Myocardial infarction detection system from PTB diagnostic ECG database using Fuzzy inference system for S-T waves

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Abstract. Heart disease was the one of major health problem in the world, which caused many deaths. Myocardial infarction (MI) is one type of heart disease which caused by a blockage in the coronary arteries. This disease could be detected by reading electrocardiogram (ECG) wave result. Knowledge and expert analysis were required to read PQRST-waves in Electrocardiograms. Fuzzy inference system was used in this detection system because it flexibility on linguistic variables. Fuzzy inference system could be performed after discovery S and T peaks. The characteristics of Myocardial Infarction could be seen through the condition of S and T wave. Detection system test was conducted on databases that obtained from Physionet bank, Physikalisch-Technische Bundesanstalt (PTB) diagnostic ECG database that were collected from 52 healthy patients and 148 diagnosed MI patients. The result of this research showed that test of detection system had sensitivity level of 73%.

1. Introduction
Cardiovascular diseases had the highest percentage of proportional mortality in Indonesia. Which 37% of total deaths in Indonesia caused by cardiovascular diseases. MI is one of the common condition of cardiovascular disease. MI is condition when there is an area in heart muscle dies or permanently damaged [1]. Myocardial occurs when the episode of ischemia lasts for longer for period of time, it caused heart muscle die so it can cause the changed of ECG signal. Before the acute MI happened to the patient, ischemia caused reversible effects and the heart cells would be able to recover [2]. So an early warning system was needed to identify MI in the change of ECG signals.

An infarction produces abnormalities in the ECG signal. Through analyzing ECG signals of patients with diagnosed MI and comparing these signals to those of healthy patients, feature can be identified characteristics of MI. the abnormalities manifested in the ECG signal are dependent on the location of infarction. Some key feature of MI is ST segment elevation or depression, T wave inversion, pathological Q wave, increased R wave amplitude [4].

Fuzzy inference systems (FIS) are rule-based systems with concepts and operations associated with fuzzy set theory and fuzzy logic. These systems map an input space to an output state; therefore, they allow constructing structures that can be used to generate responses (outputs) to certain stimulations (inputs), based on stored knowledge on how the responses and stimulations are related. The knowledge is stored in the form of a rule base. A set of rules that express the relations between inputs
and the expected outputs of the system [5]. This research design the identification system for MI using fuzzy inference system. The ultimate goal of this system is to identify the MI in real-time.

2. Numerical Method
MI detection system was created using secondary data from ECG database on physionet bank PTB diagnostic ECG. ECG’s were collected from 52 healthy volunteers and 148 patients diagnosed MI [8]. Data was used for reference on designing rules based on the data feature. To get the feature, ECG signal processed using baseline wander corrections and Savitsky-Golay noise filtrations to difference characteristics between MI and normal ECG. The characteristics of ECG was used for feature extraction which S and T wave from ECG was used for statistics parameter. This feature was used to designed (FIS) for S and T wave features in electrocardiograms. To optimize FIS performance, input variable on FIS used Gaussian membership function since it flexibility, while output variable used triangle membership function to divide two memberships, normal and MI. Besides, the rules of inference are made on the premise that detection is normal if all input variable is normal. The system decisions were taken using centroid defuzzification. System tested using reference data with level of sensitivity as the parameters. The design of the system can be seen at figure 1.

3. Results and Discussion
3.1. Signal processing
When a raw ECG signal is collected, the raw signal is not good form for analysis. Feature cannot be extracted from this form accurately. On the raw ECG signal (figure 2) there is noise and the baseline wander from horizontal axis. So the raw signal need to be processed using baseline wander corrections and noise filtering [4].
3.1.1. Baseline Wander Corrections.

The ordering baseline trend was not always in the origins, it caused ECG signals couldn’t be used in the threshold processing. We have found a solution for this problem, by using median filter that proposed by N. Siddiah [10]. We can eliminate the baseline drifts from ECG signals without giving any deformation or losing any clinical information [11,12]. The procedure of median filtering denoted as

\[ y(n) = \text{median}[x(n-k),...,x(n),...,x(n+k)] \]  

(1)

Where and are the input and output of the sequences. This filter is implemented by sliding a window of odd length over signal one sample at time. At each window are sorted by magnitude and the mid-value was the filter output.

![Figure 2. Raw ECG signal.](image)

![Figure 3. ECG signal after using median filtering.](image)

3.1.2. Noise filtering

Savitzky-Golay filtering can be thought of as a generalized moving average. The filter coefficients can be derived by performing unweighted linear least-squares fit using a polynomial of an appropriate degree. For this reason, a Savitzky-Golay filter is also called a digital smoothing polynomial filter or a least-squares smoothing filter [12,13]. Figure 4 show the ECG signal before and after noise filtering.
3.2. Feature extractions
Features extraction is used for difference condition of S and T wave. Based on characteristics of MI, T wave divided into T normal and T inverted. While S wave divided into S normal and S flat. Those differencing depend on peak values of S and T from ECG signals. To find the peaks value, thresholding is used for limitation. To find the S peaks, the signals need to be flip like we flip (+) into (-) then detect the max peaks. The max peak is defined by if it higher then x-1 or x+1 it is the higher value. Beside, T peaks was obtained by taking max peak value to determine limits. There are two limits, upper limit and lower limit. The example of feature extraction can be seen on figure 5.

3.3. Fuzzy Inference System
Fuzzy inference system is one of decision support system that using fuzzy logic. Fuzzy inference system is capable of dealing with imprecise, imperfect, uncertain and vague data and information. There are 3 main steps in FIS fuzzification, inference, defuzzification [5]. The roadmap of the whole fuzzy inference process displayed by figure 6. It is can be used to view the entire implication process from beginning to end.
3.3.1. Fuzzification

Fuzzification is used to change crisp variable into fuzzy variable. Fuzzification was designed using Gaussian membership function for each input variable and triangle membership function for output variable. Based on the amplitude, range of input variable was set as [-1000 1000], while the range of output variable was set as [0 1]. Membership function of T wave divided into T normal and T inverted with parameters [177.3 332.3] and [178.7 -177.3]. While the membership functions of S wave divided into S normal and S flat with parameter [164.9 -350.5] and [30.54 0]. The membership function of output variable divided into health and MI with parameter [-0.345 0 0.6] and [0.4 1 1.84].

3.3.2. Inference

Inference is used to make rule on FIS program for make decisions. On this research, Mamdani method was used because Mamdani method is widely accepted for capturing expert knowledge. It allows describing the expertise in more intuitive, more human-like manner. However, Mamdani-type fuzzy inference entails a substantial computational burden [5]. Maked rules was based on S and T wave conditions, which if one of those wave is not normal it means detection will show myocardial infarction. So it is formed rule

Rule 1: If (T is inverse) and (S is flat) then (detection is MI)
Rule 2: If (T is normal) and (S is normal) then (detection is normal)
Rule 3: If (T is normal) and (S is flat) then (detection is MI)
Rule 4: If (T is inverse) and (S is normal) then (detection is MI)

3.3.3. Defuzzification

Defuzzification operation is used to convert the fuzzy set coming from the inference engine into a crisp value [5]. In this FIS result Centroid method used for this defuzzifications, the procedure of centroid defuzzification denote as

\[ z^* = \frac{\int z \mu(z) dz}{\int \mu(z) dz} \] (2)

With this defuzzification, we can determine the patient condition in general information. The system will show normal or MI output.

To know the system capabilities, we need to test this system. The test has been done by matching the results of the system with the data used in the formation of the system. It shows that sensitivity level of this system is 73%.

![Figure 6. Fuzzy Rule viewer.](image)
4. Conclusion
Myocardial Infarction Detection System Using Fuzzy Inference System for S and T-Wave Features in Electrocardiograms. S and T wave feature got from processed signal using baseline correction, noise filtrations, and extraction feature. Then fuzzy inference system designed using them. The result of system test show that level of sensitivity is 73%. This system still can be upgrade by giving more information into the system.

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