Research Journal of Mathematical and Statistical Sciences ISSN 2320-6047
Vol. **5(7),** 1-8, July **(2017)** *Res. J. Mathematical and Statistical Sci.*

Thalassemia risk prediction model using fuzzy inference systems: an application of fuzzy logic

S. Thakur* and S.N. Raw
Department of Mathematics, National Institute of Technology, Raipur (CG) - 492010, India
sapnarajput85@gmail.com

Available online at: www.isca.in, www.isca.me
Received 10th April 2017, revised 2nd June 2017, accepted 10th June 2017

Abstract

Thalassemia Disease is a one of the most common genetic disease. The objective of this paper is to predict the stages of Thalassemia using Fuzzy Inference System. In this study, we have used the Mamdani type Fuzzy Inference System tool in MATLAB 8.4. Using the above tool, we have designed a mathematical model of Thalassemia disease and demonstrate that under certain fuzzy rules on the consider inputs shows the Thalassemia stage presence in an individual. Through the observed stages of Thalassemia, we have predicted the severity involve in this disease. The model is going to play a unique role in the prediction of the category of Thalassemia and helpful for medical fields.

Keywords: Fuzzy Logic, Mamdani FIS, Symptoms of Thalassemia, Thalassemia Disease.

Introduction

Hemoglobin (Hb) is a heterogeneous group of proteins made by four globin chains and four heme groups. It carries oxygen to the lungs and other parts of the body. There are three types of hemoglobin's such as HbA, HbA_2 and HbF which are found out in adults. The most common example of hemoglobin disease is Thalassemia. It has been recently identified as one of the major public health problems in the world; it is applying for global eradication. The disease occurs when there is a change in the shape of the red blood cells. Which can be characterized by the lack of the corresponding globin chain synthesis, in beta-Thalassemia Major HbA is absent, HbF is 95-98%, and HbA_2 is 2-5%[1].

In Thalassemia disease, defective genes (say Hba) are responsible for the abnormal form of Red Blood Cells. Thalassemia disease is a type of genetic blood disease and Thalassemia Major, Thalassemia Intermedia and Thalassemia Minor are the different forms of Thalassemia disease. According to which we define the stages of Thalassemia such as primary stage and secondary stage where primary stage is the stage where Thalassemia minor is generally not a severe condition of Thalassemia. People with the Beta – Thalassemia Major disease can advance to severe anemia, which is also known as Cooley's anemia.

Thalassemia trait (Aa) is an inherited condition in which both normal and abnormal hemoglobin's (assume A and a) are present in the red blood cells. Thalassemia trait is not a disease, but if both parents carry the trait, their child may have the disease. Every state of India has shared the birth rate of thalassemia children's. Approximately 12,000 children's with Thalassemia Major have born each year in India[3]. Therefore, there is need to create a mathematical model for the detection and prevention of TD. We know that fuzzy logic tools helps medical field for effective diagnosis results. In this paper, we create a Thalassemia Fuzzy model with the help of Mamdani Type Fuzzy Inference system.

Since Mamdani Type FIS is an effective tool, which is helpful for the detection of TD. In this study, we have shown how Mamdani model and fuzzy rules can be combined together for capable and profitable diagnosis of TD. The results demonstrate that this method is effective and efficient for risk prediction of Thalassemia disease.

Table-1: Thalassemia with its symptoms.

Type of Thalassemia	Different Symptoms
Thalassemia Minor	No signs or symptoms of the disorder.
Anemia	People feel tired and weak.
Severe Thalassemia (Also known as Cooley's Anemia and Thalassemia Major)	Bone deformities in the face, Fatigue, Slowed growth, Delayed puberty, Shortness of breath, Yellow discoloration of skin (jaundice) or whites of the eyes, Weakness, Abdominal swelling, Dark urine (a sign that red blood cells are having problems), Poor appetite etc.

Application to fuzzy systems

There are several diverse areas in the medical field where expert system used successfully. Disease diagnosis of various diseases like cancer, cardiovascular disease, endocrine diseases, diabetes, tumor, patient monitoring, treatment of illness, prognosis, determining the risk of disease, determination of drug dose[4]. Fuzzy sets are the most accurate tool to deal with imprecise data sets. There are a number of article publishing in medical applications using fuzzy environment[5-8]. Fuzzy systems provide tools to analyze impreciseness of medical diagnostic reports. The use of Fuzzy Inference System (FIS) can be found in following medical applications.

A Fuzzy Petri net application for Heart Disease Diagnosis was developed by Shradhanjali[9]. A Fuzzy rule based inference detection system for diagnosis of Lung Cancer was designed by Lavanya *et al.*[10]. A Fuzzy expert system for the Heart Disease Diagnosis was proposed by Adeli *et al.*[11]. The system based on the concept of fuzzy logic. In their system Fuzzification step is used to get fuzzy values. Also for the output of the system Defuzzification step is used. Sony *et al.*[12] developed an Intelligent and Efficient Heart Disease Prediction System with the help of weighted associative classifiers. A Fuzzy Expert System for diagnosis of Liver Disorder was designed by Neshat *et al.*[13]. Also Kadhim *et al.*[14] designed a fuzzy expert system for diagnosis of back pain. In their system the rules were developed by experts and decision sequence is illustrated by a decision tree.

In this paper, we are using the Mamdani type Fuzzy Inference System tool in MATLAB 8.4 for TD diagnosis. The rest of the paper is organized as follows: Thalassemia disease and its symptoms are already explained in Introduction section and the concept of fuzzy Inference System is shown in Materials and Methods section. The outputs of the given system are graphically represented in Result section. Discussion about the results is considered in Discussion section and the Conclusion section gives an output of the study.

The concept of fuzzy set theory

Conventional (Boolean) logic is a subset of fuzzy logic. Fuzzy logic has been extended to handle the concept of partial truth – values between "completely true" and "completely false"[15]. Fuzzy sets were introduced by Professor Lofti A. Zadeh in 1965 that lives in USA[16]. He and others, in the subsequent decades, found surprising applications in every field of science and knowledge: from engineering to sociology, from biology to computer science, from agronomy to linguistics, from medicine to economy, from psychology to statistics and so on. Fuzzy systems have been effectively applied to problems in modeling, control, classification, and in a significant number of applications. In many fields of medicine, fuzzy logic based approaches have been used. Now a day's applying the fuzzy system is increasing in the field of medical diagnosis gradually. Currently, fuzzy sets are armed with their own mathematical foundations, rooting from set theory basis and multi-valued logic.

Fuzzy Inference System: Fuzzy Expert System is a collection of fuzzy membership functions and rules, as a substitute of Boolean logic. Fuzzy inference model was proposed by Mamdani and Assilian in 1973, which is known as a Mamdani Fuzzy Model. Their work behind the proposed model was inspired by Zadeh[17].

A general structure of a Mamdani type fuzzy inference system was described by Iancu[18] which is known as the popular applications of fuzzy logic. The structure of FIS can be summarized in the following steps, carried out in order: Fuzzification is the first step of FIS in which crisp value of the input data is gathered and converted to a fuzzy membership value using degree of membership functions and fuzzy linguistic variables. After that the set of rules are used for hypothesis of the system body, and finally in Defuzzification step, the results of the system are converted into crisp output value.

Description of the proposed system: This work has been harnessed using Mamdani type. Based on the expert's knowledge, experience and by the information fuzzy rules was created. These formed rules provide a way to find the disease using the Mamdani Fuzzy Inference System. The following Figure-1, represents the Mamdani Fuzzy Inference System for Thalassemia disease diagnosis.

The inputs of the system are Symptoms_Score, HbA and Hba where Symptoms_Score is the score of symptoms and through the blood test we consider the value of HbA (Adult hemoglobin) also Hba is a Thalassemia gene, indicating that the parents of the patients are Thalassemia Minor or not that means the Thalassemia gene in both the parents is present or absent. Finally the output of the system is to get a value 0 to 1 through which we can predict the Thalassemia stages that indicates the severity of the Thalassemia disease.

Ranges for Input/output fields of the system: The first input variable is the Symptoms_Score type for which there are three values Low, Medium and High. High and medium are the support sets for Thalassemia patients, whereas the low type is for non-Thalassemia disease. HbA is a next input variable. There are three fuzzy regions, namely, "Low", "Medium" and "High".

The value for Low and Medium HbA belongs to the support set for Thalassemia patients. The value for High HbA belongs to the support set for no Thalassemia disease. The next input is the Hba (hemoglobin a), for which there are two values like "Absent" or "Present".

The value "Present" is in the support set for parents of the patients with Thalassemia trait. "Absent" value is in the support set for parents of the patients with no Thalassemia trait.

The system has one output such as Thalassemia_Stage which has four fuzzy sets, namely Healthy, Subclinical, Primary and Secondary which shows the stages of the Thalassemia disease in the patient. Throughout the paper membership function scale is 0 to 10.

Description of Input fields

Symptoms Score: In this study an input variable Symptoms_Score is divided into three categories Low, Medium and High, then design a Table-2 for their ranges and define mathematical interpretation in subsequent equations. Figure-2, shows the membership function of input Symptoms_Score in each category as Low, Medium and High. Membership functions of Low and High are trapezoidal and membership function of Medium is triangular.

Table-2: Classification of symptoms score.

Input Field	Range	Fuzzy sets
Symptoms_Score	<3 2-5 >4	Low Medium High

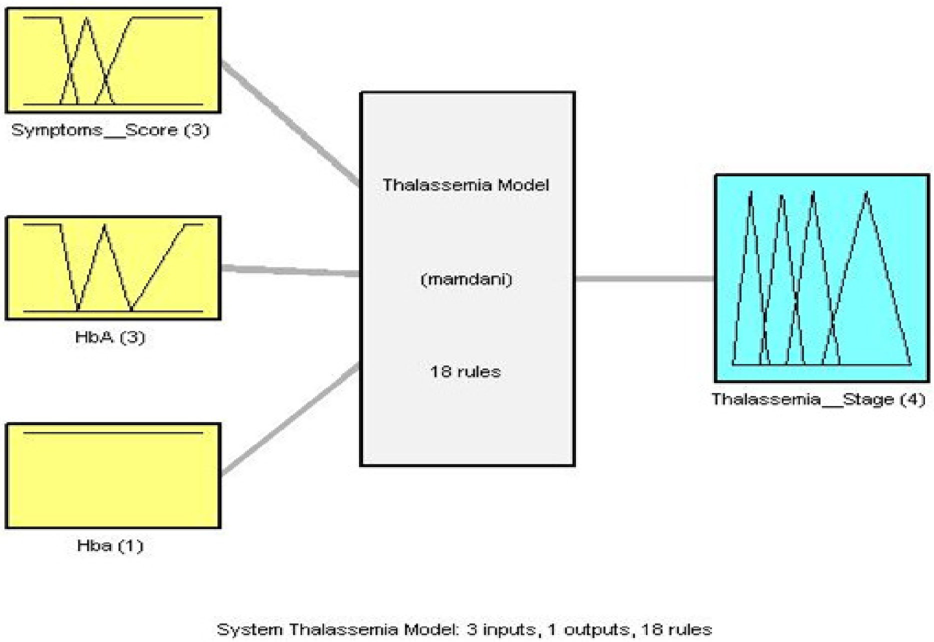

Figure-1: Mamdani Fuzzy inference system for Thalassemia.

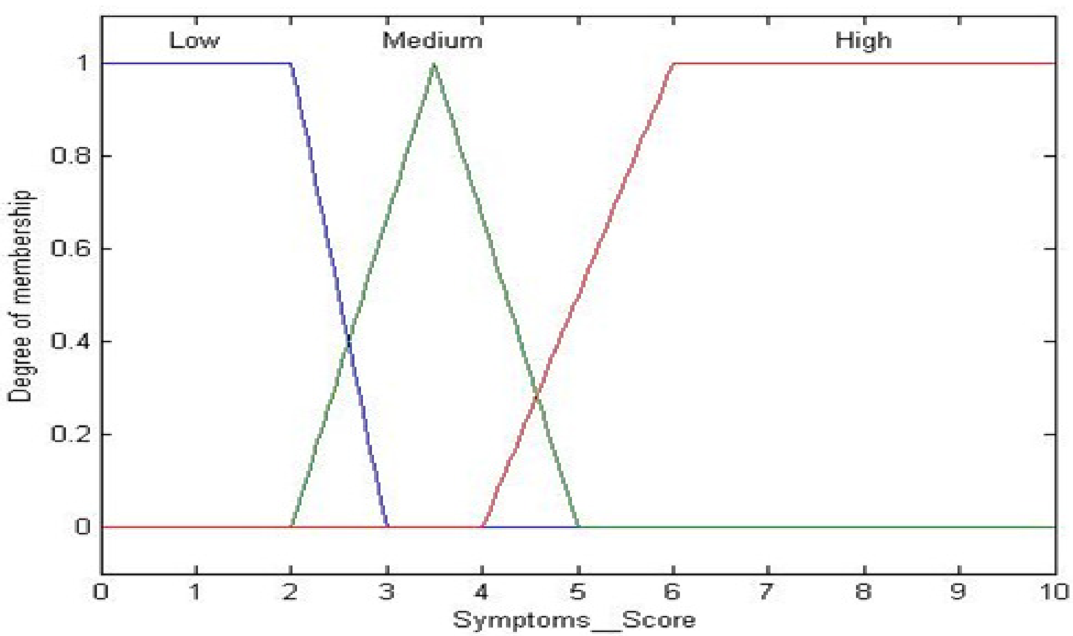

Figure-2: Membership function of symptoms score.

Input Field HbA: It contains three fuzzy sets they are Low, Medium and High. Table-3, represents the ranges of these fuzzy sets Low, Medium and High. Mathematical equations are presented. Membership functions of Low and High are trapezoidal and membership function of Medium is triangular. Figure-3, shows the membership function of input HbA in each category as Low, Medium and High.

Table-3: Classification of HbA.

Input Field	Range	Fuzzy Sets
HbA	2 - 5 4-7 6-10	Low Medium High

Input field Hba: In this field, we take two values for Present and Absent they are 1 and 0, where the value 1 represents the input Hba is Present in the parents that means they are Thalassemia carrier and value 0 represents the input Hba is Absent means parents of Thalassemia children are free of gene a, which is responsible for the Thalassemia disease. Figure-4, shows that if Hba is present, then the value is 1 otherwise absent.

Output fields: The output field Thalassemia_Stage is divided into four stages, Healthy, Subclinical, Primary and Secondary. It means if the result appears in Healthy range, then the patient is healthy. In Subclinical, the patient requires further clinical checkup to confirm the Thalassemia disease. On Primary stage, it is confirmed that the patient has with Thalassemia trait. In Secondary stage, it confirms that the patient is Thalassemia. Ranges for these stages are presented in Table-4 and the mathematical expression is presented in subsequent equations. Membership function for each stage is triangular.

Table-4: Classification of Thalassemia_Stage.

Output Field	Range	Fuzzy Sets
Thalassemia_Stage	0 – 2 1.5 - 4 3-6 5-10	Healthy Subclinical Primary Secondary

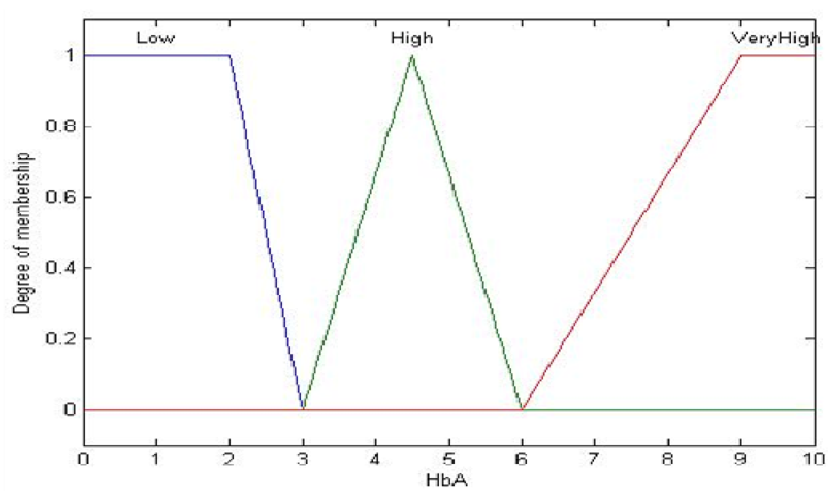

Figure-3: Membership functions of HbA.

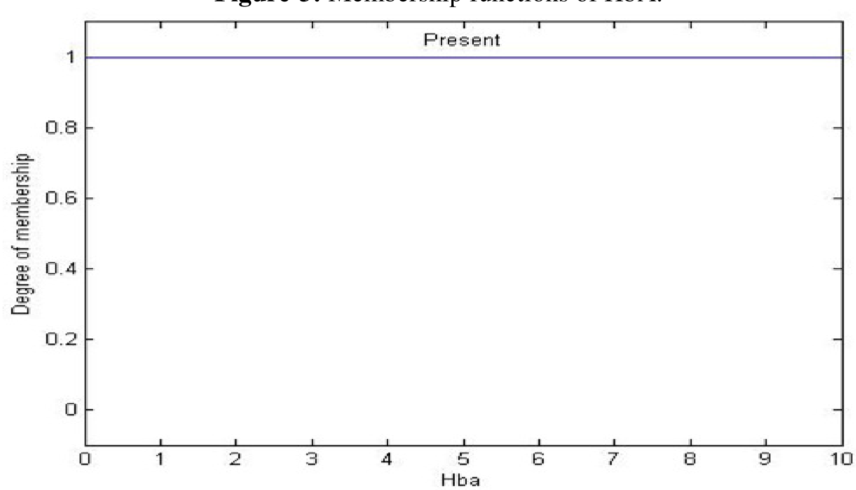

Figure-4: Hba is present.

The Figure-5, shows the membership function of Thalassemia_Stage in each category as Healthy, Subclinical, Primary and Secondary.

Framing if-then rules for multiple inputs: In this paper the membership functions using fuzzy *if-then* rules as illustrated in Table-5. The consequent parts of the rule represent the actions associated with each partition. It is evident that the MFs and the number of rules are tightly related to the partitioning. For a multiple input and multiple output system, the rules are represented as R = (R1, R2, R3…..Rn). All fuzzy rules for the prediction of Thalassemia disease are set as the following syntax:
Rule i: If symptom Score is a and
HbA is B and Hba is C then D stage of Thalassemia.
Where i = 1 to 15.

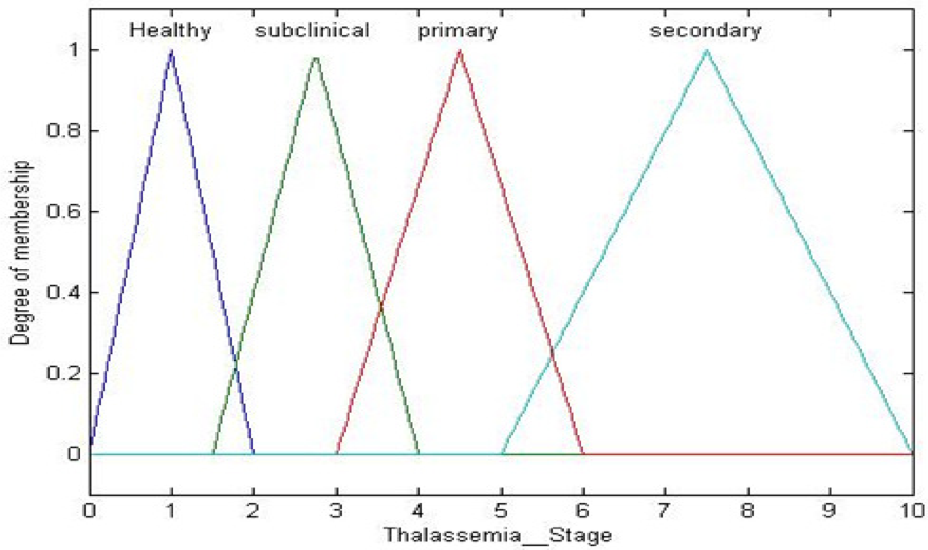

Figure-5: Membership functions of Thalassemia stage.

Table-5: Set of rules antecedent and rules consequence.

Rules (R)	Symptoms_Score	HbA	Hba	Thalassemia_Stage
Rule-1	Low	Low	Present	Primary
Rule-2	Low	High	Present	Primary
Rule-3	Low	Very_High	Present	Primary
Rule-4	Low	Low	Absent	Healthy
Rule-5	Low	High	Absent	Healthy
Rule-6	Low	Very_High	Absent	Healthy
Rule-7	Medium	Low	Present	Secondary
Rule-8	Medium	High	Present	Primary
Rule-9	Medium	Very_High	Present	Primary
Rule-10	Medium	Low	Absent	Subclinical
Rule-11	Medium	High	Absent	Healthy
Rule-12	Medium	Very_High	Absent	Healthy
Rule-13	High	Low	Present	Secondary
Rule-14	High	High	Present	Primary
Rule-15	High	Very_High	Present	Primary
Rule-16	High	Low	Absent	Subclinical
Rule-17	High	High	Absent	Subclinical
Rule-18	High	Very_High	Absent	Subclinical

Experimental results

The output field refers to the presence and absence of Thalassemia disease in the patient. Clearly, Figure-6, shows the Thalassemia_Stage as the Symptoms Score increases and HbA decreases the Thalassemia_Stage increases, as Symptoms Score increase after 1.5, the Thalassemia_stage is very high while the HbA is very low. Figure-7, shows that when HbA is greater than 4 there is no chance for Thalassemia disease, but as HbA is less and Hba is present there is surely Thalassemia disease. Figure-8, shows that Symptoms_Score and Hba together increases the level of Thalassemia and is on primary stage.

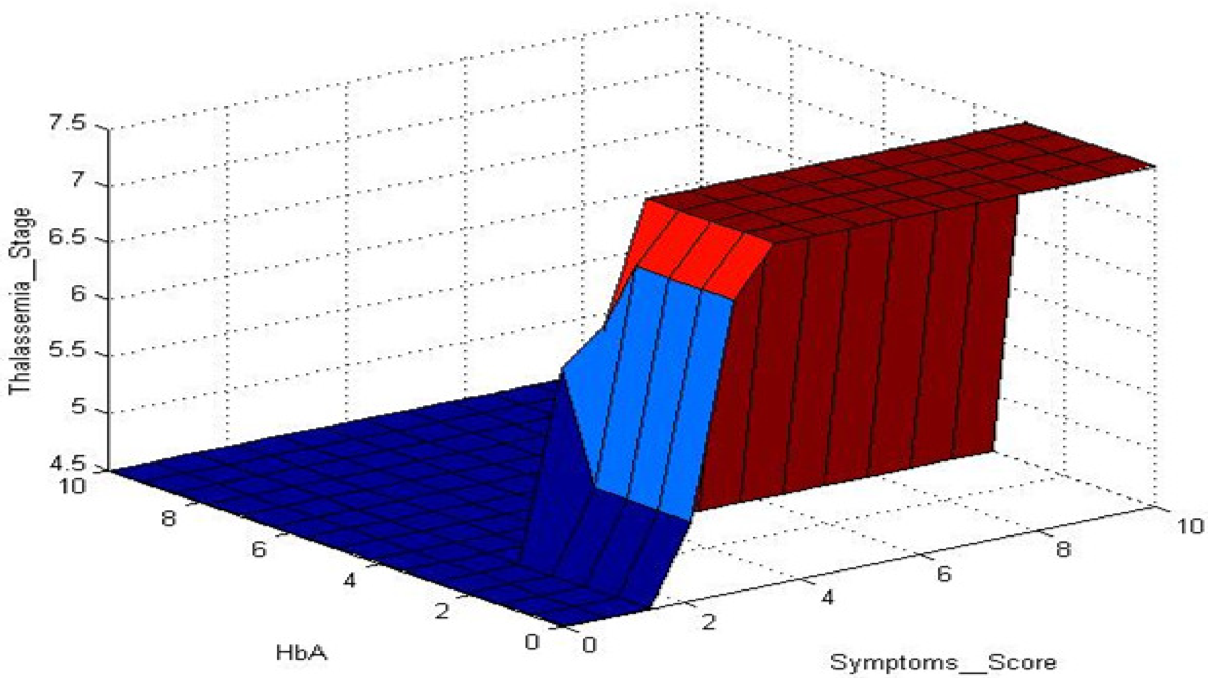

Figure-6: Surface plot of Symptoms_Score, HbA and Thalassemia_Stage

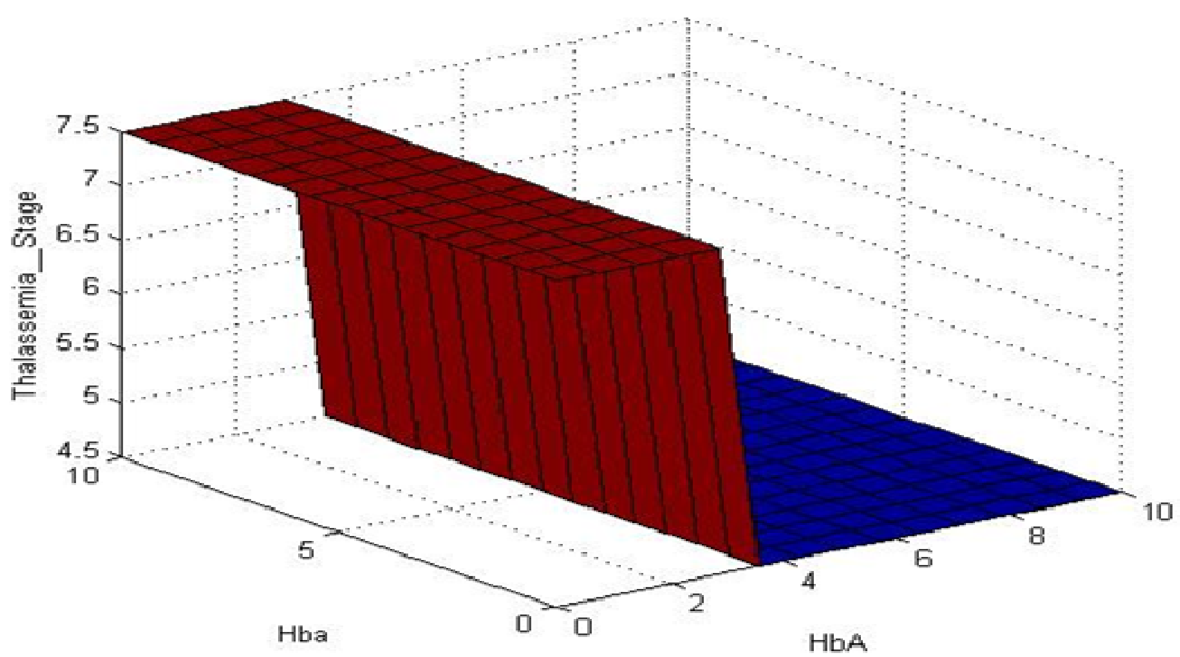

Figure-7: Surface plot Hba, HbA and Thalassemia_Stage.

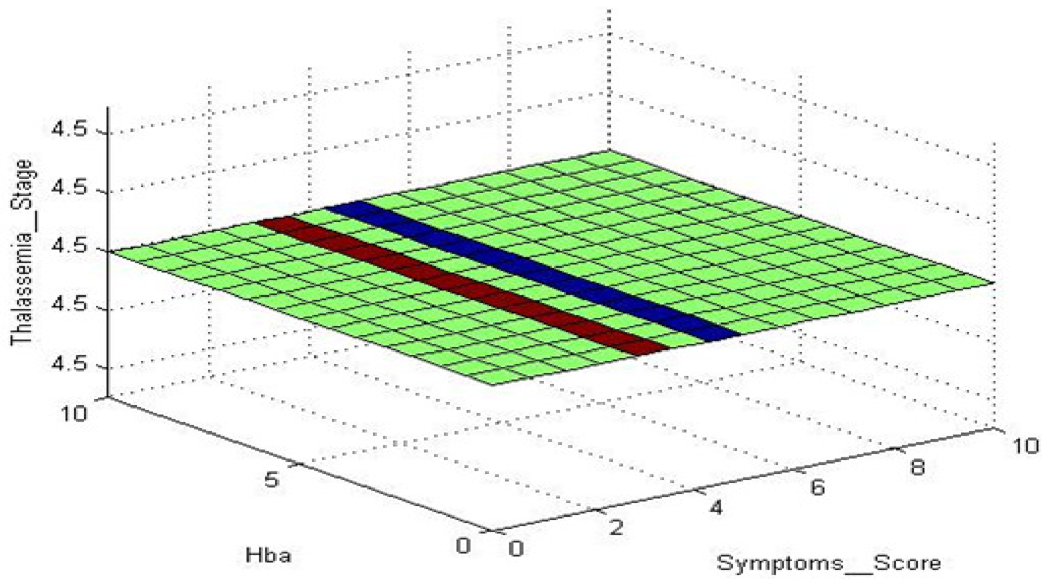

Figure-8: Surface plot of Symptoms_Score, Hba AND Thalassemia_Stage.

Conclusion

In this model we present graphical decisions for the detection of Thalassemia disease in the patients. This model is based on the Mamdani Fuzzy Inference system and programmed in MATLAB 8.4. This model is based on three basic diagnostic inputs (named: Symptoms_Score, HbA and Hba) and the model has a number of decisions to identify the level of Thalassemia disease. The result of this model is very satisfactory and has been approved by expert doctors. This model has ability to predict that the patient is Thalassemic or not to the stage of disease. Experimental results illustrate that the model is quite well than non-expert urologist. The proposed model proves to be more capable, proficient and cost effective in diagnosing of Thalassemia disease. This system can be used at hospital level by doctors and physicians to classify the patient's Thalassemia status.

Acknowledgement

The authors would like to express thanks to Mr. Pramod Puri (General Secretary Thalassemia Welfare Society, Bhilai, Chhattisgarh, India) for a number of useful discussions concerning the origins and related information of Thalassemia.

Nomenclature: HbA-Hemoglobin A, HbF-Fetal Hemoglobin, Hba-Hemoglobin a, FIS-Fuzzy Inference System, TD-Thalassemia Disease.

References

1. Grow K., Vashist M., Abrol P., Sharma S. and Yadav R. (2014). Beta Thalassemia in India: Current Status and the Challenges Ahead. *International journal of Pharmacy and Pharmaceutical Science,* 6(4), 28-33.
2. Diagnosis (2017). Thalassemia Symptoms. http://www.rightdiagnosis.com/t/ thalassemia/symptoms.htmsymptom_list
3. Thakur S. and Sharma R. (2013). Prevention Measures for Thalassemia in Chhattisgarh, India: with the help of mathematical models. *American Journal of Mathematics and Mathematical Sciences,* 2(2), 193-200.
4. Aversa F., Gronda E., Pizzuti S. and Aragno C.(2002). A fuzzy logic approach to decision support in medicine. Proceedings of the Conference on Systemics, Cybernetics and Informatics, 1-5.
5. Allahverdi Novruz (2014). Design of Fuzzy Expert Systems and Its Applications in Some Medical Areas. *International Journal of Applied Mathematics, Electronics and Computers*, 2(1), 1-8.
6. Tamalika C. and Tridib C. (2008). Intuitionistic fuzzy sets: Application to medical image segmentation. Studies in Computational Intelligence. *Springer*, 85, 51-68.
7. Schuh C. (2005). Fuzzy sets and their application in medicine. Proceedings of the North American Fuzzy Information Society, 86-91.
8. Yamada K. (2004). Diagnosis under compound effects and multiple causes by means of the conditional causal possibility approach. *Fuzzy Sets and Systems*, 145, 183-212.
9. Rout Shradhanjali (2012). Fuzzy Petry Net Application: Heart Disease Diagnosis. *Fuzzy Systems*, 4(4), 124-131.
10. Lavanya K., Durai M.A. and Sriman Narayan lyengar N. Ch. (2011). Fuzzy Rule Based Inference System for Detection and Diagnosis of Lung Cancer. *International journal of Latest Trends in computing*, 2(1), 165-171.

11. Adeli A. and Neshat Mehdi (2010). A Fuzzy Expert System for Heart Disease Diagnosis. Proceedings of the International Multi Conference of Engineers and Computer Scientists, 1, 136-139.

12. Soni J., Ansari U., Soni S. and Sharma D. (2011). Intelligent and Effective Heart Disease Prediction System using Weighted Associative classifiers. *International Journal on Computer Science and Engineering*, 3(6), 2385-2392.

13. Neshat M., Yaghobi M., Naghibi M.B. and Esmaelzadeh A. (2008). Fuzzy Expert System Design for Diagnosis of liver Disorders. IEEE Proceeding International Symposium on Knowledge Acquisition and Modeling, 252-256.

14. Kadhim M., Alam M. and Kaur H. (2011). Design and Implementation of Fuzzy Expert System for Back pain Diagnosis. *International Journal of Innovative Technology & Creative Engineering*, 1(9), 16-22.

15. Zimmermann H.J. (1996). Fuzzy Set Theory And its Applications. Third Edtion; Kluwer Academi Publishers.

16. Zadeh L.A. (1965). Information and Control. *Fuzzy Sets*, 8(3), 338-353.

17. Takagi T. and Sugeno M. (1985). Fuzzy identification of systems and its applications to modeling and control. *IEEE Transactions on Systems Man and Cybernetics*, 15(1), 116-132.

18. Dadios Elmer P., Biliran Jazper Jan C., Garcia Ron-Ron G., Johnson D. and Valencia Adranne Rachel B. (2012). Humanoid Robot: Design and Fuzzy Logic Control Technique for Its Intelligent Behaviors. *Fuzzy Logic – Controls, Concepts, Theories and Applications,* InTech, 1-20.