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A Rule-Based Fuzzy Diagnostics Decision Support System for Tuberculosis

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***Abstract* - The system is specialized for pulmonary physicians focusing on tuberculosis and for patients already diagnosed with tuberculosis. The main focus for the development of the system is on the architecture and algorithm used to find the probable class of tuberculosis a patient may have. The class of tuberculosis is determined by using a rule base populated by rules made for the different classes of tuberculosis. The clinical decision support system integrated with Fuzzy Logic and Rule-based method that generates classes of tuberculosis suits the needs of pulmonary physicians and lessens the time consumed in generating diagnosis.**

Keywords- *Fuzzy system, rule-based, diagnostics, medical support, expert system, data mining*

I. Introduction

Healthcare has been one of the top demands of this generation. In the advent of technology, the provision of healthcare continues to improve. One of the top priorities is the provision of diagnosis, and the one responsible for this is the physician. Physician's diagnosis is the most relevant factor that leads to the acquisition of proper health guides. As technology soars, there are changing medical requirements and solutions, and sometimes physicians are not updated with these upgrades, that they need to surf the internet for more information [1, 3, 8].

One of the solutions that could aid in the physician's diagnosis is the Clinical Diagnostics Decision Support System (CDSS). The CDSS is generally defined as any computer program designed to help health professionals make clinical decisions. Clinical Decision Support Systems supports case-specific advice which addresses to the aiding of physician's diagnosis via computer-based facility. Since physicians sometimes encounter complicated ailments, a CDSS can make decision making simpler by providing relevant pre-diagnosis. With the use of CDSS, a pre-diagnosis could be extracted which can strongly support the physician's decision. Hence, lesser time could only be consumed in the provision of diagnosis to the patient. Along with this CDSS is a logic which provides probabilistic conditions that leads to a specific outcome, which is the Fuzzy Logic; another one is the method to be taken, which is the rule-based method.

Fuzzy logic is a form of multi-valued logic derived from fuzzy set theory to deal with reasoning that is approximate rather than precise. Fuzzy logic variables may have a membership value of not only 0 or 1 – that is, the degree of truth of a statement can range between 0 and 1 and is not constrained to the two truth values of classic propositional logic Fuzzy logic emerged as a consequence of the 1965 proposal of fuzzy set theory by Lotfi Zadeh [2]. Through Fuzzy Logic, results present between the paradigms of true and false can be determined, therefore, there is no void or null results.

Rule-based method [7, 9] captures knowledge of domain experts into expressions that can be evaluated known as rules; an example rule might read, "If the patient has high blood pressure, he or she is at risk for a stroke". Once enough of these rules have been compiled into a rule base, the current working knowledge will be evaluated against the rule base by chaining rules together until a conclusion is reached. A rule-based method makes it easy to store a large amount of information, and coming up with the rules will help to clarify the logic used in the decision-making process. Through the rule-based method, it could demonstrate the magnitude of these types of ailments by comparing the size of the rule base to the narrow scope of the problem space.

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II. Review of Related Literature

In the study on a fuzzy rule based lung diseases diagnostic system combining positive and negative knowledge, the system was designed to diagnose multiple diseases of lung diseases in a single patient. This rule based expert system has been developed mainly on the five levels of knowledge representation used to represent medical entities and relationships between them for diagnosis of lung diseases and on inference mechanism combining positive knowledge and negative knowledge for medical diagnosis [7]. Rule-based method is one of the objectives in developing the system. A set of rules was used based on the physicians' experience that will aid in diagnosing the class of tuberculosis. This literature gives the researchers the idea on what kind of methodology and techniques to use that will be suitable for developing the proposed system.

In the study about fuzzy diagnostic system for coronary artery disease (CAD), the researchers claimed that CAD affects millions of people every year which leads to mortality. In this paper information technology was used to reduce the mortality rate and waiting time to see the specialist. Clinical decision making inherently requires reasoning under uncertainty, expert systems and fuzzy logic are the suitable techniques. The proposed technique emulates human intelligence. The methodology is developed to assist general practitioners in diagnosing and predicting patients' condition from certain 'rules' based on 'experience'. Medical practitioners other than specialists may not have enough expertise or experience to deal with certain high-risk diseases. The patients with high-risk factors or symptoms or those predicted to be highly affected with angina, unstable angina or acute MI could be shortlisted to see a specialist for further treatment. The intuition is based on the physicians' ability to make initial judgement based on his study and experience [6]. This literature contributes to the process of solving fuzzy algorithms in developing the set of rules that will determine the class of tuberculosis the patient has.

However in the study on effective analysis and diagnosis of lung cancer using fuzzy rules, the main focus of the system is on the architecture and the algorithm used to find the probable disease, stage and the appropriate treatment of cancer a patient may have. The disease is determined by using a rule base, populated by rules made for different types of lung cancer. The algorithm uses the output of the rule base and the symptoms entered by the user to determine the stage of cancer the patient is in. Both these results help the diagnostic logic to determine the treatment for the patient with accuracy. The diagnosis does a complex analysis of all the information gathered about the symptoms. The study evolved a method of choosing the best treatment for cancer using fuzzy decision making techniques [5]. This literature also contributes on the architecture and algorithms that will be used in the development of the proposed system.

In a study about fuzzy logic approach to decision support in medicine [4], the paper develops a prototype warning system for clinical activity, based on the assumption that clinical problems can be analyzed in many simple rules and that the decision process of the physician can be modeled by sets of rules. The basic rules, based on expert experience, were represented in a system based on fuzzy logic. As a working example they modeled the prognosis of a patient suffering from heart failure treated with beta-blockers. Fuzzy Logic is the main core in developing the system. This literature contributes in developing a decision support that will aid pulmonologists at the point of diagnoses based on fuzzy rule-based algorithms.

In ICD 10 based medical expert system using fuzzy temporal logic study [3], their system will provide advice, information and recommendation to the physician using fuzzy temporal logic. The knowledge base used in this system consists of facts of symptoms and rules on diseases. It also provides fuzzy severity scale and weight factor for symptom and disease and can vary with respect to time. The system generates the possible disease conditions based on modified Euclidean metric using Elder's algorithm for effective clustering. The minimum similarity value is used as the decision parameter to identify a disease. This literature provides the purpose of developing the study and that is to develop a diagnostics decision support system that will be used to diagnose patients' symptoms intensity scale and the possible class of tuberculosis.

III. Proposed Fuzzy Diagnostics Decision Support System

A Rule–based Fuzzy Diagnostics Decision Support System is a decision support system intended for pulmonary physicians. The system will analyze the class of tuberculosis the patient has. The patient must have a history in tuberculosis. The system provides a workplace in which physicians will input corresponding scores in each symptom. The scores given by physicians imply the intensity of every symptom the patient exhibits. The intensity varies depending on the symptom. Then the system will summarize and allocate the class of tuberculosis the patient has.

Fuzzy Logic was the tool used to develop the algorithm of the system. With fuzzy logic, the researchers were able to classify the intensity of each symptom according to its description given by pulmonary physicians interviewed. Some symptoms like cough were classified as low risk, moderate risk and high risk. Others were low, mild, persistent and severe just like for nose sputum for example. In the formulation of fuzzy sets, the ranges of scores were classified in each symptom. The values or scores had undergone the process of fuzzification. Figure 1 shows the proposed system architecture.

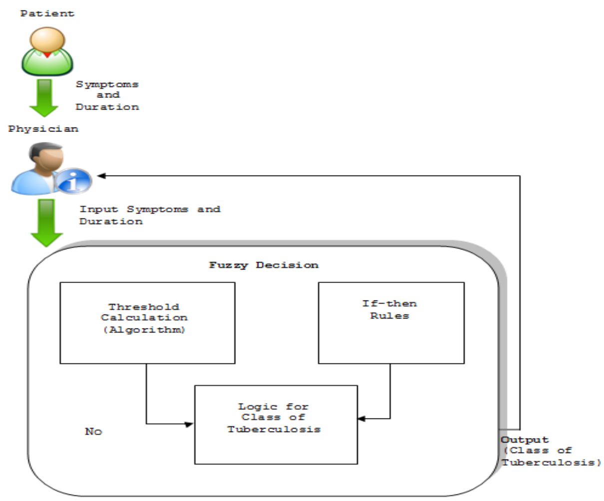

Figure 1. The proposed System Architecture

Fuzzy Logic was also responsible for the threshold calculation needed by the system for reasoning which includes the fuzzy relation step. After the calculation, the scores were graphed in a symmetrical manner. The graph illustrates the scores and its corresponding membership values (value that ties a number to each element of the universe, determining its fuzzy relations). Figure 2 shows the graph for fuzzy relations of Cough showing membership to different cough categories (low, moderate, and high risk)

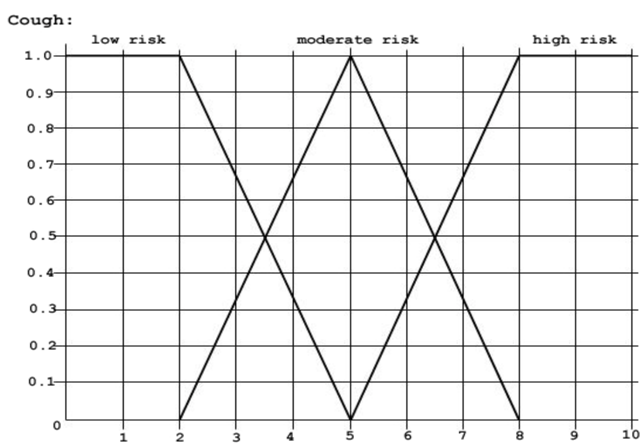

Figure 2. Graph of the Fuzzy Relation for Cough

After the graph, the fuzzy sets were then intersected and it determined the matrix. Two symptoms which are interrelated were intersected and it describes one condition. The matrix illustrates the intersection between two symptoms. In determining the rules, the scores had undergone the defuzzification which used the weighted mean process. After defuzzification, the scores were subjected for the development of rules.

IV. SIMULATION RESULTS

Rule- based method was used to determine the class of tuberculosis, populated by rules made for different classifications of tuberculosis. Fuzzy Logic used the outputs of the rule-based and the ranges of scores the physicians input in order to determine the class of tuberculosis the patient has. The values that had undergone defuzzification were used to formulate the rules that correspond to the different conditions determined by the matrix. A sample rule for condition A (cough & cough duration) states that "If score x is ≥ 0 or ≤ 3 and score y is ≥ 0 or ≤ 7 then condition A is low risk". In the classification of tuberculosis, a sample rule states that "If (condition A = "low risk") && (condition B = "low risk") && (condition C = "low risk") && (condition D = "low") && (condition E = "low risk") then TB is PTB1.

The proposed system requires the physician to input all necessary scores of symptoms needed in order to meet the system's purpose. System inputs and symptom scores with corresponding levels of intensity are as follows: cough (0-10), cough duration (0-30 days), body temperature (33-45), fever duration (0-30 days), sputum discoloration (0-10), nose sputum (0-10), afternoon chills (0-10), night sweats (0-10), weight loss (0-20 kgs), and loss of appetite (0-10).

Using fuzzy logic the researchers had come up with 16 rules for conditions A to E (the intersection of two interrelated symptoms), and 323 sets of rules (combination of 5 conditions) for the determination of the class of tuberculosis the patient has. Figure 3 shows the rules generated for tuberculosis based on various symptoms.

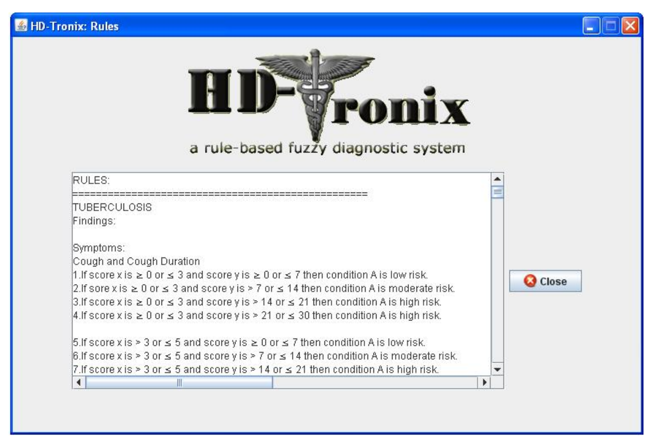

Figure 3. Simulation for generating rules based on input data

Below is a sample illustration of a Cough and Cough duration for Condition A:

1. If score x is ≥ 0 or ≤ 3 and score y is ≥ 0 or ≤ 7 then condition A is low risk.
2. If sore x is ≥ 0 or ≤ 3 and score y is > 7 or ≤ 14 then condition A is moderate risk.

3. If score x is ≥ 0 or ≤ 3 and score y is > 14 or ≤ 21 then condition A is high risk.
4. If score x is ≥ 0 or ≤ 3 and score y is > 21 or ≤ 30 then condition A is high risk.
5. If score x is > 3 or ≤ 5 and score y is ≥ 0 or ≤ 7 then condition A is low risk.
6. If score x is > 3 or ≤ 5 and score y is > 7 or ≤ 14 then condition A is moderate risk.
7. If score x is > 3 or ≤ 5 and score y is > 14 or ≤ 21 then condition A is high risk.
8. If score x is > 3 or ≤ 5 and score y is > 21 or ≤ 30 then condition A is high risk.
9. If score x is > 5 or ≤ 8 and score y is ≥ 0 or ≤ 7 then condition A is high risk.
10. If score x is > 5 or ≤ 8 and score y is > 7 or ≤ 14 then condition A is high risk.
11. If score x is > 5 or ≤ 8 and score y is > 14 or ≤ 21 then condition A is high risk.
12. If score x is > 5 or ≤ 8 and score y is > 21 or ≤ 30 then condition A is high risk.
13. If score x is > 8 or ≤ 10 and score y is ≥ 0 or ≤ 7 then condition A is high risk.
14. If score x is > 8 or ≤ 10 and score y is > 7 or ≤ 14 then condition A is high risk.
15. If score x is > 8 or ≤ 10 and score y is > 14 or ≤ 21 then condition A is high risk.
16. If score x is > 8 or ≤ 10 and score y is > 21 or ≤ 30 then condition A is high risk.

TB Main Rules:

If (condition A = "low risk") && (condition B = "low risk") && (condition C = "low risk") && (condition D = "low") && (condition E = "low risk") then TB is PTB1.

Else if (condition A = "low risk") && (condition B = "moderate risk")&& (condition C = "low risk") && (condition D = "low") && (condition E = "low risk") then TB is PTB2.

Else if (condition A = "high risk") && (condition B = "moderate risk")&& (condition C = "high risk") && (condition D = "severe") && (condition E = "high risk") then TB is PTB3.

Else if (condition A = "moderate risk") && (condition B = "moderate risk") && (condition C = "low risk") && (condition D = "low") && (condition E = "low risk") then TB is PTB4.

Else if (condition A = "moderate risk") && (condition B = "high risk") && (condition C = "high risk") && (condition D = "severe")&& (condition E = "high risk") then TB is PTB5.

V. CONCLUSION AND RECOMMENDATIONS

The system would aid in the diagnosis of the different classes of tuberculosis. It greatly helps in the decision making of the pulmonary physicians in giving the diagnosis.

Enhancements on the capabilities of the decision support systems and its integration with algorithms like Fuzzy Logic provides a set of techniques which generates reliable and precise results.

The great advent of technology provides greater opportunities for medical institutions and healthcare. Clinical decision support system integrated with Fuzzy Logic and Rule-based method that generates classes of tuberculosis suits the needs of pulmonary physicians and lessens the time consumed in generating diagnosis.

Future researchers could magnify the features and make the system more usable and marketable by adding set of diseases with corresponding treatments the system can diagnose. It is also best for the system to have a database in storing patient information, current medical records and history for future usage and references.

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