Decision Support System for Diagnosing Asthma Disease

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Abstract*- Field of medicine is more about decision making. The role of a physician is more pivotal in the diagnosis of a disease from all other possible illnesses. This is called as "Differential Diagnosis" in the field of medicine where the key aspect is the analysis of symptoms. But, due to both physicians' factors and patient's factors there occurs considerable amount of diagnostic errors which lead to dangerous consequences. So, there's a rising concern in reducing these errors in medical diagnosis worldwide. When it comes to respiratory diseases differential diagnosis is more challenging due to the commonness of symptoms of various diseases and also the connection of cardiac diseases. Proper diagnosis needs both theoretical knowledge and the knowledge comes from experience. If we can blend both types into one place it will definitely support to come to more appealing conclusions when diagnosing diseases. Due to the nature of vagueness in expressions in the medical field, a technology which can cope with this gray area is more suitable. Fuzzy logic is a type of logic that identifies more than simple true and false values and can be represented with degrees of truthfulness and falsehood. Fuzzy logic is being integrated in many experts systems to solve many real world problems. Through our project we have developed a decision support system for diagnosing Asthma (a respiratory disease) and its stages in adults using fuzzy logic. The system is built based on 21 inputs which were considered by the expert as the most important symptoms and laboratory tests in diagnosing Asthma and its severity stages. The system proves its ability of addressing the problems stated above thus can be relied upon and further improved for coverage of more diseases.

Index Terms– **Asthma Disease, Decision Support System**

I. INTRODUCTION

Accurate and error-free of diagnosis of patients has been a major issue highlighted in medical service nowadays [1]. Differentiating symptoms correctly and finding out the causes are considered vital in diagnosing. Asthma is one of the chronic lung diseases that inflames and narrows the airways which carry air to and from the lungs. Based on the World Health Organization Global report released in 2110 considering country data the worldwide prevalence of asthma ranges from three to 18 percent of population. Annually 250,000 deaths occur due to asthma worldwide while in Sri Lanka four percent of all hospital deaths are due to asthma [1]. This is one of the highest in South East Asia [2]. Common symptoms of Asthma include Wheezing, Shortness of Breath, Cough and Chest tightness. And also often misdiagnosed as COPD (Chronic Obstructive Pulmonary Disease) which is another lung disease having similar presentation as Asthma [3] [4]. Apart from that Asthma severity has four stages mild intermittent, mild persistent, moderate persistent and severe persistent and a patient can be in either of the stages at any time [5]. So the exact medication needs the proper identification of the stage as well. Diagnosing a patient having Asthma and determining the stage of it include both symptom analysis and laboratory tests. And also it's a human nature that each tiny aspects of theory or knowledge cannot be applied or thought when coming to conclusions. There's chance of missing or delaying a diagnosis due to human factors. Machines are free from this draw back thus can be relied upon. Having considered all above this research study was aiming to develop a Fuzzy Rule Based Asthma Diagnosing System which can be used as a decision support system in diagnosing Adult Asthma. The system takes into account both the symptoms and laboratory results which came from the knowledge of expert and medical books and the final output it produces id the probability of Asthma and its stage.

II. LITERATURE REVIEW

Asthma is one of the chronic lung diseases characterized by airway irritation, hyper-responsiveness, and impediment. Through the nose and mouth outside Air enters the respiratory system.

Through the pathway to the lungs, the air is moistened, temperature controlled and filtered. The air travels through the larynx (voice box) and enters into the lower airways through the trachea (windpipe). In each lung, the conducting tubes called bronchi go on separated and get gradually smaller.

The small bronchi are called bronchioles. Each bronchi branch are divided into smaller generations and ends in balloon-like air sacs called alveoli. From the alveoli, oxygen and carbon dioxide exchange is done. The exchange of gases between the lungs and blood is called external respiration.

When it comes to asthmatic patients, the inside walls of the airways are swollen or inflamed and the muscles around the airways can tighten when something triggers the symptoms. This swelling or inflammation makes the airways really sensitive to irritations and increases the vulnerability to an allergic response.

As inflammation causes the airways to become narrower, lesser amount of air is allowed to pass through them, both to and from the lungs. Symptoms of the narrowing include chest tightness, wheezing, coughing and breathing problems. Asthmatics usually experience these symptoms most frequently during the early morning night. People having a family history of asthma or any allergies are more susceptible to developing asthma. The types of Asthma are Child-Onset Asthma, Adult-Onset Asthma, Exercise-Induced Asthma, Cough-Induced Asthma, Occupational Asthma, Nocturnal Asthma, Steroid-Resistant Asthma (Severe Asthma).

There is no cure for asthma, but once it is properly diagnosed and a treatment plan is in place you will be able to manage your condition, and your quality of life will improve.

Identifying the severity level of asthmatic patients is crucial in prescribing proper medicine. A patient can be in either of the stages at a given time. Table I shows the classification of asthma severity.

Table I Classification of Asthma Severity

Stages / Features	Mild Intermittent (Stage 1)	Mild Persistent (Stage 2)	Moderate Persistent (Stage 3)	Severe Persistent (Stage 4)
Asthma Symptoms	less than twice a week	more than twice a week but less than once a day	daily	almost continual
Night time exacerbation	not more than twice a month	more than twice a month	more than once a week.	frequent daily
Lung function FEV	more than or equal to 80%	less than or equal to 80%	between 60-80%	less than or equal to 60%
Peak flow	less than 20% variability	between 20-30% variability	more than 30% variability	more than 30% variability

The following are the expert systems related to the field of medical and biology.

1. INTERNIST (Pittsburgh University, 1974): a rule-based expert system aimed to diagnose complex problems in general internal medicine. This system covered 80% of the knowledge of internal medicine.
2. MYCIN (Stanford University, 1976): MYCIN is the first well-known medical expert system developed to help doctors, not expert in antimicrobial drugs, prescribe such drugs for blood infections.
3. CASNET (Rutgers University, 1960) was an expert system for the diagnosis and treatment of glaucoma.
4. HELP -The HELP (Health Evaluation through Logical Processes) System is a complete knowledge based hospital information system including pharmacy, radiology, nursing documentation and ICU monitoring.
5. EXPERT (Rutgers University, 1979) was an extension generalized of the CASNET.
6. ONCOCIN (Stanford University, 1981) was a rule-based medical expert system designed to help out the doctors in treating cancer patients receiving chemotherapy.
7. SETH - The aim of SETH is to give exact advice about the treatment and monitoring of drug poisoning.
8. DoctorMoon: programmed in Borland Delphi and run on MS Windows9x. The knowledge base of DoctorMoon is handled by a Borland Paradox Database having 700 records where each represents a rule. Most of the rules were provided

by the physicians in the Vietnam National Institute of Tuberculosis and Lung. The other way was automatic rule creation where a program will browse the database of patients' to review the common syndromes that confirm or exclude a particular lung disease and then form new rules.

9. The research article on Fuzzy Rule Based Inference System for Detection and Diagnosis of Lung cancer [6].There they have developed the Agent based system by using JADE and Matlab Fuzzy Logic toolbox.

10. A Fuzzy Expert System for Detecting and Estimating the Level of Asthma and COPD [16] considered 12 symptoms and the output was the severity level of Asthma, COPD and Tuberculosis.

Apart from the above mentioned system, during our survey we couldn't find more working systems that deal with lung diseases. We did find that several researches are being done to diagnose lung diseases developed using fuzzy logic, prolog, ANFIS and etc. but, the number of symptoms they included were less in numbers compared to the system we developed. Most of the proposed systems were implemented in Matlab Fuzzy Logic Toolbox.

III. AIM AND OBJECTIVES

The aim of this research study is to develop a decision support system based on fuzzy logic which can be used in diagnosing adult asthma and severity stages. The research system will predict the severity stage of the asthma decease.

IV. RESEARCH METHODOLOGY

Information gathered from the domain experts and other sources must be transferred to knowledge and is expected to be used efficiently. Medical domain in its nature has most of the theories and analysis that are expressed in linguistic terms. When developing any system for this domain has to have the ability to deal with this terms. Direct traditional mathematical approach is not suitable in most of the cases. Due to the following features of fuzzy logic, it was used in the development of the system [7].

An Expert System by its own nature highly depends on the domain knowledge. The knowledge can be gathered via the domain experts, books, journals, research findingsand etc [8, 9]. To implement this project the knowledge and the experience of a Chest Specialist from a state hospital and findings from medical books and other sources were used.

At the initial stages we studied different types of respiratory diseases and their corresponding symptoms. It showed that several diseases had most of the symptoms in common and few unique. From those, Asthma and COPD (Chronic Obstructive Pulmonary Disease) were seemed misdiagnosed interchangeably. Then we identified more relevant symptoms and laboratory test results that are used in diagnosing Asthma along with its stages. They are as follows:

- Wheezing: Vibrations caused by forcing air through narrowed, uneven airways results in wheezing, squeaking or whistling sounds with each breath. Left untreated, airways can further constrict, resulting in greatly diminished or absent breath sounds.
- Chest Tightness: due to the forced usage of chest muscles in breathing.
- Cough: The excessive amount of sticky mucus caught in the bronchi becomes irritating and results in a persistent cough. This cough is not contagious.
- Shortness of Breath
- Day Time Symptoms: frequency of occurrence of symptoms during day time.
- Night Time Symptoms: frequency of occurrence of symptoms during night time.
- FEV1: forced: expiratory volume at once second.
- FEV1/FVC: FVC- forced vital capacity
- PEF: peak expiratory flow
- Response to Asthma Medication: if the patient doesn't respond, it may come to a conclusion to exclude asthma.
- Respiratory Rate: respiratory rate changes at different stages of Asthma.
- Ability of Speaking: As the difficulty of forcing air into and out of the lungs progresses, the lack of oxygenation results in anxiety, inability to speak in full sentences
- Past Medical History heart disease or blood pressure: this factor helps to exclude Asthma.

- Personal/ Family History of Atopic Disorder.
- Smoking: this habit is important when assessing signs and symptoms of pulmonary disease. History of smoking has been shown its implication to pulmonary diseases.
- Associated with Triggers: check whether there are changes in the Asthma symptoms at the exposure to factors like toxins, smoke, fur and etc.
- Night time awakenings: this factor determines the severity of Asthma.
- Occurrences of symptoms: indicates the severity of Asthma.
- SABA (Short Acting $Beta_2$ Agonist): usage of this drug for symptom control also indicates the severity.
- Inferences with normal activity: due to Asthma patients find difficult in their day today activities. Higher the severity higher the impact.

When the symptoms and lab results are considered to be the input variables of this fuzzy logic based system, then the corresponding linguistic terms have to be identified that are used to express them by the patients and physicians in the medical domain. Some of the variables are divided into sets when there's a space to fuzzy and other variables are stated as yes and no values.

A. System Design

The system consists of three modules namely Knowledge base, Inference Engine and User Interface. Here it's given the system architecture along with the structure of each module. Knowledge Base is the essential component of the expert system is the knowledge base. This includes the information about symptom along with their membership functions (stated as low, medium, high and etc.). And also the knowledge base consists of the rules, which are in If-Then format.

1. If Wheezing= moderate and SOB= yes and Chest pain= yes and ……. Then Asthma Probability= medium.
2. If Symptom Appearance= high and PEF= low and Nocturnal Symptoms= high and ……. Then Asthma Severity= severe persistent.

This module is considered to be the most important part of the project and more time was spent in developing this. At the time of writing this document there are 21 input variables including both crisp and fuzzy values, two output variables and rules. Admin can be either the expert or system engineer who is an authorized user to make changes in the database and the rule base. The system facilitates it via an interface developed in C# programming Language. This module is very important in fine-tuning the system and making it more reliable, fault tolerant and up to date.

User module consists of an interface developed in C# programming language. It allows the user to select from list of symptoms along with the values. The selected symptoms and lab results are shown in a separate portion of the interface. When the user hits the 'diagnose' button the system connects with the knowledge base specially the rule base to find the matches and finally displays as if the patient is having Asthma with probabilities and its stage. User module is designed in a way which is user-friendly and comprehensive as well.

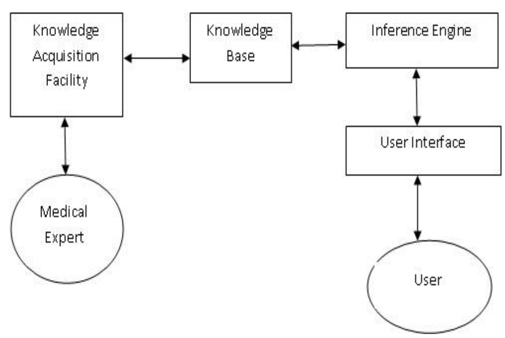

Fig 1. High-level System Architecture

The basic architecture of an expert system is the inference engine and the knowledge base containing the domain knowledge stored in the form of if-then rules. Another component, called the user interface, which provides a means of communicating with an expert system is also part of the basic architecture. The relationship between these components is shown in fig 1.

V. RESEARCH IMPLEMENTATION AND EVALUATION

The system is based on Fuzzy Logic. Fuzzy logic is an approximation process, in which crisp inputs are turned to fuzzy values based on linguistic variables, set of rules and the inference engine provided. The system was developed by using C# programming language and MS SQL. The web forms will act as the front end of the system where the users can interact with

The system has been designed in such a way that it has a strong knowledge base. The knowledge base consists of rules for 21 symptoms. Moreover, there are many rules for the 21 symptoms that are created for making decisions. For every symptom the user is selecting, the rule base generates the possible conditions from the knowledge base for asthma diagnosis. Knowledge base implementation is done by using MSSQL 2108. In this system, all the inputs are connected together through SQL and thus we reach our desired output. Several tables were created for storing symptoms/disease, membership functions (Fig 2 and fig 3) for each symptoms/disease and if-then rules (Fig 4). If the patient has no indication of any symptom it's fed to the system as all zero values. Apart from that all the other symptoms have appropriate membership functions as singletonmf, trimf and trapmf.

VariableIdentity	VariableName	VariableType	Range	InputType
111	Wheezing	Input	0,1	Singletonmf
112	SOB	Input	0,1	Singletonmf
113	Cough	Input	0,1	Singletonmf
114	Chest Pain	Input	0,1	Singletonmf
115	DayTime Symptom	Input	0,1	Singletonmf
116	NightSymptom	Input	0,1	Singletonmf
117	FEV1FVC	Input	0,10	Trimf
118	FEV1	Input	0,100	Trimf
119	EpisodicSymptom	Input	0,1	Singletonmf
120	Drug Response	Input	0,1	Singletonmf
121	Personal History	Input	0,1	Singletonmf
122	Smoking	Input	0,1	Singletonmf
123	Associate with T...	Input	0,1	Singletonmf
124	Asthma	Output	0,1	Singletonmf

Fig 2. Interface for adding variables and the membership functions

VariableDetailsI...	VariableIdentity	InputName	InputValues	Type
243	114	No	0,0	Singletonmf
244	115	Yes	1,1	Singletonmf
245	115	No	0,0	Singletonmf
246	116	Yes	1,1	Singletonmf
247	118	No	0, 0, 0	Trimf
248	118	Low	40,50,60	Trimf
249	118	Medium	55,70,85	Trimf

Fig3. Membership functions of each input and output variables

InputID	Inputs
25	Wheezing-Yes,SOB-Yes,Cough-Yes,Chest Pain-Yes,DayTime Symptom-Yes,NightSymptom-Yes,FEV1FVC-Low,FEV1-Low,EpisodicSymptom-Yes,Drug Response-Yes,Personal History-Yes,Smoking-Yes,Associate with Triggers-Yes
26	Wheezing-Yes,SOB-Yes,Cough-Yes,Chest Pain-Yes,DayTime Symptom-Yes,NightSymptom-No,FEV1FVC-No,FEV1-No,EpisodicSymptom-Yes,Drug Response-Yes,Personal History-No,Smoking-Yes,Associate with Triggers-Yes
27	Wheezing-Yes,SOB-Yes,Cough-Yes,Chest Pain-Yes,DayTime Symptom-No,NightSymptom-Yes,FEV1FVC-Low,FEV1-Medium,EpisodicSymptom-No,Drug Response-No,Personal History-Yes,Smoking-No,Associate with Triggers-No
28	Wheezing-No,SOB-Yes,Cough-Yes,Chest Pain-Yes,DayTime Symptom-Yes,NightSymptom-Yes,FEV1FVC-Normal,FEV1-Medium,EpisodicSymptom-No,Drug Response-No,Personal History-No,Smoking-Yes,Associate with Triggers-No
29	Wheezing-No,SOB-Yes,Cough-Yes,Chest Pain-Yes,DayTime Symptom-No,NightSymptom-Yes,FEV1FVC-Low,FEV1-No,EpisodicSymptom-No,Drug Response-Yes,Personal History-Yes,Smoking-Yes,Associate with Triggers-Yes
30	Wheezing-No,SOB-No,Cough-Yes,Chest Pain-Yes,DayTime Symptom-Yes,NightSymptom-Yes,FEV1FVC-Normal,FEV1-Medium,EpisodicSymptom-No,Drug Response-No,Personal History-No,Smoking-No,Associate with Triggers-No
31	Wheezing-No,SOB-No,Cough-Yes,Chest Pain-No,DayTime Symptom-Yes,NightSymptom-Yes,FEV1FVC-Normal,FEV1-Mediuml,EpisodicSymptom-Yes,Drug Response-Yes,Personal History-Yes,Smoking-No,Associate with Triggers-...
32	Wheezing-Yes,SOB-Yes,Cough-Yes,Chest Pain-Yes,DayTime Symptom-Yes,NightSymptom-No,FEV1FVC-Low,FEV1-Low,EpisodicSymptom-No,Drug Response-No,Personal History-No,Smoking-Yes,Associate with Triggers-Yes
33	Wheezing-Yes,SOB-Yes,Cough-Yes,Chest Pain-Yes,DayTime Symptom-Yes,NightSymptom-Yes,FEV1FVC-Low,FEV1-Low,EpisodicSymptom-No,Drug Response-No,Personal History-No,Smoking-No,Associate with Triggers-Yes
34	Wheezing-Yes,SOB-Yes,Cough-Yes,Chest Pain-Yes,DayTime Symptom-Yes,NightSymptom-Yes,FEV1FVC-Low,FEV1-Low,EpisodicSymptom-No,Drug Response-No,Personal History-No,Smoking-,Associate with Triggers-No
35	Wheezing-Yes,SOB-Yes,Cough-Yes,Chest Pain-Yes,DayTime Symptom-Yes,NightSymptom-Yes,FEV1FVC-Low,FEV1-Low,EpisodicSymptom-No,Drug Response-No,Personal History-No,Smoking-Yes,Associate with Triggers-No
36	Wheezing-No,SOB-Yes,Cough-Yes,Chest Pain-No,DayTime Symptom-Yes,NightSymptom-Yes,FEV1FVC-Low,FEV1-Low,EpisodicSymptom-No,Drug Response-No,Personal History-No,Smoking-Yes,Associate with Triggers-

Fig4. Collection of rules identified

A. Development of User Module

This module consists of an interface developed in C# programming language. It allows the user to select from list of symptoms along with the values. The selected symptoms and lab results are shown in a separate portion of the interface (Fig 5). When the user hits the 'diagnose' button the system connects with the knowledge base specially the rule base to find the matches and finally displays as if the patient is having Asthma with probabilities and its stage. This module is designed in a way which is user-friendly and comprehensive as well.

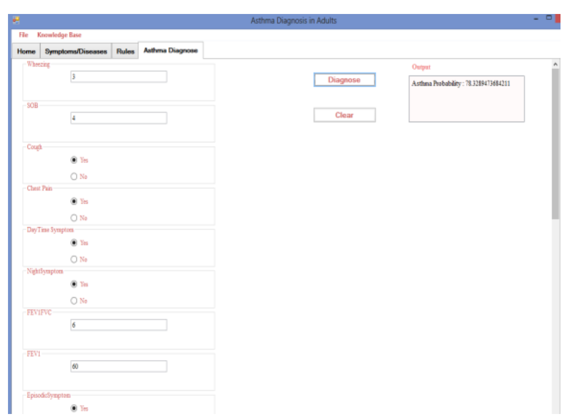

Fig5. Interface for Asthma Diagnosis

B. Implementation of Fuzzy inference system

This module is implemented in .net c# programming. To implement fuzzy logic, existing basic fuzzy logic library written in c# is used and further some classes and methods are added for fuzzy notations namely FuzzyNumber, FuzzySet and Linguistic variables which were essentially needed for our system [10]. The system-input node is straight-forward and contains an input name, a membership-function pointer, and a next-input pointer. More interesting is the membership-function structure, which contains two X-axis points and values that describe several membership functions such are singleton, triangular and trapezoidal. This information is used to calculate antecedent values (degrees of membership). The resulting antecedent value is stored in the value field of the membership-function structure. Rules can be represented by two sets of array list. The first set indicates which antecedent values are used to determine the rule's strength, and the second set points to output locations where the strength is to be applied [11]. Finally, a data arrangement similar to the input-data structure handles outputs and output membership functions include the C#-code definition of these data structures.

During the rules evaluation at the Inference system, the firing strength of the output is determined. If more rules are overlapping, the maximum of firing strengths is taken. Then we defined Defuzzification method is a method to calculate the fuzzy out to convert to a crisp value. In this system, two methods of defuzzification are used, you can choose between them in Configuration. Center of Gravity Defuzzification and Modified High Defuzzification. The method Center of Gravity employs integral calculus to obtain centre of gravity for the output fuzzy set [12].

C. Verifying the Knowledge base

Higher the accuracy of the rules, better the diagnosis will be. Towards the final phases of the implementation process the system had undergone many testing and the knowledge base had been verified and corrected several times by the expert. Analytic tests were carried out to determine whether sufficient amount of variables and rules are included in the knowledge base and time to time it was modified according to the perception of doctor and other findings. And also the system was tested by the expert in order to determine the accuracy of the rule until the conclusions from this system were acceptable.

D. Validating the knowledge base.

It’s a fundamental expectation that there should be a logical reason in defining and relating rules. A rule having higher number of variables in its antecedent part should affirm the existence of Asthma than the rule with lower number of variables in its antecedent. So the truth is maintained over conflict decisions. This type of validation was done manually and it’s expected to have it automatically whenever a new rule is created.

E. Comparing the system with the general practice of Asthma diagnosis

Common approach for diagnosing any disease is the analysis of symptoms which the doctors observe and patients present. Mean while the laboratory tests have also to be done when it comes to diagnosing respiratory diseases like Asthma. But, it’s not guaranteed that all the symptoms and possible combinations of them are considered by a doctor at a given time of diagnosis especially when he or she is not an expert. And also when the lab results are taken, the reevaluation of the symptoms takes more time. But, using the system we have developed as a decision supporter of medical practitioners makes it very easy to come to a reliable conclusion without missing and delaying.

VI. CONCLUSIONS

Decision support systems are proving its necessity in most of the areas. Effectiveness of the medical domain always depends on the efficiency of the decision making process and the accuracy and reliability of the decisions being made. The research aimed to assist this decision making process in diagnosing asthma and its stages in Adults. The system used the theory of Fuzzy Logic to handle the vagueness of expressions in presenting the symptoms. Accurately developing the knowledge base was the most challenging part in the research. As an expert system, it highly depends on the availability of the expert and his or her willingness to support. So from the great support of the doctor we identified 21 variables including inputs and outputs, their fuzzy sets and more importantly the formation of rules. Efficiency of this system can be further improved by adding more knowledge from other experts as rules. And also the system can be extended in a way that it can cover all the respiratory diseases and other diseases as well.

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