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CLASSIFICATION OF CARDIAC DISORDERS BASED ON ELECTROCARDIOGRAM DATA WITH FUZZY COGNITIVE MAP (FCM) ALGORITHM APPROACH

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Abstract. *In this article, the classification of cardiac abnormalities from electrocardiogram medical data has been carried out using the Fuzzy Cognitive Map (FCM) approach. FCM itself is a form of knowledge representation, design elements, and algorithm descriptions that are included in the FCM Expert software. The FCM model design can model complex systems. The results showed the real-time visualization of the normal heart error curve reached 16%, real-time visualization of the abnormal heart error curve reaches 31%, and the result of the convergence process of normal heart has the lowest convergence value of 0.39 and the highest convergence value of 0.91. Meanwhile, the result of abnormal heart convergence process has the lowest convergence value of 0.49 and the highest convergence value of 0.87. This research contributes to the world of health, where we classify the Electrocardiogram (ECG) data, so that it can classify abnormal and normal cardiac disorders using the Fuzzy Cognitive Map (FCM) algorithm.*
Keywords: Fuzzy cognitive map, Classification, Heart disease, Electrocardiogram, Convergence

1. **Introduction.** Machine learning technology and expert systems are technologies that are currently developing very rapidly. Many researchers are involved in it, and generally they take data objects about disease, education, and economy [1-3]. The death rate due to heart disease is estimated to continue to increase in 2030 to reach 23.3 million population. In 2015 estimated deaths of heart and blood vessel disease in the world increased to 20 million. Stated in Heart and Blood Vessel Control Guidance Number 854/Menkes/SK/IX/2009, the highest public health problem in the districts of Indonesia is heart and blood vessel disease. According to the Bureau of Communication and Community Services, the Indonesian Ministry of Health stated "Based on 2014 Sample

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Registration System (SRS) data, heart disease was ranked second highest after stroke for the highest mortality rate".

Literature studies show that data mining has been implemented for the need to predict heart disease [1,4,5], classification of paralysis [6], classification of diabetes [7], identification of heart disease with classification techniques [8], identification of the possibility of disease spread using the association rule approach and decision support [9,10]. The field of text mining has also been implemented to analyze health cases such as idenfying trends in the types of diseases of outpatients [11], evaluation of the effectiveness of medical care based on the type of disease, symptoms felt on the type of treatment given [10] to the type of disease suffered by patients [12-14], identify cardiac abnormalities based on expert systems and telemedicine [15-18], diagnosed heart disease significantly based on a semi supervised learning algorithm [19], and automatic selection and analysis using machine learning [20].

Based on some literature, there is still minimal research that discusses the classification of cardiac disorders using the fuzzy cognitive map method, which is assisted by the FCM Expert software. This research contributes to the world of health, where we classify the Electrocardiogram (ECG) data using the Fuzzy Cognitive Map (FCM) algorithm approach. The results obtained from this study regarding the classification of heart defects using the fuzzy cognitive map method are shown to be very significant. The results showed the real-time visualization of the normal heart error curve reached 16%, the real-time visualization of the abnormal heart error curve reached 31%, whereas for the results of the convergence process, the normal heart has the lowest convergence value of 0.39 and the highest convergence value of 0.91. Meanwhile, the result of abnormal cardiac convergence process has the lowest convergence value of 0.49 and the highest convergence value of 0.87.

2. **Research Method.** This research was conducted to model a heart defect indication model. The model used is the FCM (Fuzzy Cognitive Map) approach. The process of identifying heart defects is generally carried out by a cardiologist. The data used were 300 electrocardiogram medical records. 250 electrocardiogram medical record data are used as training data, while 50 electrocardiogram medical record data are used as testing data. The following are the steps in the research as follows:

- Data collection.
- Electrocardiogram medical record data.
- Preliminary classification of doctor's ECG medical record data (Expert).
- Initial classification of electrocardiogram medical record data.
- Fuzzy Cognitive Map (FCM).
- Improving the system convergence.
- Research preparation and report.

2.1. **Fuzzy Cognitive Map (FCM).** Cognitive maps are introduced by Bart Kosko. FCM is a fuzzy-graph that describes cause and effect, where causality systematically has a forward and backward chain link of knowledge [21,22]. FCM has 2 main elements consisting of concepts and causal relationships, where the concept is represented by a circle, which presents a causal relationship, while causality is represented by arrows that have a positive value "+" indicating a positive, and "−" a negative. So the concept is Ai, the new value is updated with the relationship between the concepts [23,24].

$$C_i(t+1) = f\left(\sum_{j=1}^{c} \omega_{ji} \cdot C_{j(t)} + \omega oi\right) \tag{1}$$

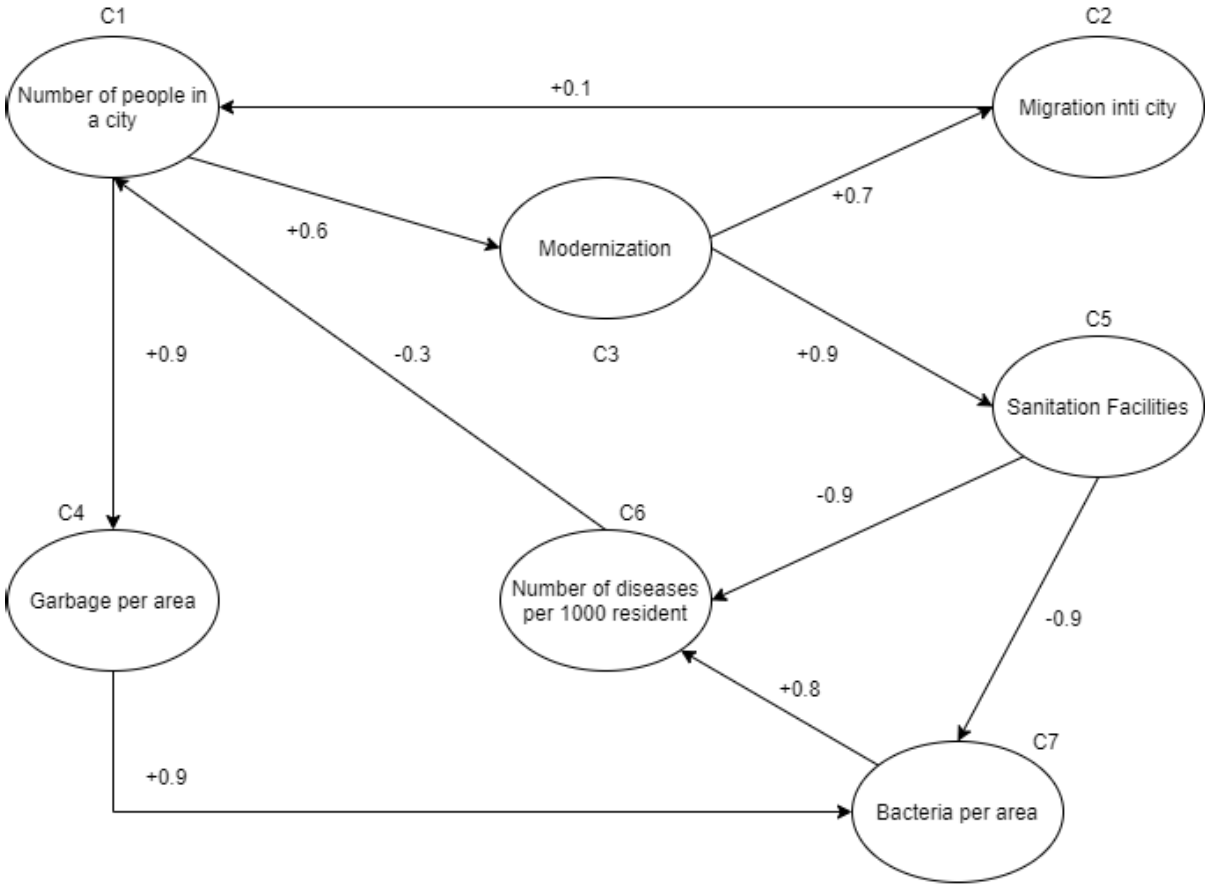

FIGURE 1. Cognitive map on public health (Source: Tsadiras dan Margaritis, 1997)

Cognitive map is a qualitative decision model in decision making that allows it to be used in managing problems easily when represented by graphs between different nodes [25].

Figure 1 shows the cognitive map used to represent scenarios that involve several problems in public health. Cognitive maps are built to predict outcomes with relevant problems interacting with each other. Rule can be used for the decision making process with all the causes and effects mentioned [26,27]. In addition, Figure 1 shows the facts of the cognitive map regarding public health, and the characteristics consist of several concepts consisting of C1, C2, C3, C4, C5, C6, and C7. Each vertex affects each other, and the weights are shown in a matrix of relationships (causal) with each other by the value of the interval $[-1, 1]$ [28].

2.2. **Modeling & experimentation framework.** The FCM Expert software is built with the Java programming language which consists of 25,000 lines of code distributed in 120 source files. FCM Expert is designed in 2 models based on Fuzzy Cognitive Map (FCM), which can model complex systems and machine learning algorithms to adjust model parameters and optimize the results of its performance. Figure 2 shows the hierarchy for the FCM software including main packages and sub packages.

3. **Evaluation Result.** Electrocardiography is a tool for recording electrocardiogram medical records. The result of this electrocadiogram medical record is a graph of the electrical potential of the heart affixed to the surface of the body from 12 leads, where the 12 leads are at some point on the surface of the body, and the ECG configuration recorded is also in the form of waves.

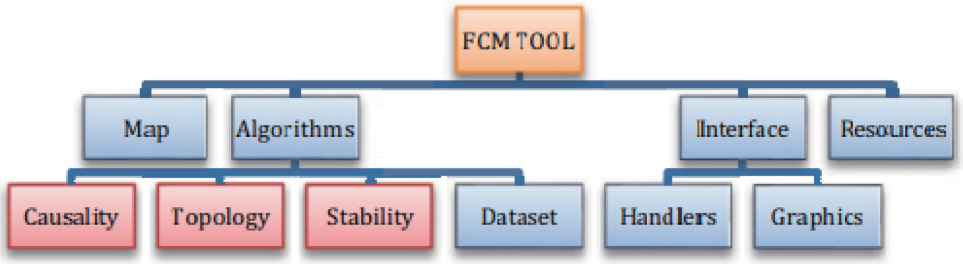

FIGURE 2. Tree of packages for FCM Tool architecture (Source: Gonzalo et al., 2016)

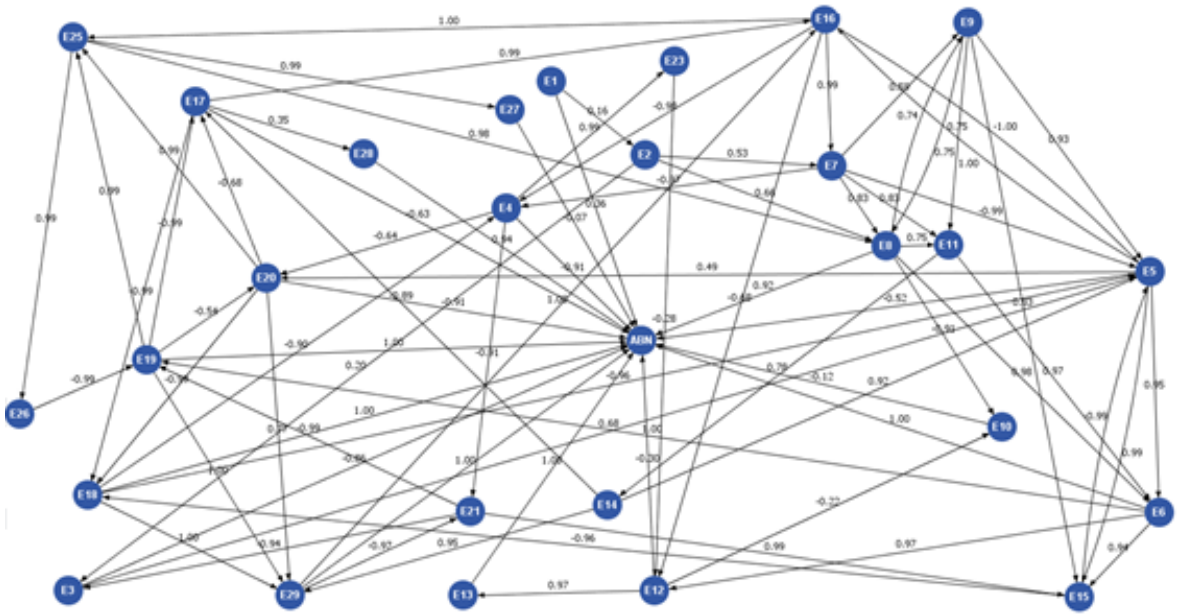

FIGURE 3. Abnormal cardiac

The FCM Expert test is carried out by the testing process by entering several vector inputs to the causal matrix of the relationship between concepts. The causal matrix E was then tested using the FCM Expert to produce cardiac abnormal and normal.

Figure 3 shows the fuzzy cognitive map of the abnormal heart and Figure 4 shows the fuzzy cognitive normal heart. Figures 3 and 4 are fuzzy cognitive maps with causality values, both the value of causality between evidence and evidence, and the value of causality between evidence and hypothesis. The difference from Figures 3 and 4 lies in the process of rules which are formed from 250 ECG data as training data. For abnormal rules formed 34 rules with 28 variables are shown in Figure 3, whereas in Figure 4 the formed rules are 27 rules with 28 variables. FCM Expert designed an FCM based system by drawing network structures or heart abnormalities data in the form of a weight matrix from the SCV file. Besides that it describes the network topology efficiently, FCM Expert can simulate in visual mode according to the activation value.

Figure 5 shows a system that models the causal relationship from the electrocardiogram results of abnormal heart failure medical records, the horizontal line is the causality value of evidence and the vertical line is the causality value of the hypothesis (objective), while the graph which has a different color shows the variables. Based on the results of the FCM inference process from abnormal, there are 5 variables whose graphs have decreased because the yes value is below 0.5, while there are 22 variables whose graphs increase because the value is above 0.5.

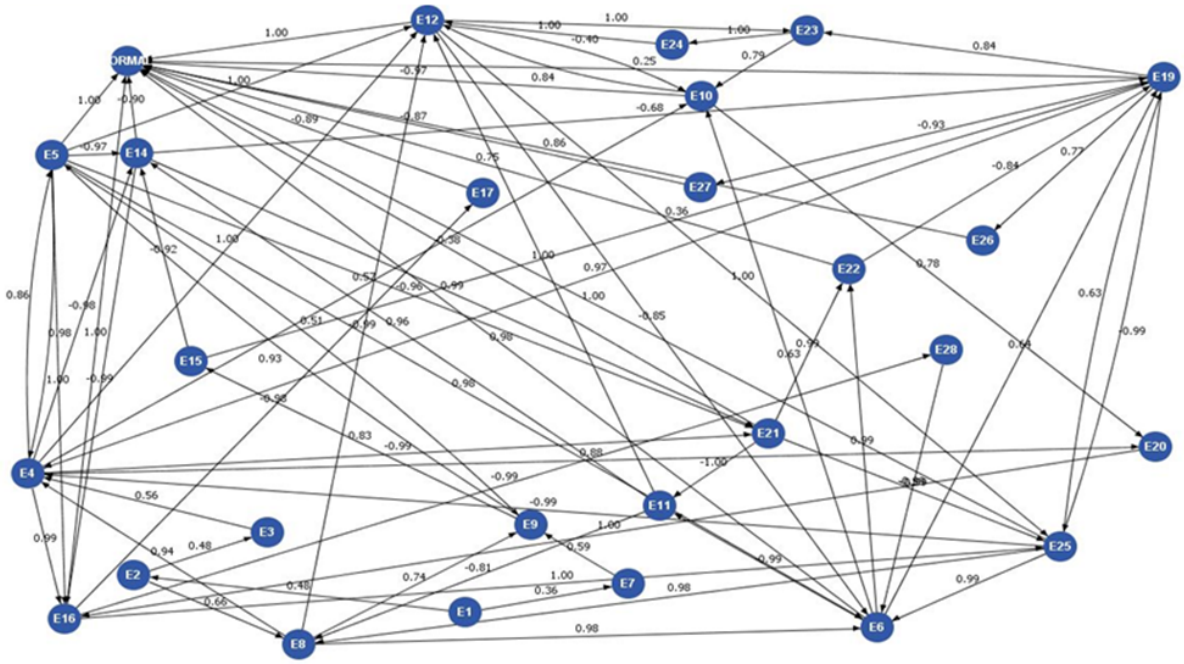

FIGURE 4. Normal heart

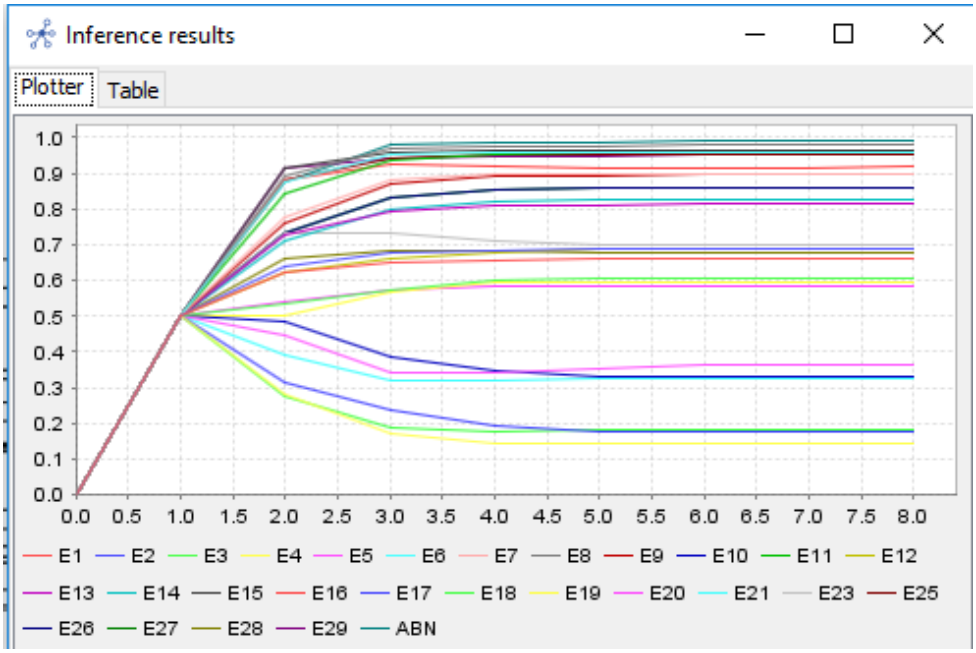

FIGURE 5. (color online) Dialogue summarizing the FCM inference process from abnormal heart abnormalities

Figure 6 shows a system that models the variable causal relationship from the results of the electrocardiogram medical record for normal heart failure. Horizontal graph is the proof value of causality and vertical graph is the value of the causality of the hypothesis (objective), while the graph which has a different color shows the variable. Based on the results of the FCM inference process from normal, there are 4 variables whose graphs have decreased because the yes value is below 0.5, while there are 23 variables whose graphs increase because the value is above 0.5.

3.1. **Convergence.** FCM Expert is software related to causal relationships, where the FCM model performs an optimization process with various heuristic search methods.

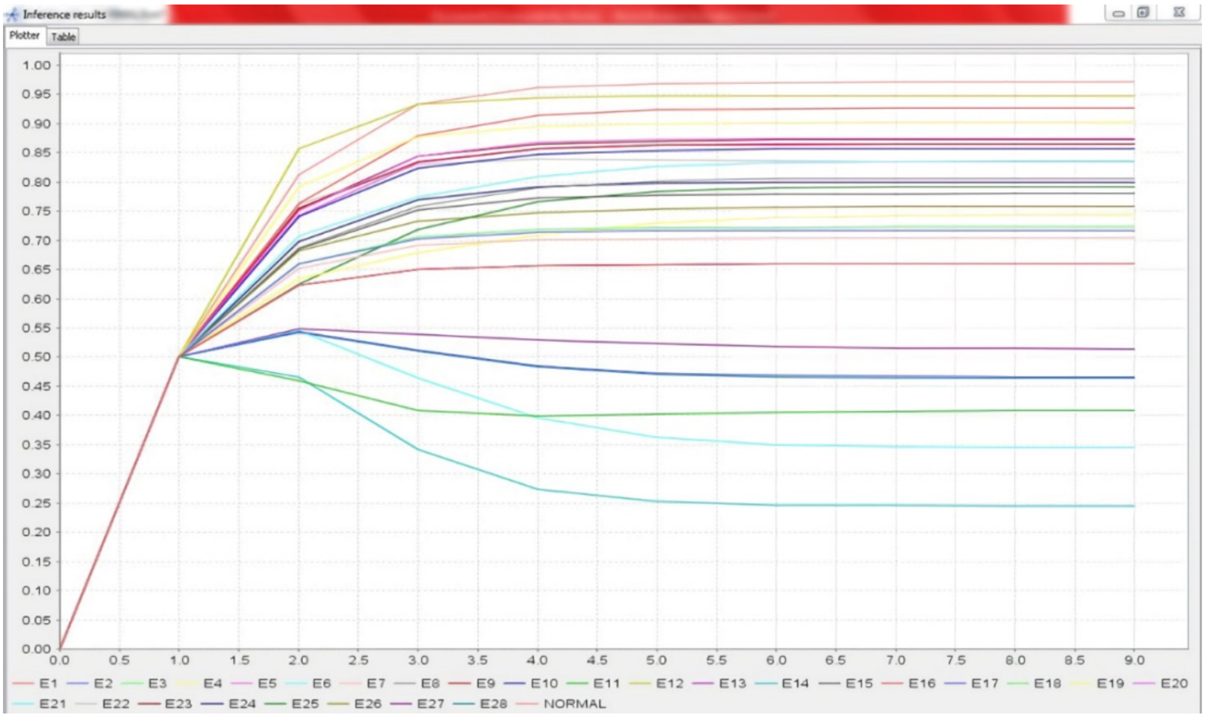

FIGURE 6. (color online) The dialog summarizing the FCM inference process from the normal heart

FIGURE 7. (color online) Convergence plot of normal values

Figure 7 shows convergence plot of normal values, while Figure 8 shows the classification of abnormal heart with a model based on the FCM classification.

Figure 7 shows the result of normal cardiac convergence process from the results of the FCM Expert software. The parameters used are variables from the results of the ECG record, which is indicated by a colored graph, the data used are 250 ECG data as training data, and the next process is modeling a causal relationship. From the results of the

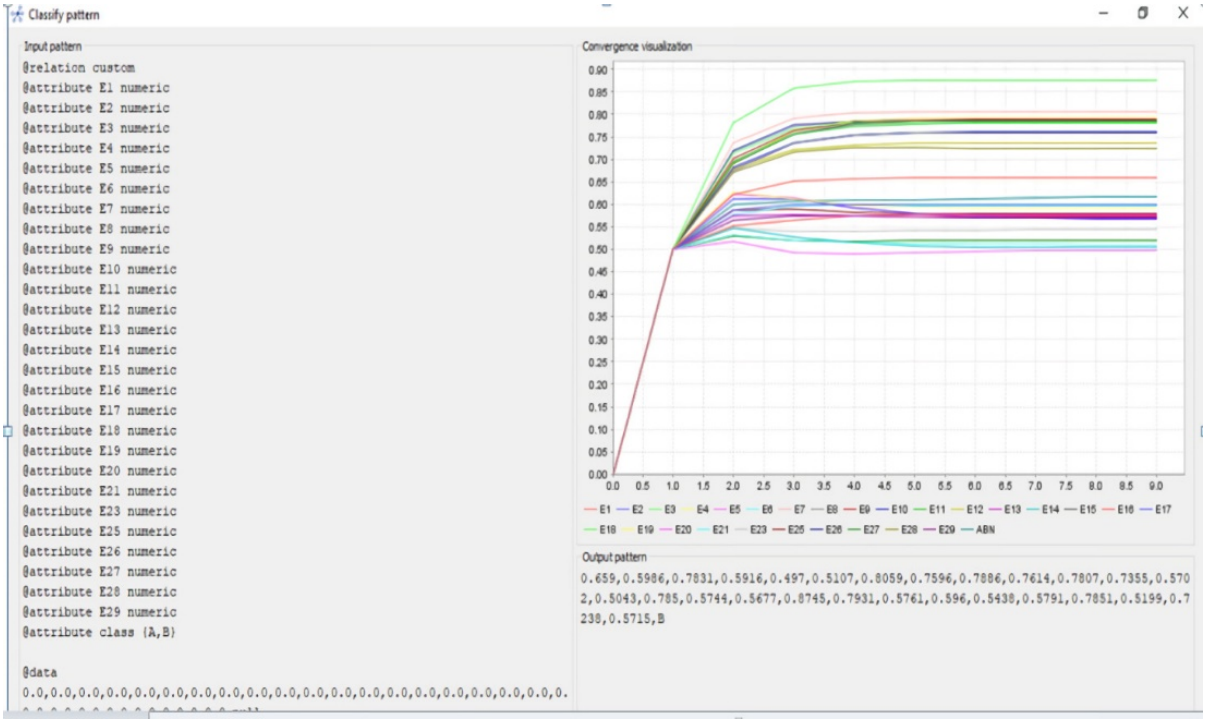

FIGURE 8. (color online) Convergence plot of abnormal values

convergence process, the normal heart has the lowest convergence value of 0.39, while the highest convergence value is 0.91.

Figure 8 shows the results of the abnormal cardiac convergence process from the results of the FCM Expert software. The parameters used are variables from the results of the ECG record, which is shown in a colored graph, the data used is 250 ECG data as training data, and the next process is modeling the causal relationship. From the results of the convergence process, the abnormal heart has the lowest convergence value of 0.49, while the highest convergence value is 0.87.

Figure 9 shows that this algorithm supports the convergence of FCM without information, and the error learning method for calculating weights does not consider the problem when estimating the final solution. The comparison of the normal cardiac curve error rate from the initial error is 0.030% while the current error is 16%.

Figure 10 shows this algorithm allows for increased FCM convergence without loss of information, and an error-based learning method for calculating weights does not consider stability problems when estimating the final solution. The comparison of the abnormal heart curve error rate from the initial error is 0.027% while the current error is 31%.

3.2. **Improving the system convergence.** The FCM-based model has the ability to analyze and classify patterns, but not at fixed points. In the decision-making process obtained for non-oscillation solutions that ensure convergence to a fixed point, to increase the convergence of sigmoid-based FCM classifications it has a causal hybrid. The convergence feature can be enhanced by an algorithm that calculates sigmoid parameterss in each nerve entity. FCM Expert implements algorithms for analysis in classification. Supervised learning is usually used by data analysts or data scientists to solve classification or regression problems. In this case, the data owned has a target label that is predicted for the future.

4. **Conclusions.** The results of this research can be used in various fields to be implemented. With the Fuzzy Cognitive Map (FCM) approach, we can model heart defects.

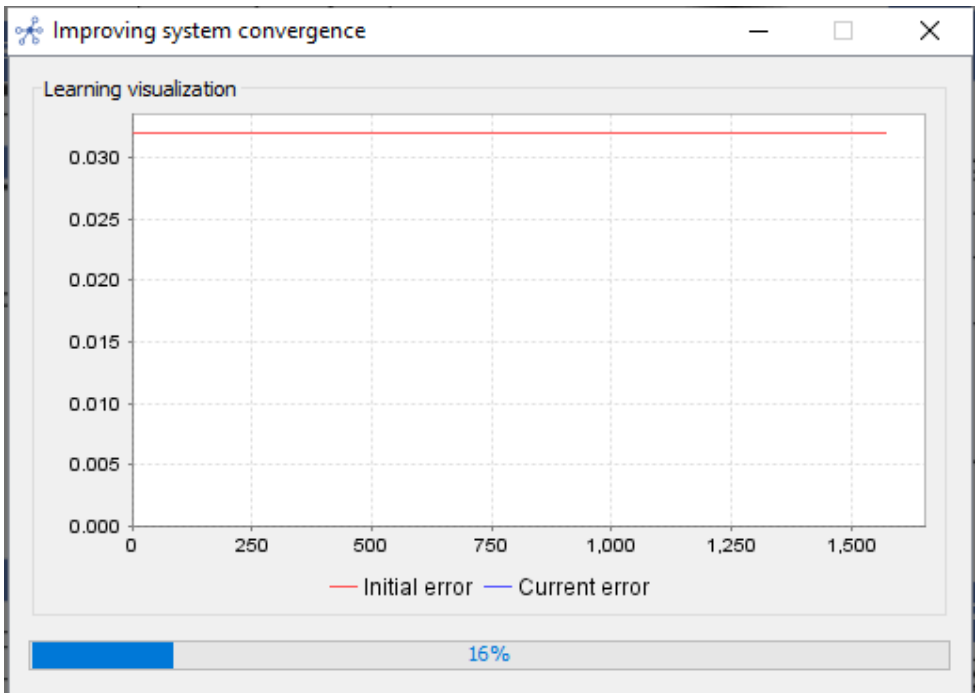

FIGURE 9. A real-time visualization of normal heart error curve

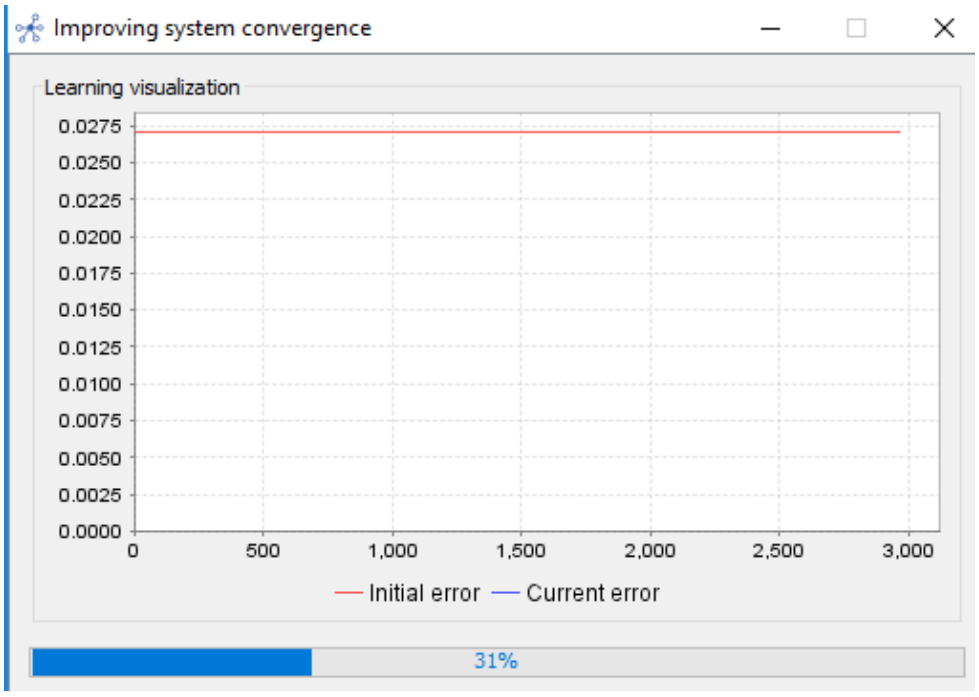

FIGURE 10. A real-time visualization of abnormal heart error curve

The resulting FCM approach is able to simulate and model cardiac failure based on electrocardiogram medical record data. There is still minimal research that discusses the classification of cardiac disorders using the fuzzy cognitive map method, which is assisted by the FCM Expert software. This software is able to describe modeling and experimentation as a form of representation of design element knowledge, algorithm description into the software, then this research contributes to the world of health, where we classify the Electrocardiogram (ECG) data, so that it can classify heart failure (abnormal) and normal. The FCM Expert includes an algorithm that defines the FCM model, which can optimize for the FCM topology process, thereby increasing convergence. FCM Expert is a

classification model in the decision making process with various modeling. In the process of improving the normal convergence system the real-time visualization of error value is 16%, while for the process of improving the abnormal convergence system the real-time visualization of error value is 31%.

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