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 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.

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). 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, Werdiningih, & 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

| No. | Symptoms               | Heart disease       | 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                   | X                      |               |                           |                    |                                  |
| T04 | Out of breath          | X                   | X                      | X             |                           |                    |                                  |
| No. | Symptoms                      | Coronary heart disease | Heart muscle disease (cardiomyopathy) | Ischemic heart disease | Heart failure | Hypertensive heart disease | Heart valve disease | Cardiomegaly or hypertrophic heart |
|-----|-------------------------------|------------------------|---------------------------------------|------------------------|--------------|--------------------------|-------------------|----------------------------------|
| T05 | Indigestion                  |                        |                                       |                        |              |                          |                   |                                  |
| T06 | Nausea                        |                        |                                       |                        |              |                          |                   |                                  |
| T07 | Irregular Heartbeat           | X                      | X                                     |                        |              |                          |                   |                                  |
| T08 | Dizzy                         |                        | X                                     |                        | X            |                          |                   |                                  |
| T09 | Swollen foot                  | X                      | X                                     |                        |              |                          |                   |                                  |
| T10 | Heart palpitations            |                        |                                       |                        | X            |                          |                   |                                  |
| T11 | Tired Easily                  | X                      | X                                     | X                      |              |                          |                   |                                  |
| T12 | Pain in the middle chest area | X                      | X                                     | X                      | X            |                          |                   |                                  |
| T13 | Sweating easily               |                        |                                       |                        |              |                          |                   |                                  |
| T14 | Chest Tightening              |                        |                                       |                        |              |                          |                   |                                  |
| T15 | Swelling of the heart         |                       |                                       |                        |              |                          |                   |                                  |
| T16 | Heart dysfunction             |                        |                                       |                        |              |                          |                   |                                  |
| T17 | Bleeding from the nose        |                        |                                       |                        |              |                          |                   |                                  |
| T18 | Reddish face                  |                        |                                       |                        |              |                          |                   |                                  |
| T19 | Gough                         |                        |                                       |                        |              |                          |                   |                                  |
| T20 | Stomach ache                  |                        |                                       |                        |              |                          |                   |                                  |
| T21 | Fast heart rate               |                        |                                       |                        |              |                          |                   |                                  |
| T22 | Pain in the area of the left arm |                   | X                                     |                        |              |                          |                   |                                  |
| T23 | Back feels bad                |                        |                                       |                        |              |                          |                   |                                  |
| T24 | Headache                      |                        |                                       |                        |              |                          |                   |                                  |

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.

![FSA Diagram for Diagnosis of Heart Disease](image-url)

**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](image)

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 |
| T10  | Heart palpitations |
| T11  | Tired Easily |
| T12  | Pain in the middle chest area |
| T13  | Sweat easily |
| T14  | Chest Tightening |
| T15  | Swelling of the heart |
| T16  | Heart function disorders |
| T17  | Bleeding from the heart |
| T18  | Face redness |
| T19  | Cough |
| T20  | Stomach ache |
| T21  | Heartbeat fast |
| T22  | Pain in the area of the left arm |
| T23  | Back feels bad |
| T24  | 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 \( M = (Q, \Sigma, \delta, S, F) \), meaning:

- \( Q \) = set of state / position
- \( \Sigma \) = the set of input / input / alphabetical symbols
- \( \delta \) = transition relation
- \( S \) = initial state
- \( F \) = set of final states

So to state Figure 4 is as follows:

\[
Q = (T01, T02, T03, T04, T05, T06, T07, T08, T09, T10, T11, T12, T13, T14, T15, T16, T17, T18, T19, T20, T21, T22, T23, T24), P0, P1, P2, P3, P4, P5, P6, P7
\]

\( \Sigma = \{a, b\} \)

\( S = \{T01\} \)

\( F = \{P0, P1, P2, P3, P4, P5, P6, P7\} \)

\( \Delta \) = transition relation can be seen in Table 2.

| \( \Delta \) | 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         |
| T10            | P0             | P2, P6         |
| T11            | P0             | P2, P5, P6     |
| T12            | P0             | P3, P6, P7     |
| T13            | P0             | P3             |
| T14            | P0             | P3             |
| T15            | P0             | P3, P4         |
| T16            | P0             | P4             |
| T17            | P0             | P5             |
| T18            | P0             | P5             |
| T19            | P0             | P6             |
| T20            | P0             | P7             |
| T21            | P0             | P7             |
| T22            | P0             | P1, P3         |
| T23            | P0             | P1             |
| T24            | P0             | P5             |
| P01            | -              | -              |
| P02            | -              | -              |
| P03            | -              | -              |
| P04            | -              | -              |
| P05            | -              | -              |
| P06            | -              | -              |
| P07            | -              | -              |

Table 2 Relationships
Transition relations can also be written by:
\[
\Delta = \left\{ \begin{array}{l}
((T01, a), p0), ((T01, b), p1), ((T02, a), p0), ((T02, b), p1), ((T03, a), p0), ((T03, b), p1), ((T04, a), p0), ((T04, b), p1, p2, p4), ((T05, a), p0), ((T05, b), p1, p6), ((T06, a), p0), ((T06, b), p1), ((T07, a), p0), ((T07, b), p1, p2, p7), ((T08, a), p0), ((T08, b), p2, p5), ((T09, a), p0), ((T09, b), p2, p6), ((T10, a), p0), ((T10, b), p2, p6), ((T10, a), p0), ((T10, b), p2, p6), ((T10, a), p0), ((T10, b), p2, p6), ((T10, a), p0), ((T10, b), p2, p6), ((T10, a), p0), ((T10, b), p2, p6), ((T10, a), p0), ((T10, b), p2, p6), ((T10, a), p0), ((T10, b), p2, p6), ((T10, a), p0), ((T10, b), p2, p6), ((T10, a), p0), ((T10, b), p2, p6), ((T10, a), p0), ((T10, b), p2, p6), ((T10, a), p0), ((T10, b), p2, p6), ((T10, a), p0), ((T10, b), p2, p6), ((T011, a), p0), ((T011, b), p2, p5, p6), ((T012, a), p0), ((T012, b), p3, p6, p7), ((T013, a), p0), ((T013, b), p3), ((T014, a), p0), ((T014, b), p3), ((T015, a), p0), ((T015, b), p3, p4), ((T016, a), p0), ((T016, b), p4), ((T017, a), p0), ((T017, b), p5), ((T018, a), p0), ((T018, b), p5), ((T019, a), p0), ((T019, b), p6), ((T020, a), p0), ((T020, b), p7), ((T021, a), p0), ((T021, b), p7), ((T022, a), p0), ((T022, b), p1, p3), ((T023, a), p0), ((T023, b), p1), ((T024, a), p0), ((T024, b), p5) \end{array} \right. 
\]

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 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 Heart failure

Figure 9 is the condition of the N-DFA design that diagnosed heart failure. This condition is a condition where 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 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 == "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 achilles thickening" THEN final_state = "Ischemic Heart Disease"
write (final_state)
end if
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 alphabetical == "stomachache" AND alphabetical == "irregular heartbeat" AND alphabetical == "fast heart rate" AND alphabetical == "chest pain" THEN final_state = "Hypertrophic Heart Disease (Cardiomegaly)"
write (final_state)
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 pseudocode 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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