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Design of a Knowledge-based Expert System as Physician's Assistant in Diagnosis of Heart Diseases through ECG Image Processing

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Abstract. Diagnosis is the most important step in the treatment of diseases. In the diagnosis of heart diseases which have a complex structure and for which there is no specific algorithm, the use of expert systesms[1] is the best solution. The present study introduces a knowledge-based expert system for diagnosing tachycardia, as a heart disease, based on image processing of electrocardiograms as well as the results of physical examination and experiments. Beckman feasibility test was conducted for the system. The database of this system is rule-based and is devised in such a way that uses a faultless inference engine which yields to future developments. The inference engine of the system employs forward chaining and works on the basis of deductive and inductive inference. Cost reduction, synthetic knowledge and greater availability are among the advantages of this system.

Keywords: knowledge-based expert system, heart disease, ECG, image processing.

1. INTODUCTION

Heart disease is one of the most common reasons for human death. Heart diseases, if not diagnosed properly and treated appropriately, could result in heart attacks and sometimes death. In the typical process of diagnosis and treatment, when the possibility of occurrence of heart disease is confirmed, an electrocardiogram is taken from the patient and some other tests will be taken, if necessary. This helps the physician to diagnose the type of disease. However, sometimes is it observed that the analysis of tests and the symptoms of the disease leads to the confusion of the physician; for example, the pattern of ECG taken from the patient and the observed symptoms are not consistent with each other so that the physician could not have a diagnosis with complete certainty owing to the fact that the physician has not witnessed such ECG signals and physical symptoms together. In these cases, only experience counts and the experience and overall diagnosis of some experiences physicians could yield a high probability diagnosis. These cases are referred to medical commissions in the health system where several physician work together to decide on the specific disease. The purpose of the present article is to introduce a knowledge-based expert system which could function as the specialists' intelligent assistant in diagnosis of heart diseases.

2. EXPERT SYSTEM

With the development of information technology, decision making systems or, generally speaking, computer-based decision making has attained considerable significance. In this regard, expert systems play a key role as one of the applied branches of artificial intelligence. In expert systems, all decisions are made by computer. In knowledge-based expert systems, knowledge is the most important component. In such systems, knowledge is transferred from specialists to computers in every discipline. Expert systems have had great extensive applications in various sciences. Many expert systems in various fields of study such as

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industry, control, space navigation, financial decision making and so on have been designed so far (1).

Expert systems, as the most significant application of artificial intelligence, function as the best choice for solving complex problems which do not follow a precise and definite algorithm, or have an imperfect structure, or could not be easily solved through commons ways of problem solving. The knowledge used in these systems comes from various sources and the expertise of specialists in each field. These systems are designed to make specialists' knowledge available to the non-specialists. Such systems have found their way into medical sciences. Some of them are as follows: DENDRAL program was introduced in 1965 for the description and analysis of molecular structure (2). NYCIN software was introduced in 1976 for diagnosis of heart diseases (3). PUFF software was introduced for diagnosis of pulmonary diseases (4), VM software for monitoring patients in need of intensive care, CADCUCEUS for diagnosis of internal medicine diseases, BULE BOX for diagnosis and treatment of depression and expert systems used to diagnose acids and electrolytes, training in management of anaesthesia, and diagnosis of internal medicine diseases are some of these widely used expert systems. In figure 1, the structure of a knowledge-based expert system is illustrated.

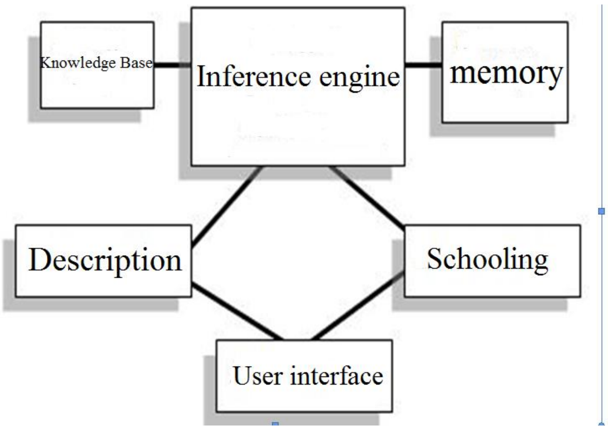

Figure 1. The structure of an expert system.

3. PROPOSED EXPERT SYSTEM

This system includes four basic components of knowledge database, database, inference engine, and user interface.

4. DATABASE

Database contains ECG signal patterns of all diseases which are recognizable thorough electrocardiogram. This includes ECG signal pattern of a healthy heart, symptoms of any possible disease as well as the treatment proposed for any disease.

5. KNOWLEDGE DATABASE

Much of knowledge in expert systems is heuristic in nature. The knowledge required for designing of the knowledge database, as a key part of knowledge engineering which has a high and determining role in obtaining the results, comes from the experience of an expert, books and other scientific resources and is configured through a scientific method. In the proposed system, rule-based method is used for the configuration of database (in some cases, these two databases are not distinguishable).

6. INFERENCE ENGİNE

The inference engine, in knowledge-based expert systems, contains techniques for problem solving. Due to the diagnostic nature of the problem, backward chaining1 has been used for the simulation of argumentation and expert decision making. In this method, the inference engines starts with the 'THEN" section of the last rule and continues to attainment of a fact in "IF' section of a rule which is incorporated into the system as a fact.

7. METHOD

Signals of a healthy heart have special and constant features in a period. This has made it possible to divide it into different sections, each of which illustrating part of the process of heart throbbing (Fig 1). For example, QRS section show the time of depolarization of ventricles. S, R, & Q each show a special operation all of which work together in depolarization. As a result, a change in the pattern of each signal can indicate a problem in complete execution of a throbbing and the existence of a disease in the heart. For example, in Figure 2 which shows the electrocardiogram of the heart of a patient, we can see an obvious disorder in the pattern of some periods. This system simulates the diagnosis process of a heart specialist. The system first analyzes ECG; it is just enough to scan one period of a number of periods of the heart and give it to the system (the number of necessary periods is determined by the specialist).

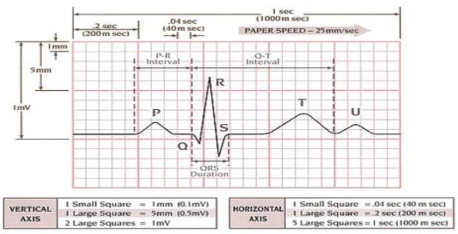

Figure 2. A time cycle.

Figure 3. Electrocardiogram of a patient.

8. IMAGE PRE PROCESSİNG

The physician clicks on a point in the picture which contains signal tape so that the color spectrum of the electrocardiogram which is spread in all parts of the ECG is revealed to the system. Then, the system transforms the picture from colored or gray white to black and white in a way that all the points whose color is the same as the determined color for electrocardiogram becomes black and all the other points remain white. This separates the electrocardiogram from other additional points and makes it ready for processing. The system has to be able to differentiate between each of the periods. To do this, a matrix is located over the pre-processed picture (the more the number of lines and columns of the matrix, the more precise the matrix). In this matrix, every point of the picture which is black has the value of 1 and every point which is white has the value of 0. The matrix in figure 6 has lines and columns. We find many points in columns which have the greatest lines and consider them as maximum points (figure 5). Then, we look after a range of consecutive columns between these points in which the value of the line remains constant or changes between 1 and M (the range is, in fact, the TP part of signal. In this time, a throbbing period is gone and we wait for the next throbbing to occur which makes the signal look like an extended line. Thus, the value of M is determined by the type of the matrix (number of lines and columns). The middle point of this range is stored. We consider the middle points between the two maximums as the final point of a single period. In this way, we can approximately differentiae each signal period from others. However, this method is not without problems. Therefore, there is a need to find more precise ways for separation or differentiation.

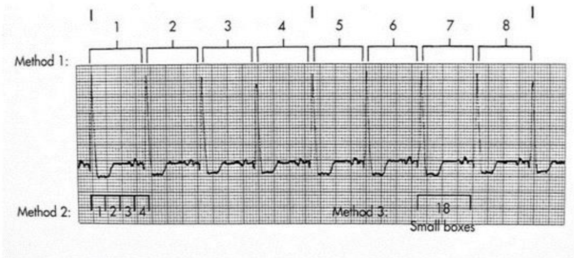

Figure 4. Determining the maximum value in each time period.

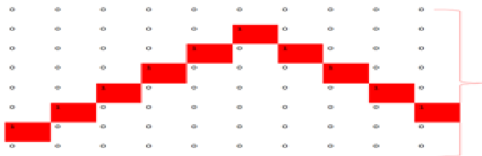

Figure 5. 0-1 Matrix on the Picture.

When all the periods are separated, the next stage begins. For each period, a matrix similar to previous matrices is placed (fig 6). Then, coordinates of every part of the matrix which has the value of 1 on the basis of line and column are found and stored in an nx2 table (fig 7). Inasmuch as the value of table line is the same for all periods and changes between 0 and n, one could transmit the table to an n arrangement. In fact, this arrangement represents features of a signal period which is separated and stored. This course of action is repeated for all periods.

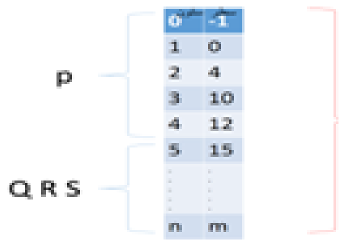

Figure 6. Table of line and column.

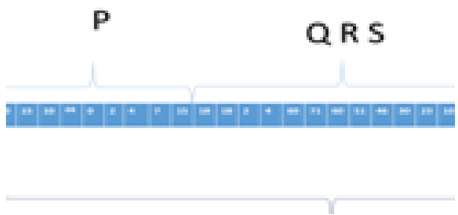

Figure 7. n arrangement.

In the next phase, the features of each period are compared to all the previously stored patterns which could include healthy patterns or patterns belonging to a specific disease (Fig 8). If the separated features of ECG of a patient are the same as a healthy pattern, the period will be considered as a healthy one and will be put aside (the degree of similarity is determined by an experienced specialist). On the other hand, if the period is recognized as dissimilar to the healthy pattern, it is considered as a problematic period and could indicate the presence of a specific disease. In this case, it is compared to pre-determined patterns (which include the patterns of all diseases that could be detected on ECG).

When features of a period of heart signals conforms with one of the patterns, the system opens up all the other patterns of that specific disease each of which could show the existences of specific features of that disease (those features that are not common to all diseases but could be present in some diseases but not in others). For example, if the detected features conform with the pattern of tachycardia, all the other patterns of possible types of tachycardia is recognized by the system and the detected features are compared with all of them so that the diseases is recognized in a more precise manner. This comparison is made for all the periods.

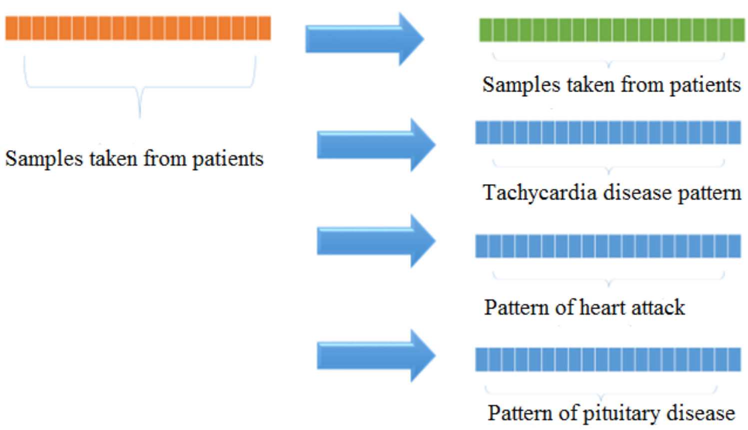

Figure 8. Comparison the patients’ pattern with pre-determined patterns.

After the healthy signals are put aside, it is possible to find that all the problematic signals conform to one of the pre-determined patterns or problematic features might conform to two, three or more patterns. In general, when the physician looks into the electrocardiogram, he can detect the disease or the signal could indicate the presence of a number of diseases. When this happens, the physician might get confused. For example, the signal could be similar to signals of many diseases or the electrocardiogram does now show a specific disease (which means the physician could not diagnose a specific disease by reading the electrocardiogram but the patient's symptoms show the presence of a disease) or the patients' symptoms do not conform to ECG's pattern. In such cases, the only solution to the problem is to make use of the experience of many experiences specialists.

The system asks questions from the physician on the basis of the behavior of an experienced specialist when he comes up with this kind of electrocardiogram: what disease or diseases he diagnoses when reading such an electrocardiogram and what signals he searches for in order to diagnose the disease. These questions ask whether the patient has x, y, or z symptoms which require a yes or no answer. However, there are some cases in which these questions could not be answered in a yes-no manner and require explanation. In such cases, the physician ticks one or more of the explanations as the answer to the question. Depending on the type of diseases mentioned in the processing of signal as well as the types of symptoms that an experienced specialist searches for, the manner of question asking and the method of decision making might differ. It is possible that in questioning, all the questions and basic symptoms of a disease come together, or rather, come in a layered manner in which first the basic symptoms are asked and depending on which question is ticked, some of the following questions are deleted since their answer are not needed. In the decision making component, depending on the type of diseases or symptoms that an experienced physician searches for, some of the questions might be more significant than others, that is to say, the presence of some symptoms in the patient might increase the possibility of diagnosing a specific disease. There are cases in which the symptoms are such that answering to n questions from m questions is necessary so that the diagnosed disease in the patient has high likelihood of being true. If the inference is over and the disease is not confirmed with acceptable certainty, the system goes to another disease which was deemed possible as the second choice in analyzing the ECG and asks questions in this regard to the extent that the disease is diagnosed. It is necessary to note that the expert system is able to propose the required treatment of the disease with all the details and exceptions to the physician, after the disease is diagnosed. This is because the system uses many patterns of various diseases together with specific features of that disease which is not common to other diseases (which might not be present in all the patients having that disease or does not appear in specific cases). In many cases, the proposed treatment is the one that is proposed by an experienced specialist. When the treatment is proposed, the job of the system is over and the physician can make use of the outputs of this system for confirming his diagnosis or correcting his errors that might have happened in diagnosing of the disease (Fig 9).

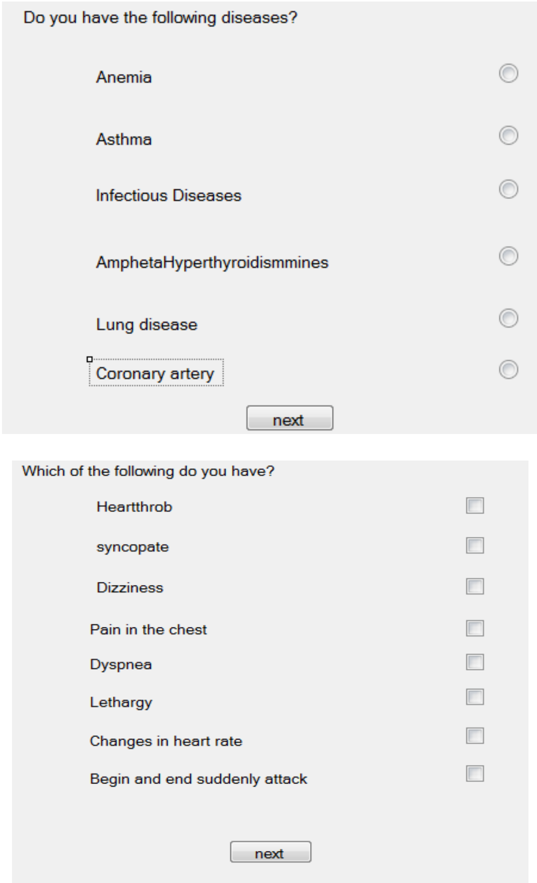

Figure 9. A sample of the method of analysis of symptoms by inference engine.

9. RESULTS and DISCUSSION

The proposed expert system can function as an intelligent assistant for cardiologists. The adoption of this expert system in diagnosing diseases could have advantages such as time reduction of diagnosis process, decrease of possible errors and high precision in diagnosis of diseases which are considered as vital elements in the process of diagnosis. Cost reduction, synthetic knowledge and high availability are other advantages of the proposed system,

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