Identification of Premature Ventricular Contraction ECG Signal using Wavelet Detection

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ABSTRACT
In this paper, the wavelet method used for detecting an electrocardiogram signal is the detection of a new wavelet. Specific form of the electrocardiogram signal which gives angle, amplitude, phase and certain frequency is used as the basis of new wavelet formation. Algorithm DeGePVC is a new algorithm to detect Premature Ventricular Contraction wave electrocardiogram signal. The advantage of using this algorithm DeGePVC is reducing the sensitivity to noise compared to other techniques, with the determination of each component of P, Q, R, S, T wave of the electrocardiogram accurately and quickly. The originality of this study was applied to Premature Ventricular Contraction electrocardiogram wave, with varying leads and it is analyzed for each component of its electrocardiogram signal. The results show the effectiveness of DeGePVC wavelet algorithm utility to detect Premature Ventricular Contraction electrocardiogram wave for 6 lead electrocardiogram. With the value of auc=0.988 by using Receiver Operating Charactheristic (ROC) curve.

Keywords
DeGePVC, Electrordiogram, Wavelet Detection, Premature Ventricular Contraction.

1. INTRODUCTION
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 Premature Ventricular Contraction 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 a 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.

2. FUNDAMENTAL THEORY

2.1 Premature Ventricular Contraction
PVC is an extra electrical impulse arising from the left ventricle. Normally, the heart rhythm is controlled by electrical signals that arise in the sinus node of the right atrium. This signal goes through the atrium, then into the ventricles through the AV node and His bundle. The normal pattern of electrical activation of this makes the atrium contracts, blood in the ventricular emptying, and makes the ventricles contract. Normal heart rhythm, then, to maintain optimal synchronization between the atria and ventricles (Shirley, 2005). PVC is caused by spontaneous electrical impulse that appears in the ventricles. Impulse is the impulse occurs earlier than normal (premature) as shown in Figure 1

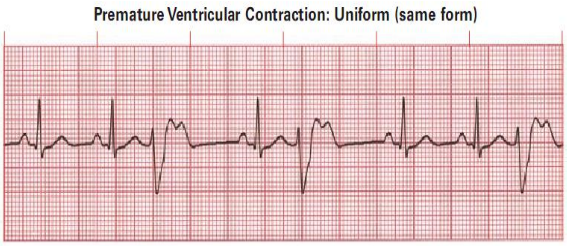

Figure 1. Same Form Premature Ventricular Contraction (Shirley, 2005)

PVC can also occur at the beginning of the cycle. This phenomenon called the R-to-T, after the T wave or the end of the cycle is often fused with the next QRS. PVC-on-T R can be harmful in acute ischemic situation, because it can be more susceptible to ventricular tachycardias or ventricular fibrillation

2.2 Wavelet
Wavelet is a mathematical function that divides the data into several components of different frequencies and analyze each component with a resolution corresponding to the scale. Short waves have the advantage when compared to Fourier style shift methods in analyzing a non-stationary signals. A wave is normally defined as an oscilation 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 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):

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

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.

3. NEW FORM WAVELET DETECTION

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

The equation used for the cross-correlation is as follows

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

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 include Wavelet for Premature Ventricular Contraction 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 Premature Ventricular Contraction electrocardiogram signal. Seen from the group, function that obtained by shifting and making the scale of the parent mother wavelet Ψ (t) $\in L_2(R)$,

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

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

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

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

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

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

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

4. EXPERIMENTAL RESULT

4.1 Wavelet DeGePVC$_1$

This Research create first equation, named Wavelet DeGePVC$_1$ as written in the following equation 5:

$$\psi_{DeGePVC_1} = e^{-x^2/2} * \left\{\left[\cos\left(2x - \frac{7\pi}{4}\right)\right] + \left[\sin\left(5x - \frac{6\pi}{4}\right)\right]\right\}$$
(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(2*x-(7*pi/4))+sin(5*x-(6*pi/4))) (6)

As shown in Figure 2 Wavelet DeGePVC$_1$ it is expected to have high enough correlation value to be able to determine the shape of a Premature Ventricular Contraction electrocardiogram signal. Left peak and right peak are created in different amplitude.

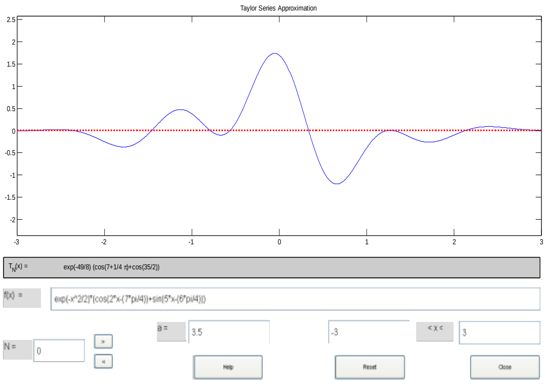

Figure 2. Wavelet DeGePVC$_1$ are simulated in the Taylor series

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 figure 3.

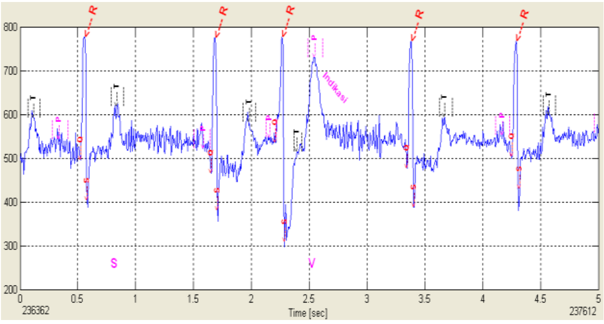

Figure 3. Wavelet DeGePVC$_1$ testing onSecond Lead with noise

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

Pasien 1	Lead 1	Lead 2	Lead 3	avr	avl	avf
Total Components PVC	34	34	34	34	34	34
Detected PVC	30	27	32	33	33	30
True positive	30	27	32	33	33	30
False negative	4	7	2	1	1	4
False positive	0	0	1	2	1	4
Sensitivity (%)	88	79	94	97	97	88

From the result of table 1 above it appears that the average program sensitivity is 90.5% to be able to detect Premature Ventricular Contraction with detection of DeGePVC$_1$ Wavelet

4.2 Wavelet DeGePVC$_2$

This Research make the second equation, named Wavelet DeGePVC$_2$ as written in the following equation 7:

$$\psi_{DeGePVC_2} = e^{-x^2/2}[(\cos 3x) + (\sin 5x)] \qquad (7)$$

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

exp(-x^2/2)*(cos(3*x)+sin(5*x)) (8)

As shown in Figure 4, this Wavelet DeGePVC$_2$ has a different equation than the Wavelet DeGePVC$_1$ that is at the top right hand has higher amplitude than the amplitude at the top left.This is use to detect T components without P components in the front.

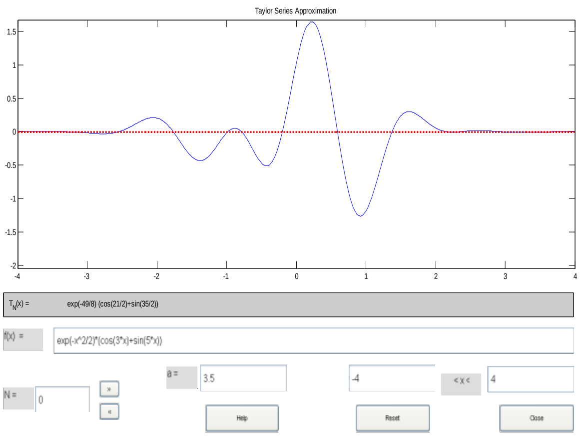

Figure 4. Wavelet DeGePVC$_2$ are simulated in the Taylor series

Wavelet DeGePVC$_2$ are used to detect the Premature Ventricular Contraction electrocardiogram as shown in Figure 5 which shows detection that experience error detection. The first error is the detection of R peak which is not positioned at the crest of a wave, the second error is the false detection of the R component exceeds a peak current of normal conditions, this can be seen the identification of a component of T.

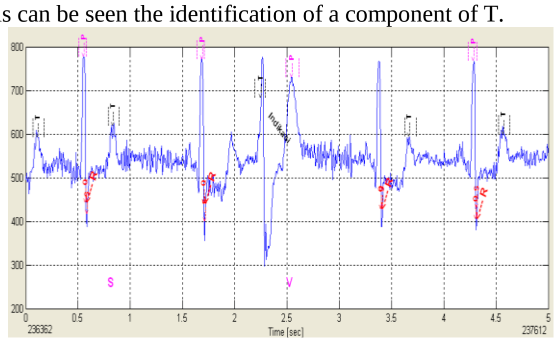

Figure 5.*Wavelet Test DeGePVC$_2$*

Testing for Wavelet DeGePVC$_2$ detection can be seen in Table 2 below.

Table 2. Sensitivity result of detection of the QRS component with DeGePVC$_2$

Pasien 1	Lead 1	Lead 2	Lead 3	avr	avl	avf
Total Components PVC	34	34	34	34	34	34
Detected PVC	26	27	30	22	27	26
True positive	26	27	30	22	27	26
False negative	8	9	4	12	9	8
False positive	1	4	1	2	1	4
Sensitivity (%)	76	79	88	64	79	76

From the above results it appears that average program sensitivity is 77% to be able to detect the components of the QRS with Wavelet detection DeGePVC$_2$.

4.3 Wavelet DeGePVC$_3$

This research made the third equation, named Wavelet DeGePVC$_3$ as written in the following equation 9

$$\psi_{DeGePVC_3} = e^{-x^2/2} * \left\{\left[\cos\left(5x - \frac{3\pi}{4}\right)\right] - \left[\sin\left(3x - \frac{7\pi}{4}\right)\right]\right\} (9)$$

Now we know the equation of the Wavelet DeGePVC$_3$ will be simulated by taylor tools into equation 10 as follows

exp(-x^2/2)*(cos(5*x-(3*pi/4))-sin(3*x-(7*pi/4))) **(10)**

As shown in Figure 6, Wavelet DeGePVC$_3$ has a different equation than the other new wavelet. the peak amplitude of the right side has repeatedly used to detect the components of P and T.

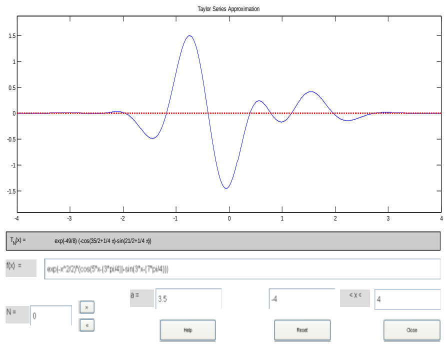

Figure 6. Wavelet DeGePVC$_3$ are simulated in the Taylor series

The short wave detection results can be seen in Figure 7 where Premature Ventricular Contraction abnormalities can not be detected by short wave 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 abnormal electrocardiogram with Premature Ventricular Contraction with negative amplitudes are also not detected by short wave this DeGePVC$_3$

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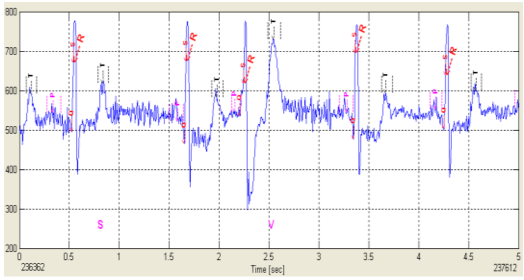

Figure 7. Wavelet testing DeGePVC$_3$

Wavelet DeGePVC$_3$ detection can be seen in Table 3 below. From the results it appears that the average program sensitivity is 63% to be able to detect the components of the QRS with Wavelet detection DeGeNorm$_3$.

Table 3. Sensitivity result of detection of the QRS component with DeGePVC$_3$

Pasien 1	Lead 1	Lead 2	Lead 3	avr	avl	avf
Total Components PVC	34	34	34	34	34	34
Detected PVC	20	22	18	22	25	23
True positive	20	22	18	22	25	23
False negative	14	12	16	12	9	11
False positive	3	4	6	2	3	4
Sensitivity (%)	58	64	52	64	73	67

Table.4 Comparison Of DeGePVC ROC Curve

Comparison of ROC curves

Variable 1	DeGepvc1
Variable 2	DeGepvc2
Variable 3	DeGepvc3
Classification variable	PVC

Sample size	36
Positive group : PVC = 1	24
Negative group : PVC = 0	12

	AUC	SE [a]	95% CI [b]
DeGepvc1	0,988	0,0133	0,880 to 1,000
DeGepvc2	0,792	0,0810	0,624 to 0,909
DeGepvc3	0,649	0,107	0,473 to 0,800

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

Pairwise comparison of ROC curves

DeGepvc1 ~ DeGepvc2	
Difference between areas	0,196
Standard Error[c]	0,0783
95% Confidence Interval	0,0428 to 0,350
z statistic	2,506
Significance level	P = 0,0122
DeGepvc1 ~ DeGepvc3	
Difference between areas	0,339
Standard Error[c]	0,102
95% Confidence Interval	0,138 to 0,539
z statistic	3,304
Significance level	P = 0,0010
DeGepvc2 ~ DeGepvc3	
Difference between areas	0,142
Standard Error[c]	0,0678
95% Confidence Interval	0,00950 to 0,275
z statistic	2,100
Significance level	P = 0,0357

[c] DeLong et al., 1988

5. CONCLUSIONS

Wavelet detection algorithm with a new form is used to detect a Premature Ventricular Contraction electrocardiogram signal. The highest correlation value is used to detect the electrocardiogram signal. The new Wavelet DeGePVC designed to detect abnormalities of the electrocardiogram signal Premature Ventricular Contraction, with the result: Wavelet DeGePVC$_1$ testing with negative amplitude components of T and P Balanced Sensitivity = 90.05% yield. This value is high compared to most Wavelet DeGePVC$_2$ sensitivity = 77% and sensitivity = 63% wavelet DeGePVC$_3$

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