DIAGNOSIS OF HEART DISEASE USING AUTOMATA FINITE STATE ALGORITHM

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Abstract- The heart is a vital organ for humans. If our heart has a problem, it is very dangerous because considering that many deaths are caused by heart disease. With minimal knowledge and information, it is impossible to maintain a healthy heart. Therefore we need an expert who is an expert on the heart and its various diseases. Based on the facts above, this research was created to help diagnose heart health and anticipate heart disease by designing and implementing a web-based pseudocode. In this application, the concept of Finite State Automata (FSA) is applied to realize and capture patterns of heart health diagnoses. In this application, Finite State Automata (FSA) is applied to read a given input symbol from initial state to final state so that the language can be recognized by the machine. Furthermore, the process will be carried out in accordance with the language being read.

Keywords: Finite State Automata Algorithm, Heart Disease, Pseudocode.

Abstrak— Jantung merupakan organ vital bagi manusia jika jantung kita mempunyai masalah maka sangat berbahaya sekali mengingat bahwa banyak kematian disebabkan oleh penyakit jantung. Dengan pengetahuan dan informasi yang minim, mustahil untuk dapat menjaga kesehatan jantung. Oleh karena itu dibutuhkan seorang pakar yang ahli tentang jantung dan macam-macam penyakitnya. Berdasarkan fakta diatas, maka Penelitian ini dibuat untuk membantu mendiagnosa kesehatan jantung dan mengantisipasi jika mempunyai resiko penyakit jantung dengan merancang dan mengimplementasikan aplikasi berbasis web yang masih berupa pseudocode. Dalam aplikasi ini, konsep Finite State Automata (FSA) diterapkan untuk mengenali dan menangkap pola diagnosa kesehatan jantung. Dalam aplikasi ini, Finite State Automata (FSA) diterapkan untuk membaca simbol input yang diberikan dari status awal hingga status akhir agar bahasa dapat dikenali oleh mesin. Selanjutnya proses akan dilakukan sesuai dengan bahasa yang dibaca.

Kata Kunci*: Algoritma Finite State Automata, Penyakit Jantung, Pseudocode.*

INTRODUCTION

In this modern era, The use of technology or computer science in the world of health is very important, this encourages experts to further develop technology. The computer science component has two main components, first, models and basic ideas about computing, second, engineering techniques for designing computational systems(Saptadi & Marwi, 2016). Automata is a system consisting of a finite number of states, where each state states information about the previous input, and can also be considered as machine memory. Input to the automata machine is considered a language that the machine must recognize. Then the automata machine makes decisions that indicate whether the input is accepted or not, so that the automata machine can be used to produce a language whose rules are determined by the language(Saputra, Fauziah, & Gunaryati, 2018). The expert system is a system that uses human knowledge(Nugroho, 2018). The knowledge is put into a computer and then used to solve problems that usually require human expertise or expertise.

Heart disease is the number one killer disease in the world. One of the diseases that we often encounter is coronary heart disease, besides that many cardiovascular diseases are also found, such as heart infections (endocarditis) and hypertension.(Ramadan & Winata, 2019). Most ordinary people pay very little attention to health, especially heart health. They are reluctant to have their heart health checked because of the lack of service to patients, a lack of medical personnel, especially heart specialists and limited doctor working hours. Based on the background of the problems above, a computer application or program is needed that can store the knowledge of an expert to diagnose heart disease and provide consistent, fast and precise results. Based on this opinion, researchers are interested in conducting research related to designing an expert system program(Septiana, 2016) Who is able to make a diagnosis and provide accurate and fast solutions to the symptoms of heart disease. The method used is the Finite state Automata algorithm method (Allauzen & Riley, 2018) where Finite State Automata is an abstract machine in the form of a mathematical model system with discrete input and output that can recognize the simplest language (regular language) and can be implemented in real terms where the system can be in one of the a finite number of internal configurations are called state (Wicaksono, Amrizal, & Mumtahana, 2019). In this study, the problem raised was designing a computer application to diagnose heart disease using the Finite State Automata algorithm.

There have been many researches regarding the manufacture of disease diagnosis systems using the Forward Chaining Method to design an application or create a system. In the research entitled "Perancangan Sistem Pakar Diagnosa Penyakit Jantung dengan Metode Forward Chaining"(Nugroho, 2018), " Aplikasi Sistem Pakar Diagnosa Penyakit Pada Anak Bawah Lima Tahun Menggunakan Metode Forward Chaining" (Yanto, Werdiningsih, & Purwanti, 2017) and the "Sistem Pakar Diagnosa Penyakit THT" (Lisnawita, Van FC, & Lianda, 2016)

Based on the studies that have been conducted, the researchers will discuss the application of the diagnosis of heart disease using the Finite State Automata algorithm. This system is designed to make it easier for users to check symptoms of heart disease easily and quickly.

This research is expected to provide the following benefits: For the general public to know in advance the early symptoms of heart disease so that they can take appropriate action to deal with the disease without the help of a heart disease specialist. For doctors who specialize in heart disease, this system can be used as an experienced assistant and relieve the workload based on the symptoms felt by the patient.

MATERIALS AND METHODS

The research that was carried out was completed through stages which were divided into three stages (Yusri, 2015), namely: (1) Needs analysis and data collection in the form of symptoms of heart disease, (2) System design (3) System implementation.

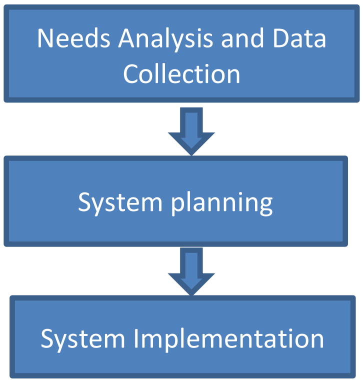

Figure 1 Research Methodology

The research stages, starting with the needs analysis and data collection stage, are collecting and analyzing the symptoms caused by heart disease through literature studies, while the data is collected to build the system. At the stage of making the system design, the use of finite state automata is applied to diagnose heart disease in the form of a flowchart(Nuraini, 2015). The next stage is the implementation and testing of the system, at this stage the system implementation is carried out in the form of a program and system testing and analysis of the implementation of the system that has been made are carried out, whether it is in accordance with the concept of diagnosing heart disease using finite state automata, if there are still errors then it is done improvements so as to get better results.

The system to be built to diagnose heart disease is limited to 7 types and their respective symptoms as shown in Table 1

Table 1 Symptoms of Heart Disease

No.	Symptoms	Heart						
		Coronary heart disease	Heart muscle disease (cardiomyopathy)	Ischemic heart disease	Heart failure	Hypertensive heart disease	Heart valve disease	Cardiomegaly or hypertrophic heart
T01	Chest pain	X						
T02	Left Shoulder feels bad	X						
T03	A cold sweat	X						
T04	Out of breath	X	X		X			

No.	Symptoms	Heart						
		Coronary heart disease	Heart muscle disease (cardiomyopathy)	Ischemic heart disease	Heart failure	Hypertensive heart disease	Heart valve disease	Cardiomegaly or hypertrophic heart
T05	Indigestion	X					X	
T06	Nausea	X						
T07	Irregular Heartbeat	X	X					X
T08	Dizzy		X			X		
T09	Swollen foot		X				X	
T010	Heart palpitations		X				X	
T011	Tired Easily		X			X	X	
T012	Pain in the middle chest area			X			X	X
T013	Sweating easily			X				
T014	Chest Tightening			X				
T015	Swelling of the heart			X	X			
T016	Heart dysfunction				X			
T017	Bleeding from the nose					X		
T018	Reddish face					X		
T019	Cough						X	
T020	Stomach ache							X
T021	Fast heart rate							X
T022	Pain in the area of the left arm	X		X				
T023	Back feels bad	X						
T024	Headache					X		

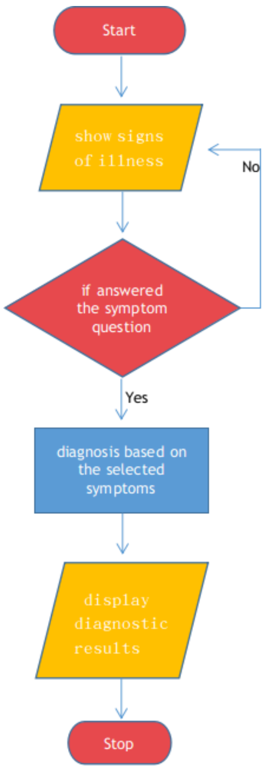

Figure 2 Diagnosis Process of Heart Disease

The design of the Heart Disease Diagnosis Process in Figure 2 is designed to take all the possibilities that can occur during the Heart Disease Diagnosis process. The process in the Figure above will be useful in designing the finite state automata design because all the possibilities are represented. Based on the Design of the Heart Disease Diagnosis Process in the Figure above, a finite state automata design can be made in stages. Every process that occurs is a state / condition in the finite state automata. In designing the diagram for diagnosing heart disease, Non Deterministic Finite Automata (N-DFA) are used.(Gopalakrishnan, 2019). The FSA diagram can be seen in Figure 3.

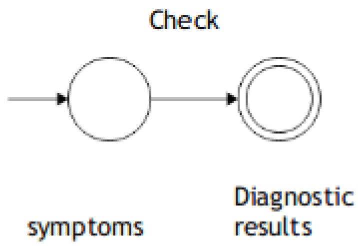

Figure 3 FSA Diagram for Diagnosis of Heart Disease

Figure 3 is a design process diagram of the FSA that was built. The FSA flow diagram steps can be described as follows: a) The start state of the state diagram process is a symptom of heart disease; b) Reading the input checking whether experiencing the displayed symptoms or not; and c) Towards the final state in the form of diagnosis results whether or not you have heart disease by accepting checking input. The results of the diagnosis are in accordance with the symptoms experienced.

RESULTS AND DISCUSSION

This section will discuss in detail the design of the FSA diagram for diagnosing heart disease. This section will also cover the diagnostic process. Based on the symptoms in Table 1 and the design of the FSA diagram, the symptoms will be modeled into a more detailed finite state automata diagram to make a decision. The FSA diagram can be seen in the Figure below.

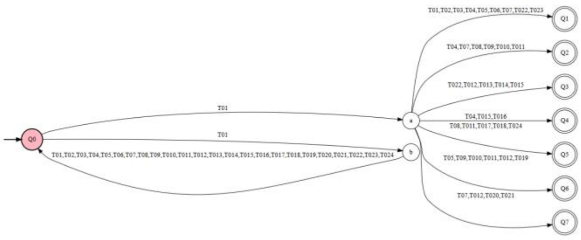

Figure 4 N-DFA State Diagram for Diagnosis of Heart Disease

In the N-DFA diagram for diagnosing heart disease, there are alphabets {a, b}. These symbols are compared to symptoms experienced and symptoms not experienced, a for having no symptoms and b for experiencing symptoms. Symbol T01-T024 is an existing state, namely symptoms of heart disease, while Symbols P0, P1, P2, P3, P4, P5, P6 and P7 are states that contain diagnostic results which will be explained as follows:

T01 : Chest pain
T02 : Left Shoulder feels bad
T03 : A cold sweat
T04 : Out of breath
T05 : Indigestion
T06 : Nausea
T07 : Heartbeat Irregular
T08 : Dizzy
T09 : Swollen foot
T010 : Heart palpitations
T011 : Tired Easily
T012 : Pain in the middle chest area
T013 : Sweat easily
T014 : Chest Tightening
T015 : Swelling of the heart
T016 : Heart function disorders
T017 : Bleeding from the nose
T018 : Face redness
T019 : Cough
T020 : Stomach ache
T021 : Heartbeat fast
T022 : Pain in the area of the left arm
T023 : Back feels bad
T024 : Headache
P0: Not Heart Disease
P1: Coronary heart disease
P2: Heart muscle disease (cardiomyopathy)
P3: Ischemic heart disease
P4: Heart Failure
P5: Hypertension Heart Disease
P6: Heart Valve Disease
P7: Cardiomegaly or hypertrophic heart

Formally N-DFA in Figure 4 is expressed in 5 tuples or M = (Q, ∑, δ, S, F), meaning:
Q = set of state / position
∑ = the set of input / input / alphabetical symbols
Δ = transition relation S = initial state
F = set of final states

So to state Figure 4 is as follows:
Q = (T01, T02, T03, T04, T05, T06, T07, T08, T09, T10, T011, T012, T013, T014, T015, T016, T017, T018, T019, T020, T021, T022, T023, T024 , P0, P1, P2, P3, P4, P5, P6, P7}
∑ = {a, b}
S = {T01}
F = {P0, P1, P2, P3, P4, P5, P6, P7}
Δ = transition relation can be seen in Table 2.

Table 2 Relationships

Δ	A	B
T01	P0	P1
T02	P0	P1
T03	P0	P1
T04	P0	P1, P2, P4
T05	P0	P1, P6
T06	P0	P1
T07	P0	P1, P2, P7
T08	P0	P2, P5
T09	P0	P2, P6
T010	P0	P2, P6
T011	P0	P2, P5, P6
T012	P0	P3, P6, P7
T013	P0	P3
T014	P0	P3
T015	P0	P3, P4
T016	P0	P4
T017	P0	P5
T018	P0	P5
T019	P0	P6
T020	P0	P7
T021	P0	P7
T022	P0	P1, P3
T023	P0	P1
T024	P0	P5
P01	-	-
P02	-	-
P03	-	-
P04	-	-
P05	-	-
P06	-	-
P07	-	-

Transition relations can also be written by:
Δ = (((T01, a), p0), ((T01, b), p1), ((T02, a), p0), ((T02, b), p1), ((T03, a), p0), ((T03, b), p1), ((T04, a), p0), ((T04, b), p1, p2, p4), ((T05, a), p0), ((T05 , b), p1, p6), ((T06, a), p0), ((T06, b), p1), ((T07, a), p0), ((T07, b), p1, p2, p7), ((T08, a), p0), ((T08, b), p2, p5), ((T09, a), p0), ((T09, b), p2, p6), ((T10 , a), p0), ((T10, b), p2, p6), ((T10, a), p0), ((T10, b), p2, p6), ((T10, a), p0) , ((T10, b), p2, p6), ((T10, a), p0), ((T10, b), p2, p6), ((T10, a), p0), ((T10, b), p2, p6), ((T10, a), p0), ((T10, b), p2, p6), ((T011, a), p0), ((T011, b), p2, p5, p6), ((T012, a), p0), ((T012, b), p3, p6, p7), ((T013, a), p0), ((T013, b), p3), ((T014 , a), p0), ((T014, b), p3), ((T015, a), p0), ((T015, b), p3, p4), ((T016, a), p0), ((T016, b), p4), ((T017, a), p0), ((T017, b), p5), ((T018, a), p0), ((T018, b), p5), ((T019, a), p0), ((T019, b), p6), ((T020, a),p0), ((T020, b), p7), ((T021, a), p0), ((T021, b), p7), ((T022, a), p0), ((T022, b), p1, p3), ((T023, a), p0), ((T023, b), p1), ((T024, a), p0), ((T024, b), p5)).

Based on the results of the N-DFA design in Figure 4, the overall N-DFA design will be discussed as follows.

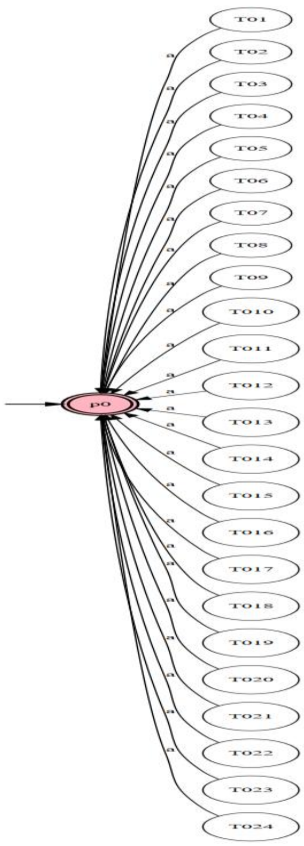

Figure 5 N-DFA State Diagram for Undiagnosed Heart Disease

Figure 5 is the condition of the N-DFA design that is not diagnosed with heart disease. This condition is a condition where at symptom 1 or symptom 2 or symptom 3 or symptom 4 or symptom 5 or symptom 6 or symptom 7 or symptom 8 or symptom 9 or symptom 10 or symptom 11 or symptom 12 or symptom 13 or symptom 14 or symptom 15 or symptoms 16 or symptoms 17 or symptoms 18 or symptoms 19 or symptoms 20 or symptoms 21 or symptoms 22 or symptoms 23 or symptoms 24 not experienced by the user. Transition from state T01 to state T024, if one of the conditions is not fulfilled, it will lead to the final state p0. The final state p0 results in an undiagnosed heart disease.

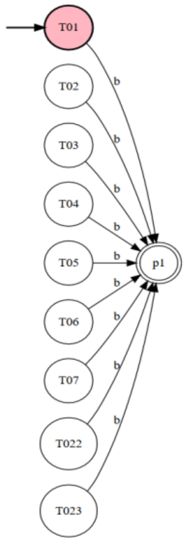

Figure 6 N-DFA State Diagram for diagnosed coronary heart disease

Figure 6 is the condition of the N-DFA design results in which coronary heart disease is diagnosed. This condition is a condition in which symptom 1, symptom 2, symptom 3, symptom 4, symptom 5, symptom 6, symptom 7, symptom 22, and symptom 23 must be met all of the conditions. The state flow will then go to the final state p1 which results in a diagnosis of coronary heart disease.

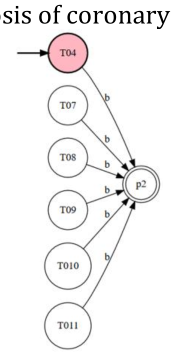

Figure 7 N-DFA State Diagram for a Diagnosed Heart muscle disease

Figure 7 is the condition of the N-DFA design that diagnosed heart muscle disease. This condition is a condition where symptom 4, symptom 7, symptom 8, symptom 9, symptom 10, and symptom 011 must all be met. The state flow will then go to the final state p2 which results in a diagnosis of heart muscle disease.

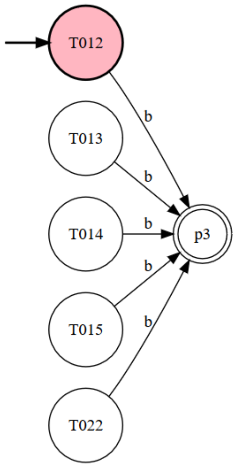

Figure 8 N-DFA State Diagram for a Diagnosed of Ischemic Heart Disease

Figure 8 is the condition of the N-DFA design that is diagnosed with ischemic heart disease. This condition is a condition where symptom 12, symptom 13, symptom 14, symptom 15, and symptom 022 must all be fulfilled. The state flow will then lead to the final state p3 which results in a diagnosis of ischemic heart disease..

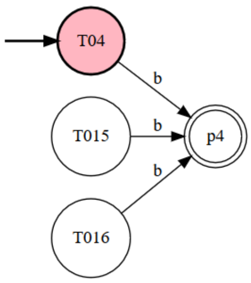

Figure 9 N-DFA State Diagram for a Diagnosed of Heart failure

Figure 9 is the condition of the N-DFA design that diagnosed heart failure. This condition is a condition where in symptom 4, symptom 15, and symptom 016 all conditions must be met. The state flow will then go to the final state p4 which results in a diagnosis of heart failure.

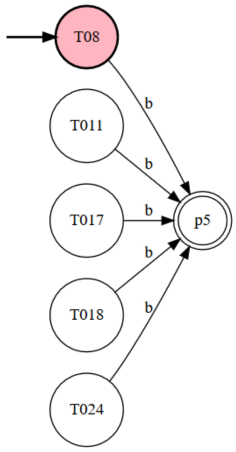

Figure 10 N-DFA State Diagram for a Diagnosed of Hypertensive Heart Disease

Figure 10 is a condition of the results of the N-DFA design in which hypertensive heart disease is diagnosed. This condition is a condition where symptom 8, symptom 11, symptom 17, symptom 18, and symptom 024 must all be fulfilled. The state flow will then lead to the final state p5 which results in a diagnosis of hypertension heart disease.

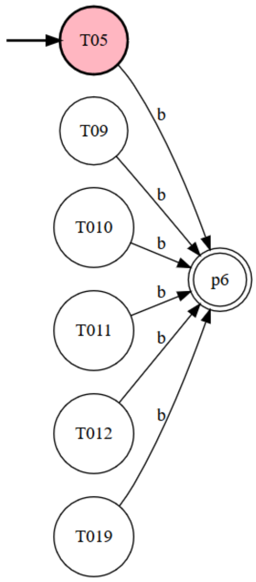

Figure 11 N-DFA State Diagram for a Diagnosed Heart valve disease

Figure 11 is the condition of the N-DFA design in which heart valve disease is diagnosed. This condition is a condition where symptom 5, symptom 9, symptom 10, symptom 11, symptom 12 and symptom 019 must be met all of the conditions. The state flow will then go to the final state p6 which results in a diagnosis of heart valve disease.

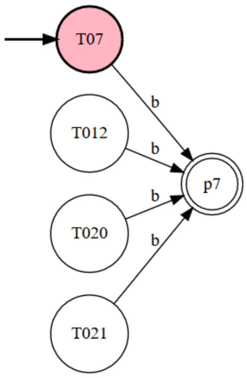

Figure 12 N-DFA State Diagram for a Diagnosed of Hypertrophic Heart Disease

Figure 12 is the condition of the N-DFA design that is diagnosed with hypertrophic heart disease. This condition is a condition where symptom 7, symptom 12, symptom 20, and symptom 021 must be met. The state flow will then lead to the final state p7 which results in a diagnosis of hypertrophic heart disease..

The algorithm for diagnosing heart disease is based on the previously made Non Deterministic Finite Automata (N-DFA) design (Barua & Gupta, 2019). The algorithm is in the form of steps to solve problems in the form of diagnosing heart disease. This algorithm will be used to facilitate the preparation of pseudocode before making it into program form. The pseudocode of the process of diagnosing heart disease is as follows:

```
Diagnosis of Heart_Disease Program
start_state, final_state state,
alphabet: string

Start
start_state = "diagnosis of heart
disease"
Write (start_state)
Read the alphabet

IF alphabet == "chest pain" AND
alphabetical == "left shoulder feels
bad" AND alphabet == "cold sweat" AND
alphabet == "shortness of breath" AND
alphabet == "indigestion" AND alphabet
== "nausea" AND alphabetical ==
"irregular heartbeat" AND alphabetical
== "left arm feels bad" AND alphabetical
== "back feels bad" THEN final_state =
"Coronary Heart Disease"
write (final_state)
end if
else
final_state = "no heart disease"
write (final_state)

read alphabetically
IF alphabetical == "shortness of breath"
AND alphabetical == "dizzy" AND
alphabetical == "swollen feet" AND
alphabet == "heart palpitations" AND
alphabetical == "easily tired" AND
alphabetical == "irregular heartbeat
"THEN final_state =" Heart Muscle
Disease (Cardiomyopathy) "
write (final_state)
end if
else
final_state = "no heart disease"
write (final_state)
end if
else
final_state = "no heart disease"
write (final_state)
read alphabetically
IF alphabetical == "pain in the middle
chest area" AND alphabetical == "easy to
sweat" AND alphabetical == "chest
tightens" AND alphabetical == "pain in
the left arm area" AND alphabetical ==
"tendon achiles thickening" THEN
final_state = "Ischemic Heart Disease"
write (final_state)
read alphabetically
IF alphabetical == "shortness of breath"
AND alphabetical == "swelling of the
heart" AND alphabetical == "abnormal
heart function" THEN final_state =
"Heart Failure"
write (final_state)
read alphabetically
IF alphabetical == "headache" AND
alphabetical == "bleeding from the nose"
AND alphabetical == "dizzy" AND
alphabetical == "reddish face" AND
alphabetical == "easily tired" THEN
final_state = "Hypertension Heart
Disease"
write (final_state)
end if
else
final_state = "no heart disease"
write (final_state)

read alphabetically
IF alphabet == "easily tired" AND
alphabetical == "palpitations" AND
alphabet == "chest pain" AND
alphabetical == "shortness of breath"
AND alphabet == "cough" AND alphabet ==
"swollen feet" THEN final_state = "Heart
Valve Disease"
write (final_state)
end if
else
final_state = "no heart disease"
write (final_state)

read alphabetically
IF alphabetical == "stomachache" AND
alphabetical == "irregular heartbeat"
AND alphabetical == "fast heart rate"
AND alphabetical == "chest pain" THEN
final_state = "Hypertrophic Heart
Disease (Cardiomegaly)"
end if
else
```

```
final_state = "no heart disease"
write (final_state)
end if
end
```

The algorithm for diagnosing heart disease that has been created is applied to making pseudocode into a simple structural programming language. The pseudocode declares the variables to be used and the functions to be used. The existing symptoms are declared as start state and state, while the diagnosis results are in the final state variable. In addition to symptoms and diagnosis, the answers to each symptom question are accommodated in alphabetical variables.

CONCLUSION

Based on the design, manufacture and implementation of a pseudecode for diagnosing heart disease with the finite state automata algorithm method, diagnosing heart disease with the finite state automata algorithm method is quite helpful in making early diagnoses of heart disease that is felt by ordinary people. In addition, this method is highly dependent on the ability of doctors who are a source of knowledge in making this system. This system is very helpful for everyone because it can be used by many people anywhere and anytime, because it can be web-based and can be a solution for people before consulting directly with a heart specialist.

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