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Jurnal Nasional Teknik Elektro

| ISSN (Print) 2302-2949 | ISSN (Online) 2407-7267 |

Electrocardiogram Abnormal Classification Based on Abnormality Signal Feature

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ARTICLE INFORMATION

Received: September, 30, 2020
Revised: July, 19, 2021
Available online: November, 30, 2021

KEYWORDS

Classification, Electrocardiogram, Abnormality, Signal Feature

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A B S T R A C T

Heart rate abnormalities can lead to many cardiovascular diseases such as heart arrythmia, heart failure, heart valve disease and many more. Some cardiovascular disease can cause death. Abnormalities signal feature can be seen using electrocardiogram. Electrocardiogram is an electric signal record from heart activity. Normal heart and abnormal heart have a different electrocardiogram signal pattern. This research is aim to detect abnormality from heart rate using electrocardiogram abnormality signal feature. Abnormality signal pattern can be used to classify normal and abnormal heart rate. Abnormality feature consists of P signal condition, R signal condition, P – R interval rate, and double R interval. Electrocardiogram data that used in this study is obtain from MIT-BIH Arrythmia database. 20 electrocardiogram data have been used to see detection and classification performance while classifying normal and abnormal heart rate. Research result shows that feature based has 90.00% in accuracy, 90.00%in precision, and 90.00% in sensitivity while classify normal and abnormal heart rate. Research result can conclude that abnormality feature can be used to classify normal and abnormal heart rate. This method can be used for embedded system device that has limitation in memory and size.

INTRODUCTION

Heart is vital organ in human body. Heart has a role to pump blood throughout the body. Heart healthy is important to be considered. Unhealthy heart can cause cardiovascular disease such as heart arrythmia, heart failure, heart valve disease and many more. Some cardiovascular disease can cause death. Risk of death caused by cardiovascular disease has an increasing trend. Death caused by cardiovascular disease are expected to increase up to 23,3 million at 2030 [1]. World Health Organization (WHO) data expected 17,5 million people are death around the world. Cardiovascular disease such as heart failure and stroke give 80% risk of death around the world. This condition is expected to increase in the future [2]. Many methods can be used to observe heart health. Electrocardiogram is one from many methods that commonly used to observe hearth health. Electrocardiogram (ECG) is an electric signal record from heart activity. Heart produces an electric response in human body called heart signal [3]. Heart signal is read by electrocardiograph and produce electrocardiogram. Normal and abnormal heart has a unique pattern in their electrocardiograms. Information from electrocardiograms can be justified to diagnose someone heart is normal or abnormal.

Electrocardiogram pattern is grouped with P, Q, R, S, and T signal [4]. This pattern represents the activity of heart. Pattern P, Q, R, S, and T can be indicating heart healthy and something that affect heart. Pattern P is a heart signal that produce by depolarization normal atrium while main electric vector directed from nodus Sinoatrial to nodus Atrioventricular. Pattern Q is a heart signal that represent heart electric activity from septal ventricle. Pattern R is a positive heart signal that produce while ventricle muscle is depolarized after pattern Q. Pattern T is a negative heart signal that produce while ventricle muscle is depolarized after pattern Q [5]. Heart signal pattern which is P, Q, R, S, and T pattern in different for every people. Normal and abnormal heart also can be observed form P, Q, R, S, and T signal pattern. The challenge while doing signal processing is varying peak pattern distance, shape of peak signal, and noises signal from another organ [6].

Research about electrocardiogram and electrocardiograph shows increasing trends. Electrocardiogram signal processing for reduction false alarm [7], biometric authentication using electrocardiogram [8], and electrocardiogram for emotion recognition [9] explain that electrocardiogram not only just heart signal. Electrocardiograph device also get an improvement. Development of electrocardiograph based on android system [10], improvement of 12 channel electrocardiograph device for monitoring heart signal [11], electrocardiograph device for firefighter usage [12], wearable electrocardiograph for monitoring human motion [13], and low-cost portable electrocardiograph machine for medical observation [14] are trend research in electrocardiograph. Among many research

https://doi.org/10.25077/jnte.v10n3.829.2021

about electrocardiogram and electrocardiograph, signal processing in electrocardiogram needs many improvements. Signal processing in electrocardiogram covered detection signal pattern. Electrocardiogram signal pattern detection such as pattern P wave detection [15], R peaks detection [16], filter for noise reduction in electrocardiogram [17], and filter for QRS pattern detection [18][19].

Electrocardiogram pattern classification to detect normal and abnormal electrocardiogram needs improvement. Electrocardiogram classification method has been done. The result is still not satisfying because the accuracy rate is 70.80% [20]. This research is aims to improve electrocardiogram classification method. Many methods can be implements for improving classification in electrocardiogram. The most promising method in a classification method based on signal pattern.

METHOD

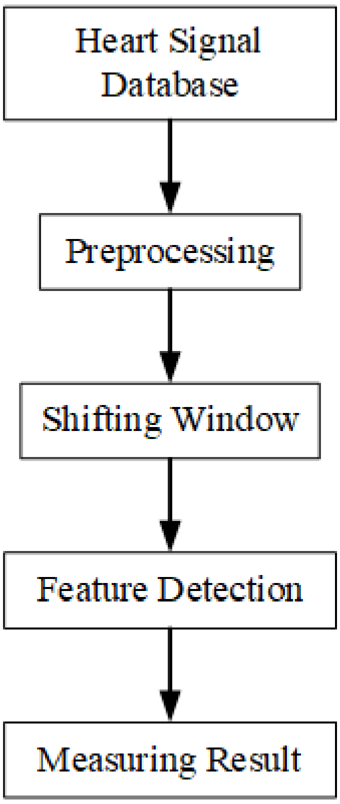

Figure 1. Research Flow Block Diagram

Figure 1 show how research have been done. First is input heart signal database. This research use database from PhysioNet MIT-BIH Arrythmia database. After heart signal database ready, next step is preprocessing. Preprocessing process consists of filtering and normalization. Filtering is needed to process original electrocardiogram to make sure that heart rate signal is clear from noise. Normalization is process for set an offset for heart signal. Next step is shifting window. Shifting window is a process for splitting heart signal into specific time. This step is very important because of abnormality feature can be found in specific window. Window consists of P, Q, R, S, and T pattern signal for one window respectively. Next step is feature detection. This research uses 8 features for detecting abnormality in heart signal. If a heart signal in one window has an abnormality feature, that signal is grouped in abnormal activity.

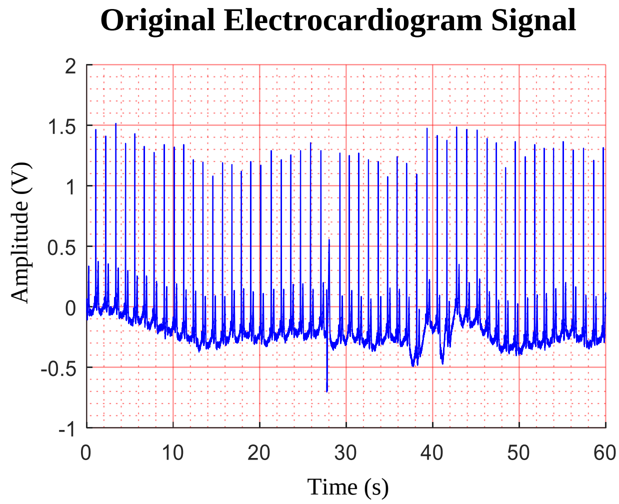

Figure 2. Original Electrocardiogram

Figure 2 shows the original recording of electrocardiogram. Original electrocardiogram comes with many noises. Before using original electrocardiogram for processing, some preprocessing process is needed. Preprocessing first step is filtering. This research uses a high pass filter (HPF). High pass filter is needed to eliminate a signal below 25Hz.

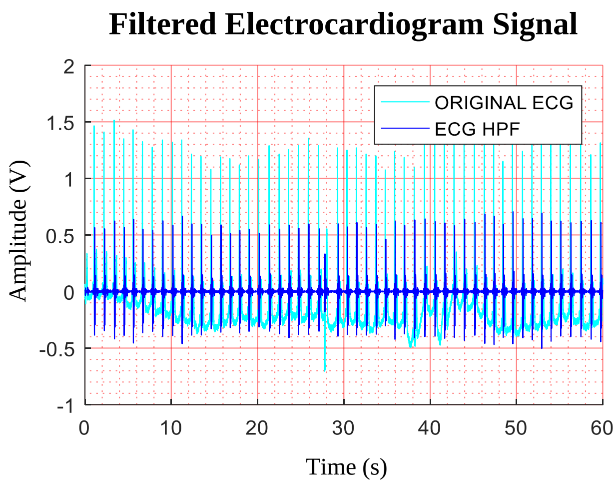

Figure 3. Compared Original Signal with Filtered Electrocardiogram Signal

Figure 3 shows comparation between original signal and filtered signal. Original signal still contains noises from another human body signal such as muscle. Original signal in Figure 3 represents by light blue color. The highest amplitude from original signal is 1.5V before implementing HPF. This signal is quite high because of noise. Highest amplitude is 0.63V after implementing HPF. Filtered signal in Figured 3 is represent by blue color. Filtered signal is still containing negative value in amplitude. Negative value can be seen in 10 second from Figure 3. The amplitude of this signal in 10 second is -0.4V even after implementing HPF. This condition occurs because heart signal does contain negative

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value. For processing purpose negative value must be normalized. Normalization process can be done by measuring the most negative value from electrocardiogram signal and adding positive value with same value.

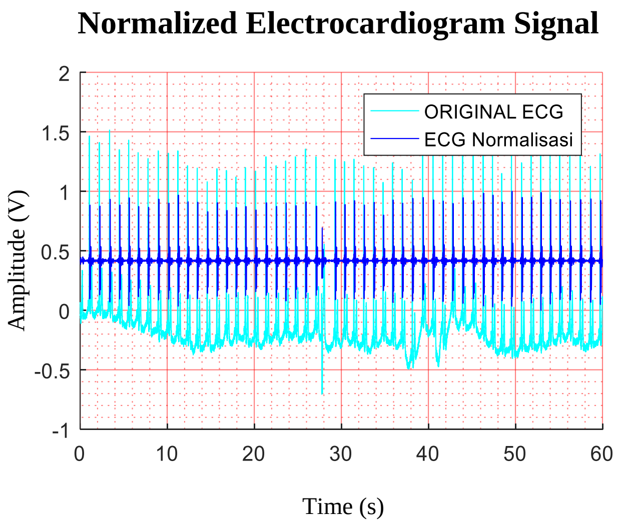

Figure 4. Compared Original Signal with Filtered and Normalized Electrocardiogram Signal

Figure 4 shows electrocardiogram signal after normalization process. Normalized signal in Figure 4 represents by blue color signal. Normalized signal shows the minimum amplitude is 0V in all range. Comparing with original signal represent by light blue color in Figure 4, the normalized signal is ready for next processing.

Next processing step is shifting window. Shifting window is a method for splitting signal for each P, Q, R, S, and T signal respectively. Shifting window needs to detect P, Q, R, S, and T signal for all range in processing signal. Detecting R signal can be done by measuring highest amplitude. Next step is detecting signal P between 2 R signal. Signal P is defined by a signal that the amplitude is between 40 – 70% from R signal.

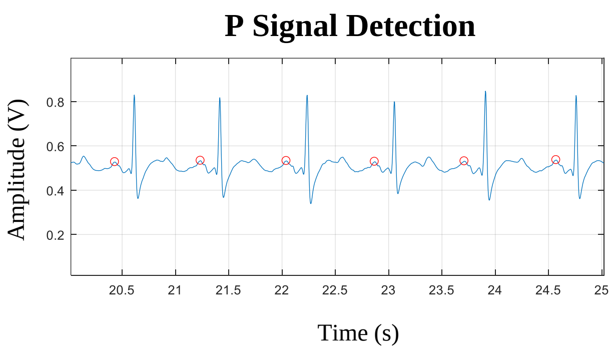

Figure 5. P Signal Detection Electrocardiogram Signal

Figure 5 shows while P signal is detecting between 2 R signal. The location of P signal is between 2 R signal. Detecting P signal not only need the amplitude but also a location. The amplitude is 40 – 70% from R signal and the location is between 2 R signal as a window. Detecting P signal is very important. One of eight feature that use to classify normal and abnormal heart rate related with signal P in one window. Next step is detecting T signal. Location of T Signal is before P signal and the amplitude is quite same as P signal. Signal T can be defined as maximum amplitude between P signal and R signal.

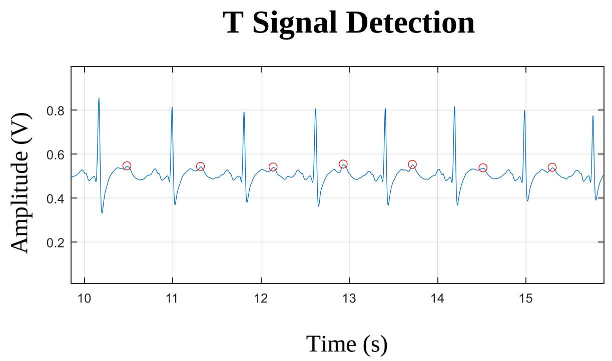

Figure 6. T Signal Detection Electrocardiogram Signal

Figure 6 shows how T signal is detection in electrocardiogram signal. Amplitude of signal T from one into another electrocardiogram is varying. Missing T signal in electrocardiogram is possible according to heart activity.

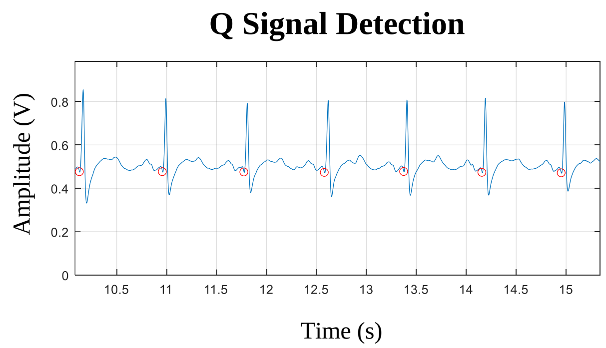

Figure 7. Q Signal Detection Electrocardiogram Signal

Figure 7 shows Q signal detection in electrocardiogram signal. Signal Q is defined by minimum amplitude value between R signal and P signal. Window for detecting signal Q is from P to R signal. After Q signal is found, next step is to found S signal in electrocardiogram. Detecting S signal is quite different from detecting another signal.

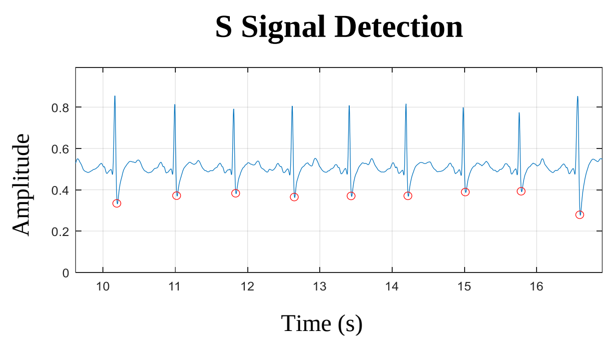

Figure 7. S Signal Detection Electrocardiogram Signal

https://doi.org/10.25077/jnte.v10n3.829.2021

Figure 7 shows S detection in electrocardiogram. Detecting S signal can be done by inverting electrocardiogram signal. After that, soft maximum signal from inverted signal. Information of maximum amplitude and location from inverting signal must be stored. Location of maximum signal from inverted signal can be used to finding S signal.

After all P, Q, R, S, and T signal was found, next step is matching electrocardiogram signal respectively with abnormality feature. Normal heart rate has heart beat between 60bpm – 100bpm. Besides, abnormality heart rate has many types. Abnormality heart rate from heart beat such as bradycardia and tachycardia. Bradycardia comes while someone heartbeat under 50bpm. Tachycardia occurs while someone heart beat is above 100bpm. Bradycardia, Tachycardia, heart rate, and other abnormality feature in heart can be found by observing P, Q, R, S, and T pattern in electrocardiogram. Next step for classifying heart signal according to Figure 1 is detecting abnormality feature.

Table 1. Abnormality Heart Rate Feature

No	Abnormality Feature	Status
1	Beat of signal P in electrocardiograms readings below 60bpm	Abnormal
2	Beat of signal P over 100bpm and beat of signal R over 100bpm in electrocardiograms readings	Abnormal
3	Beat of signal P in electrocardiograms readings over 150bpm	Abnormal
4	Beat of signal R in electrocardiograms reading below 60bpm	Abnormal
5	Beat of signal R over 100bpm and beat of signal P over 250bpm in electrocardiograms readings	Abnormal
6	Beat of signal R in electrocardiograms readings over 120bpm	Abnormal
7	P – R interval in electrocardiograms readings over than 0.2 second	Abnormal
8	Found double R – R beat in electrocardiograms readings	Abnormal

Table 1 is a list for abnormality feature that used on this research. First feature is P signal below 60bpm. This feature can be found by observing electrocardiogram in one minute and counting P signal on it. If P signal is below 60bpm, feature 1 will be marked by 1. If P signal is normal, feature 1 will be marked by 0. Second feature is P signal over than 100bpm and R signal over than 100bpm. This condition will be observed in one minute electrocardiogram. If this condition occurs, then feature 2 will be marked as 1. If this condition doesn't occur, then feature 2 will be marked as 0. Third feature is signal P over than 150bpm in one minute. If this condition occurs, then feature 3 will be marked as 1. If this condition doesn't occur, then feature 3 will be marked as 0. Fourth feature is R signal below 60bpm in one minute. Abnormality heart rate maybe contain lower R signal in special case. Fourth feature will be marked 1 if it is happened. If this condition doesn't occur, then fourth feature will be marked by 0. Fifth feature is R signal is over than 100bpm and P signal is over than 250bpm in one minute electrocardiogram reading. This condition can happen while R signal amplitude is too low. Because of that condition, R signal mostly known as P signal. The amplitude is the most significant factor in this feature. Lower R signal is sign for abnormality heart rate. While this condition is happened, then fifth feature will be marked by 1. If this condition doesn't occur then fifth feature will be marked by 0. Sixth feature is R signal is over than 120bpm in one minute electrocardiogram read. This condition can be occurred while user is anxiety. If R signal is over than 120bpm, then feature sixth will be marked as 1. If this condition doesn't occur, then sixth feature will be marked as 0. Seventh feature is P – R interval is over than 0.20 second. This condition can be found by observing x axis in electrocardiogram. Different with another feature, this feature is focus on time position and not the amplitude. If this condition is occurred, then seventh feature will be marked as 1. If this condition doesn't occur, then seventh feature will be marked as 0. Eighth feature is double R signal. Interval double R can be found by observing overall signal. After overall signal is obtain, split it using shifting window and if R signal found in one window, then double R is found. If this condition occurs, then eighth feature will be marked as 1. If this condition doesn't occur, then eighth feature will be marked as 0.

The next step is measuring result. Result can be divided by measuring performance of feature selection in electrocardiogram signal and classification performance. Feature selection performance is obtaining by observing one signal in long interval and applied feature detection. If in this condition is same with doctor diagnose, then feature detection is work well. After make sure feature selection is work, followed by classifying user condition. This data can be obtaining by observing electrocardiogram signal more than 1 user. This research use 10 signal for normal electrocardiogram user and 10 signal that contain abnormality.

Table 2. Confusion Matrix

N		*Actual Values*	
		Positive	*Negative*
Predicted Values	Positive	TP	FN
	Negative	FP	TN

Both feature selection performance and classification performance will be measure using confusion matrix. Confusion matrix is composed like Table 2. Actual value is obtaining by observing truth condition. If truth condition for electrocardiogram is normal observed by experts and system prediction also give normal prediction, then True Positive (TP) get one score for every correct prediction in predicting normal electrocardiogram. If truth condition for electrocardiogram is abnormal and system prediction also give abnormal prediction, then True Positive (TN) get one score for every correct prediction in predicting abnormal electrocardiogram. If truth condition for electrocardiogram is normal and system prediction give abnormal prediction, then false prediction is occurred while detecting normal electrocardiogram. If this condition happened, False Positive (FP) get one score for every false prediction in predicting normal

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electrocardiogram. If truth condition for electrocardiogram is abnormal observed and system prediction give normal prediction, then false prediction is occurred while predicting abnormal electrocardiogram. If this condition happened, False Negative (FN) get one score for every false prediction in predicting abnormal electrocardiogram.

$$Precision = \left(\frac{TP}{TP+FP}\right) X\ 100\ \% \quad (1)$$

$$Acurracy = \left(\frac{TP+TN}{TP+FP+FN+TN}\right) X\ 100\ \% \quad (2)$$

$$Recall = \left(\frac{TP}{TP+FN}\right) X\ 100\ \% \quad (3)$$

Performance measurement consist of 3 parameters. The parameters are precision, accuracy, and recall. Calculate precision, accuracy, and recall is use Equation 1, Equation 2, and Equation 3 respectively. Calculation can be done after collecting TP, TN, FP, and FN while research experiment.

RESULTS AND DISCUSSION

Feature detection has been done using patient number 202 electrocardiogram data. This research uses 30 minutes electrocardiogram recording data for patient 202.

Table 3. Signal Status in Every Minutes Observed by Experts

Minute	Second	Status
1	1 – 61	Normal
2	61 – 121	Normal
3	121 – 181	Normal
4	181 – 241	Normal
5	241 – 301	Normal
6	301 – 361	Normal
7	361 – 421	Normal
8	421 – 481	Normal
9	481 – 541	Normal
10	541 – 601	Abnormal
11	601 – 661	Abnormal
12	661 – 721	Abnormal
13	721 – 781	Normal
14	781 – 841	Normal
15	841 – 901	Normal
16	901 – 961	Normal
17	961 – 1021	Normal
18	1021 – 1081	Normal
19	1081 – 1141	Abnormal
20	1141 – 1201	Abnormal
21	1201 – 1261	Abnormal
22	1261 – 1321	Abnormal
23	1321 – 1381	Normal
24	1381 – 1441	Normal
25	1441 – 1501	Abnormal
26	1501 – 1561	Abnormal
27	1561 – 1621	Abnormal
28	1621 – 1681	Abnormal
29	1681 – 1741	Abnormal
30	1741 – 1801	Abnormal

Table 2 is an electrocardiogram status observed by experts. This information is a reference for measuring abnormality feature detection. Table 2 shows that abnormality is found 13 times in minute 10, 11, 12, 19, 20, 21, 22, 25, 26, 27, 28, 29, and 30 respectively. Normal electrocardiogram signal is found 17 times in minute 1, 2, 3, 4, 5, 6, 7, 8, 9, 13, 14, 15, 16, 17, 18, 23, and 24 respectively. This diagnose has been done by Moody and Mark.

Table 4. System Feature Detection

Minute	Feature								Status
	1	2	3	4	5	6	7	8	
1	0	0	0	0	0	0	0	0	Normal
2	0	0	0	0	0	0	0	0	Normal
3	0	0	0	0	0	0	0	0	Normal
4	0	0	0	0	0	0	0	0	Normal
5	0	0	0	0	0	0	0	0	Normal
6	0	0	0	0	0	0	0	0	Normal
7	0	0	0	0	0	0	0	0	Normal
8	0	0	0	0	0	0	0	0	Normal
9	0	0	0	0	0	0	0	0	Normal
10	0	0	0	0	0	0	0	0	Normal
11	0	0	0	0	0	0	0	0	Normal
12	0	0	0	0	0	0	0	0	Normal
13	0	0	0	0	0	0	0	0	Normal
14	0	0	0	0	0	0	0	0	Normal
15	0	0	0	0	0	0	0	0	Normal
16	0	0	0	0	0	0	0	0	Normal
17	0	0	0	0	0	0	0	0	Normal
18	0	0	0	0	0	0	0	0	Normal
19	0	0	0	0	0	0	0	1	Abnormal
20	0	0	0	0	0	1	0	1	Abnormal
21	0	1	0	0	0	1	0	1	Abnormal
22	0	0	0	0	0	1	0	1	Abnormal
23	0	0	0	0	0	1	0	1	Abnormal
24	0	0	0	0	0	1	0	1	Abnormal
25	0	0	0	0	0	1	0	1	Abnormal
26	0	0	0	0	0	1	0	1	Abnormal
27	0	0	0	0	0	1	0	1	Abnormal
28	0	0	0	0	0	1	0	1	Abnormal
29	0	0	0	0	0	1	0	1	Abnormal
30	0	0	0	0	0	1	0	1	Abnormal

Result of system abnormality feature detection can be observe in Table 4. According result of feature detection system in Table 4, normal signal detects 18 times in minute 1 – 18. Abnormal signal detects 12 times in minute 19 – 30. Data from Table 3 and Table 4 have same data from patient number 202. The difference is data in Table 3 is from expert observation and data in Table 4 is from software system. Result from proposed system and expert observation has a different decision. Different decision occurs 5 times and can be found in minute 10, 11, 12, 23, and 24 respectively. System wrong while recognizes normal signal and predict abnormal signal in minutes 23 and 24. This condition can happen because of system found abnormality feature R signal above 120bpm and double R signal in minutes 23 and 24. System wrong while recognizes abnormal signal and predict normal signal in minute, 10, 11, and 12. This condition can be happened because of system cannot find any abnormality feature for electrocardiogram signal in minutes 10, 11, and 12.

Table 5. Feature Detection Confusion Matrix

N = 30		*Actual Values*	
		Positive	*Negative*
Predicted Values	Positive	15	3
	Negative	2	10

Confusion matrix for feature detection can be form using data from Table 4. TP can be found 15 times in electrocardiogram signal minutes 1, 2, 3, 4, 5, 6, 7, 8, 9, 13, 14, 15, 16, 17, and 18. TN can be found 10 times in electrocardiogram signal in minutes 19, 20, 21, 22, 25, 26, 27, 28, 29, and 30. FP can be found 2 times in electrocardiogram signal in minutes 23 and 24. FN can be found 3 times in electrocardiogram signal in minutes 10, 11, and 12. Confusion matrix form can be seen in Table 5 above. Thus, the precision, accuracy and recall can be calculate using Equation 1, 2, and 3.

$$Precision = \left(\frac{15}{15+2}\right) X\ 100\ \% = 88{,}23\%$$

$$Acurracy = \left(\frac{15+10}{15+2+3+10}\right) X\ 100\ \% = 83.33\%$$

$$Recall = \left(\frac{15}{15+3}\right) X\ 100\ \% = 83{,}33\%$$

Performance for feature detection system in precision, accuracy, and recall is 88.23%, 83.33%, and 83.33% respectively. This result is quite high for feature detection. This performance can be increase by adding more feature detection.

Table 6. Classification System

Patient Number	Feature								Status
	1	2	3	4	5	6	7	8	
1	0	0	0	0	0	0	0	0	Normal
2	0	0	0	0	0	0	0	0	Normal
3	0	0	0	0	0	0	0	0	Normal
4	0	0	0	0	0	0	0	0	Normal
5	0	0	0	0	0	0	0	0	Normal
6	0	0	0	0	0	0	0	0	Normal
7	0	0	0	0	0	0	0	0	Normal
8	0	0	0	0	0	0	0	0	Normal
9	0	0	0	0	0	0	0	0	Normal
10	0	0	0	0	0	0	0	1	Abnormal
11	0	0	0	0	0	0	0	0	Normal
12	0	0	0	0	0	0	0	0	Abnormal
13	0	0	0	0	0	0	0	1	Abnormal
14	0	0	0	1	0	0	0	0	Abnormal
15	0	0	0	0	0	0	0	1	Abnormal
16	0	0	0	0	0	0	0	1	Abnormal
17	0	0	0	1	0	0	1	0	Abnormal
18	0	0	0	0	0	0	1	1	Abnormal
19	0	0	0	0	0	0	0	1	Abnormal
20	0	0	0	0	0	1	0	1	Abnormal

After make sure performance of feature detection system, next experiment is classifying electrocardiogram from another patient. Table 6 shows how performance system while classifying patient status. Experiment consists of 10 patients with normal electrocardiogram and 10 patients with abnormal electrocardiogram. Patient number 1 – 10 is a patient with normal electrocardiogram and patient number 11 – 20 is a patient with abnormal electrocardiogram according to information from physionet.org. From Table 6, system still has a wrong recognition while recognize data from patient 10 and 11.

Table 7. Classification Confusion Matrix

N = 30		*Actual Values*	
		Positive	*Negative*
Predicted Values	Positive	9	1
	Negative	1	9

Table 7 is confusion matrix form according to data in Table 6. Patient number 10 in actual value is normal but according to system decision, patient number 10 is abnormal. This case is FP, this scoring for FP is adding by 1. Patient number 11 in actual value is abnormal but according to system decision, patient number 11 is normal. This case is FN, this scoring for FN is adding by 1.

$$Precision = \left(\frac{9}{9+1}\right) X\ 100\ \% = 90.00\%$$

$$Acurracy = \left(\frac{9+9}{9+1+1+9}\right) X\ 100\ \% = 90.00\%$$

$$Recall = \left(\frac{9}{9+1}\right) X\ 100\ \% = 90.00\%$$

From Table 7 and Equation 1, 2, and 3. The Precision result for classification system is 90.00%. The accuracy result for classification system in 90.00%. The recall result for classification system is 90.00%.

CONCLUSIONS

According to data while experimenting in feature detection, the result is 88.23%, 83.33%, and 83.33% for precision, accuracy, and recall respectively. Data is obtaining by observing one electrocardiogram in long interval. This result is quite high but the highest. For classifying experiment, this research get result 90.00%, 90.00%, and 90.00% for precision, accuracy and recall respectively. Data is obtaining by observing 20 patients with 10 patients has normal electrocardiogram and 10 patients has abnormal electrocardiogram pattern. This result is higher comparing with previous result. According precision, accuracy, and recall value system can be classifying electrocardiogram signal from another data. This system can be implemented in embedded system because of simplicity algorithm.

https://doi.org/10.25077/jnte.v10n3.829.2021

ACKNOWLEDGMENT

Author want to say thank you to dean and deputy dean from Faculty of Telecommunication and Electrical Engineering Institut Teknologi Telkom Purwokerto that give author motivation to write this research.

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