTSeg_3$ will be simulated by taylor tools into equation 10 as follows:

exp(-x^2/2)*(cos(3*x-(3*pi/4))*sin(5*x-(1*pi/4))) (10)

As shown in Fig. 6, Wavelet $DeGeSTSeg_3$ have the characteristics to be able to detect ST segment elevation angle experienced many shifts with different amplitudes.

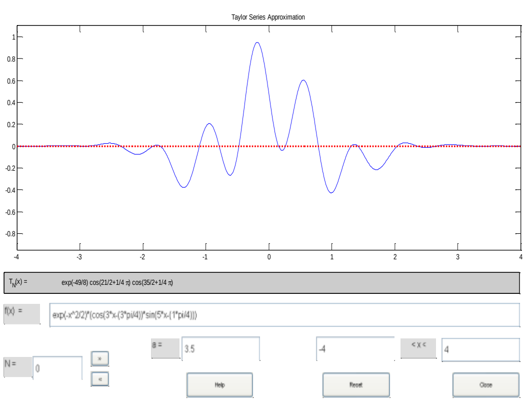

Fig. 6: Wavelet $DeGeSTSeg_3$ are simulated in the Taylor series

Wavelet detection results can be seen in Fig. 7 where ST Segment can not be detected by wavelet $DeGePVC_3$ even if it has detected several components including the component of T. but the detection of abnormalities can not be done. Detection of ST Segment electrocardiogram with negative amplitudes are also not detected by wavelet $DeGeSTSeg_3$

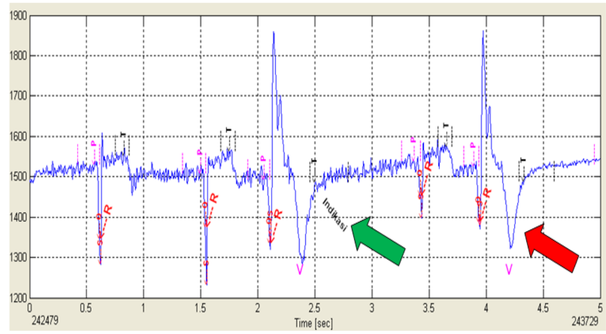

Fig. 7: *Wavelet testing $DeGeSTSeg_3$ on aVL Lead*

Wavelet $DeGeSTSeg_3$ detection can be seen in Table 3 below. From the results it appears that the average program sensitivity is 65% to be able to detect the ST Segment components with Wavelet detection $DeGeSTSeg_3$.

Table 3: Sensitivity result of detection of the STSegment component with $DeGeSTSeg_3$

	Lead 1	Lead 2	Lead 3	avr	avl	avf
Total Components ST	43	43	43	43	43	43
Detected ST Segment	29	31	28	30	31	32
True Positive	29	31	28	30	31	32
False Negative	14	12	15	13	12	11
False Positive	5	7	4	3	1	4
Sensitivity (%)	67	72	65	69	72	74

Table 4: Comparison of DeGeSTSeg ROC Curve

Comparison of ROC curves

Variable 1	DeGeSTSeg1
Variable 2	DeGeSTSeg2
Variable 3	DeGeSTSeg3
Classification variable	STSeg

Sample size		36
Positive group :	STSeg = 1	21
Negative group :	STSeg = 0	15

	AUC	SE [a]	95% CI [b]
DeGeSTSeg1	0,994	0,00615	0,891 to 1,000
DeGeSTSeg2	0,816	0,0706	0,652 to 0,925
DeGeSTSeg3	0,651	0,0968	0,474 to 0,802

[a] DeLong et al., 1988
[b] Binomial exact

Pairwise comparison of ROC curves

DeGeSTSeg1 ~ DeGeSTSeg2	
Difference between areas	0,178
Standard Error [c]	0,0704
95% Confidence Interval	0,0398 to 0,316
z statistic	2,525
Significance level	P = 0,0116
DeGeSTSeg1 ~ DeGeSTSeg3	
Difference between areas	0,343
Standard Error [c]	0,0952
95% Confidence Interval	0,156 to 0,529
z statistic	3,602
Significance level	P = 0,0003
DeGeSTSeg2 ~ DeGeSTSeg3	
Difference between areas	0,165
Standard Error [c]	0,0736
95% Confidence Interval	0,0208 to 0,309
z statistic	2,243
Significance level	P = 0,0249

[c] DeLong et al., 1988

V. CONCLUSIONS

Wavelet detection algorithm with a new form is used to detect a ST Segment electrocardiogram signal. The highest correlation value is used to detect the electrocardiogram signal. The new Wavelet DeGeSTSeg designed to detect ST Segment of the electrocardiogram signal with the result: Wavelet $DeGeSTSeg_1$ testing with inverted P component amplitude and without repetition have a Sensitivity = 93% yield. This value is high compared to most Wavelet $DeGeSTSeg_2$ sensitivity = 76,8% and sensitivity = 65% from wavelet $DeGeSTSeg_{3.}$

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