HEARTBEAT ANOMALY DETECTION METHOD BASED ON ELECTROCARDIOGRAM USING IMPROVED CERTAINTY COGNITIVE MAP

SUMIATI

ASIA e UNIVERSITY

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A Thesis Submitted to Asia e University in
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ABSTRACT

Diagnosing heart defects is generally done through the Certainty Factor (CF) approach and the Cognitive Map (CM) approach. The first problem is the lack of the Certainty Factor method, the CF value has not shown a semantic relationship between one evidence and another, so that it forms a complete rule and shows the degree of confidence with a clear map of evidence. The second problem lies in the weakness of CM, namely cognitive maps do not model certainty in variables but only form deductive reasoning. This research was conducted using the Certainty Cognitive Map (CCM) approach used to diagnose heart disorders based on electrocardiogram data. This research has 3 objectives To develop algorithms for detecting heart conditions as either abnormal or normal using the modified cognitive map (CM) approach, To develop detection algorithms for anomalous heart conditions based on the enhancement of Certainty Factor (CF) technique, and To evaluate and validate the effectiveness of the new proposed model specifically the Certainty Cognitive Map (CCM) for identifying heart defects. The results of this test were carried out using the Mean Squared Error (MSE) and Root Mean Squared Error (RMSE) approaches. Based on the results CF Method gave a Mean Squared Error (MSE) of 0.24 and Root Mean Squared Error (RMSE) of 0.48. The results of testing the CM Method gave a Mean Squared Error (MSE) of 0.80 and Root Mean Squared Error (RMSE) of 0.89, the results of testing the MCF Method with a Mean Squared Error (MSE) of 0.79 and gave Root Mean Squared Error (RMSE) of 0.89. The test results of the MCM Method gave a Mean Squared Error (MSE) of 0.65 and Root Mean Squared Error (RMSE) of 0.80 and the test results of the CCM Method with a Mean Squared Error (MSE) of 0.15 and a Root Mean Squared Error (RMSE) of 0.39. So the CCM method which is a modification of CF and modification of CM provides a better level of accuracy in diagnosing heart defects as compared to the CF method and the CM method

APPROVAL

This is to certify that this thesis conforms to acceptable standards of scholarly presentation and is fully adequate, in quality and scope, for the fulfilment of the requirements for the degree of Doctor of Philosophy

The student has been supervised by: **Prof. Dr. Titik Khawa Abdul Rahman** and co-supervised by: **Prof. Dr. Hoga Saragih**

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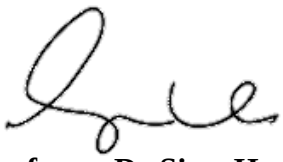
This thesis was submitted to Asia e University and is accepted as fulfilment of the requirements for the degree of Doctor of Philosophy.



Professor Dr Siow Heng Loke

Asia e University

Chairman, Examination Committee

(17 April 2023)

DECLARATION

I hereby declare that the thesis submitted in fulfilment of the PhD degree is my own work and that all contributions from any other persons or sources are properly and duly cited. I further declare that the material has not been submitted either in whole or in part, for a degree at this or any other university. In making this declaration, I understand and acknowledge any breaches in this declaration constitute academic misconduct, which may result in my expulsion from the programme and/or exclusion from the award of the degree.

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Signature of Candidate: **Date:** 17 April 2023

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Sumiati

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LIST OF ABBREVIATION

CF	Certainty Factor
CM	Cognitive Map
CCM	Certainty Cognitive Map
AeU	Asia e University
ECG	Electrocardiogram
OSA	Obstructive Sleep Apnea
DCW	Dynamic Cepstral Warping
SEM	Structural Equation Model
FCM	Fuzzy Cognitive Map
PJK	Jantung Koroner
DST	Dempster Shafer Theory
EKNN	Evidential K-Nearest
AV	Antrioventrikular
VV	Interventrikular
AS	Aortic stenosis
PSO	Particle Swarm Optimization
FCM	Fuzzy C-Means
OWA	Order Weighted Averaging
LVQ	Method Learning Vector Quantization

HDPSO	Hybrid Discrete Particle Swarm Optimazation
NHL	Non Linier Algoritma Hebbian
KNN	K-Nearest Neighbours Support Vector Machine (SVM)
EKNN	Evidential K- Nearest
NB	Naïve Bayes
PCC	Pearson Correlation Coeeficient

CHAPTER 1

INTRODUCTION

1.1 Background of the Study

Heart disease is one of the most common diseases and one of the factors causing the high mortality rate in Indonesia. Data in the field shows that the risk level for men to suffer heart disease higher than which of women. This is due to the habit of men who often smoke, which causes constriction of blood vessels, which triggers chest pain and shortens the breath. In addition, the narrowing of the blood vessels affects the hands and feet, which results in pain, tingling, numbness, coldness, and weakness.

The high mortality rate for heart disease is due to the lack of availability of cardiac specialist medical personnel, based on data from the Ministry of Health, Indonesia has only 5,290 cardiologist who have not spread evenly in Indonesia, especially for underdeveloped, frontier and outermost areas (3T) (Ministry of Health RI, 2017). The ECG tool does not currently have a feature that is currently able to analyze and identify the patient's heart condition automatically. To be able to find out the patient's heart condition, the ability of a cardiologist is still needed in order to interpret the results of measurement of heart muscle activities. This condition causes so many cases of heart disease that are often handled late because the analysis carried out takes a long time even through a lot of consideration of the results before confirming the patient's actual heart condition. In fact, with the development of information technology today, especially in the field of computing, difficulties in identifying heart disease early can be overcome.

Several studies in the field of computing have been carried out to contribute to the world of health, particularly in an effort to provide alternative solutions for analyzing heart disease. Researchers use the concept of data mining to diagnose

abnormalities and heart disease in patients (Deng et al., 2017). Some of the approaches used to diagnose abnormalities and heart disease are the particle swarm optimization (PSO) algorithm and the neural network (Feshki & Shijani, 2016), prediction techniques (Shaikh et al., 2015), genetic neural networks (Amin et al., 2013) and radial base classification network techniques (Alsalamah et al., 2014; Amin et al., 2013). Several other studies such as those conducted (Lindow et al., 2016; Rawi & Al-Ani, 2013; Shortliffe & Buchanan, 1975) also discusses the same thing regarding the diagnosis ofheart disease using a certainty factor approach.

CF has its own advantages when carrying out the inference process in determining the final outcome of a disease diagnosis, such as it can solve problems related to incomplete knowledge. CF works based on statistical values with value intervals from

-1 to +1. In the CF concept, the main advantage it has is, each piece of evidence selected by the patient has a confidence value based on the level of confidence someone experiences the evidence (Lindow et al., 2016). Likewise, the rules which apply to the knowledge base, the value of CF is an important part of the rule which is formed whether certain evidence refers to the type of disease in question or not. This level of confidence shows how the expert believes that evidence must refer to the hypothesis. However, one of the main drawbacks of CF is, that the existing CF rule value does not necessarily show a semantic relationship between evidence and other evidence. CF does not discuss how a belief value relates to one piece of evidence with other evidence so that it forms a complete rule and shows the degree of confidence with a clear evidence map (Wang et al., 2009).

Apart from using CF, another approach used to diagnose heart disease is the concept of Cognitive Map (CM). The advantages of CM are in the decision-making process and classification process. Besides that, it can also diagnose a disease, and provide predictions in the treatment process, so that it is very helpful for medical personnel who still lack experience (Bourgani et al., 2013), besides that, it can diagnose a disease, and predictions in the treatment process, so that it is very helpful for medical personnel who still lack experience (Bourgani et al., 2013), used in decision making and prediction (Tsadiras & Margaritis, 1997). Another widely used approach in diagnosing heart disease is using CM (Hjelm, 2013). Several other studies such as those conducted (Ghaderyan & Abbasi, 2018; Hassan & Haque, 2017; Mathews et al., 2018; Sedki & De Beaufort, 2015; Stylios et al., 2013; Yano et al., 2016; Zheng et al., 2017) also discussed the same thing regarding the diagnosis of heart disease using the CM approach.

CM has the advantage of being able to show a causal relationship between one variable and another in the form of a semantic map. This relationship is indicated by the weight ranges of values -1, 0, and +1. Weight value> 0, has positive causality. CM is a qualitative decision model that is often used in decision making, This model easily organizes individual judgments, thoughts or beliefs about a given problem in a graphical representation containing various concepts and influences, However, the reasoning of this model presents several limitations, among others, that CM does not model uncertainty in changing permissibility, but only in the form of deductive reasoning (Sedki and de Beaufort, 2015), the sum of the values of the range of causality weights between one cognitive and another cognitive can be worth 0. If two cognitive pieces each have a weight range of +1 and -1, then the level of causality between the two cognitive will produce a weight of zero (0) or have no causality at all, whereas in

semantics the map shows that the two cognitive ways can be connected with a flow to describe the causality of both.

The research has the main objective of overcoming the limitations/drawbacks of both CF and CM especially for the need for diagnosing heart disease disorders. CM has a range of values that makes the causal relationship of cognitive disappear because the two cognitive weights are added. To overcome this, the CM concept is modified using the CF approach. The range of weight values owned by CF allows the calculation of the causality of two cognitive pieces is not equal to zero (0) because it is not done by adding the weight values, can be implemented with the CM approach so that it can be seen clearly the relationship between evidence and another to refer to a particular hypothesis.

The process of determining the causality value of two cognitive pieces is carried out based on the formulation of CF, Thus the weight of causality that is owned is the combined CF value between the two CF values of each cognitive. In the case of a diagnosis of heart disease, the combined concept of CF modification and CM modification is carried out to determine what kind of heart disease or defect of the patient experiencing based on the recorded data from the ECG. Data from the patient's medical record from the ECG are then traced based on the available knowledge base in which previously the database has been formed into CM. The values of the weight range of one cognitive with another on the knowledge base have been predetermined by the expert. As for the final value of causality between the evidence experienced by patients with heart disease and the knowledge base, it is applied by comparing the CF values between the input results of the user confidence level with the expert on the knowledge base.

Based on the results of the study it is shown that the proposed technique is able to provide higher degree of accuracy in the diagnosis of heart disease and minimize the possibility of loss of cognitive intermediate causality such as CM. The proposed technique compares the expert causality value with the patien's causality value through CF values combined with a cognitive map.

1.2 Problem Statement

Based on this background, the formulation of the problem is that heart diseaseis one of the most common diseases and and the factor causing the high mortality rate in Indonesia. The ECG does not have a feature which is able to automatically analyze and identify a patient's heart condition. To be able to find out the patient's heart condition, the ability of a specialist is still needed to be able tointerpret the results of measurements of heart muscle activity.

In addition, the formulation of the problem the main drawback of the CF method is that the existing CF rule values do not necessarily show a semantic relationship between one piece of evidence and other evidence. CF does not discuss how a belief value relates to one piece of evidence with other evidence so as to form a complete rule and show the degree of confidence with a clear evidence map (Wang et al., 2009), and CM has a weakness, especially when adding values to the range of causality weights between one cognitive and another cognitive. If each of two cognitive pieces has a weight range of +1 and -1, then the causality value between the two cognitive will produce a weight of zero (0) or have no causality at all, whereas in semantics the map shows that the two cognitive can be connected with a flow to describe the causality of both, and the cognitive map does not model uncertainty in variables but only in the form of deductive reasoning (Sedki & De Beaufort, 2015).

1.3 Objectives

The objectives of the research are:

i To develop algorithms for detecting heart conditions as either abnormal or normal using the modified cognitive map (CM) approach.

ii To develop detection algorithms for anomalous heart condition based on the enhancement of Certainty Factor (CF) technique.

iii To evaluate and validate the effectiveness of the new proposed model specifically the Certainty Cognitive Map (CCM) for identifying heart defects

1.4 Research Questions

The research questions of the research are:

i How to modify CM to determine the value of causality between evidence and another using a certainty factor approach in cases of diagnosis of abnormal and normal heart defects?

ii How to combine the certainty factor modification approaches and CM modification into a new method which is then called CCM for the need of identifying heart defects?

iii How to determine the causality value of two cognitive pieces using the Certainty Factor formulation in CM?

1.5 Research Hypothesis

The hypothesis being tested is one of the most important aspects of statistics. Statistical practitioners use hypothesis testing techniques to draw conclusions whether the initial hypothesis they form in a problem is supported by data or not. Evaluate and validate the effectiveness of the new proposed model specifically the Certainty Cognitive Map (CCM) for identifying heart defects, developed an algorithm to detect cardiac

conditions as abnormal or normal using a modified cognitive map (CM) approach, and developed an algorithm for detecting anomalous heart conditions based on an increase in the Certainty Factor (CF) technique.

1.6 Operational Definitions

Table 1.1: Operational Definitions

Variable	Definition operational variable	Measuring instrument variable	How to measure variable	Measurement results (indicators) variable	Scale measuring variable
Electrocardiogram medical record results	Failed case heart that diagnosed by heart doctor based on inspection echocardiogram written in record medical	Record medical	Observation data in the lab Hospital Dr Drajat Prawiranegara Hospital	Categorized as become: Normal heart abnormal heart	ordinal
Type Sex	Difference biological and physiological ones can differentiate man with that girl listed in the column gender on record medical	Record medical	Observation data in the lab Hospital Dr Drajat Prawiranegara Hospital	Categorized as become: 1. When gender man 2. When gender Woman	nominal

1.7 Justifications and Significance of the Study

The study was conducted because heart disease is one of the main factors causing the high mortality rate. In addition, the current ECG tool is not yet able to analyze and identify the patient's heart condition, it still requires specialist skills. Based on these problems, this study aims to modify CM to determine the causality value of two cognitive units using Certainty Factor formulation in detecting heart rate anomalies, and to develop a CCM approach which is a combination of CM modification and CF modification for cardiac needs abnormality analysis, thus providing a better level of accuracy in diagnosing heart rate anomalies.

1.8 Theoretical Contributions

The study is able to contribute for knowledge of research studies in the field of Computational Intelligence, related to the development of CCM which is a modified of CF and modified of CM.

1.9 Practical Contributions

The study is able to contribute to medical science related to the analysis of electrocardiogram medical records with the CCM method which is a modified of CF and modified of CM for prediction models of abnormal and normal heart defects.

1.10 Contribution to Methodology

Contribute by modifying a modified Certainty Factor approach and a modified Cognitive Map, so that the result is a new method called CCM for the identification of cardiac abnormalities.

1.11 Structure of Thesis

The thesis is organized according to the following chapters :-

Chapter 1 – explained the background of study, problem statements, formulate the research objectives and research questions, justifications and contributions of the study

Chapter 2 – discussed and analysed the previous researches and techniques on heart abnormaly detection.

Chapter 3 – explained the research design and methodology developed and adapted in the study.

Chapter 4 – presented the results from the developed techniques and discussed the findings.