

A Multi-layered Fuzzy Inference System for the Diagnosis of Hepatitis B

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Abstract

Hepatitis B is a virus, which can attack the liver of a human body and leads to major disease of the liver. The prime aim or objective of this research work is to develop a medical diagnostic system to diagnose the Hepatitis B virus infection. A multi-layered fuzzy inference system has been proposed by using the Mamdani fuzzy model. In this proposed system, there are two layers, and both layers have different input variables. This system classifies the hepatitis B patient and non-hepatitis B patients into different classes. The input variables used for layer 1 are jaundice, dark urine, abdominal pain and vomiting. Similarly, layer 2 uses the input variables such as HBsAg, Anti-HBs or HBsAb, Anti-HBc or HBcAb, HBV DNA and Anti-HBcAg-IgM. The layer 1's output is also used as the input for layer 2. The layer 1's output is either yes or no as this layer only detects whether the individual suffering from this virus or not. Likewise, layer 2 gave the output as no HBV, acute disease or chronic disease. The accuracy of the system is also evaluated with test cases. Various parameters used to calculate the performance of the system are also determined. The classification accuracy of this system is 94%.

Keywords: Hepatitis B, fuzzy Logic, Medical diagnostic system, artificial intelligence.

1. Introduction

Hepatitis B is a deadly and severe infection of the liver. This infection is mainly caused by a virus namely hepatitis B virus or HBV [1]. This disease is also a major health issue globally. If this disease is not diagnosed at a time then this will lead to chronic infection and also the probability of death of that particular patient increases due to liver cancer or cirrhosis [2]. The hepatitis B virus-infected more than 240 million people at a global level. Hence, the treatment of this disease became crucial [3].

In the past years, this disease grabs attention at a wider level as this disease has an extreme risk of cancer as well as the liver diseases on the health of human. Various researchers used different methodologies for the detection as well as diagnosis of Hepatitis B infection. The biomarkers for this disease has been identified and also compared with each other by using the multimodel biomarkers [4]. The mining mutation hotspots were also used by the researchers to identify or to detect the best clinical biomarkers. The feature tree has been used to find the contribution of the biomarkers in causing disease. These biomarkers are further assists in the detection and treatment of the HBV virus in a particular patient at early stages [5].

The Granular Computing theory has been used to categorize the life-threatening disease by using the symptoms and stages [6]. There are numerous cells which cause this Hepatitis B. These host cells are identified by using the mathematical models, and also this model helps to understand the dynamic nature of cells. The different symptoms are accounted, and according to those symptoms, Hepatitis B is diagnoses [7]. There are five different viruses which can be considered as hepatitis infection. These are HAV, HEV, HBV, HCV and HDV. The classifiers such as Naïve Bayes, J48 and K-Star have been used to classify these different viruses into distinct classes [8]. The HBV RNA is also a biomarker for hepatitis B infection that circulate in the patient body [9].

The data mining approaches such as clustering, classification and others are also used for the diagnosis of Hepatitis B infection. The meaningful information from the experimental results is also extracted by using data mining techniques [10]. The missing values and normalization on the experimental data are also done by using data mining techniques [11]. The K-means classification is also used for the classification of different DNAs that causes this deadly disease [12], [13]. The Bayesian inference based methodology has been used for the detection of several viruses like hepatitis B virus, hepatitis C virus, as well as HIV. This detection basically has been done

according to the mutation patterns [14]. The random forest technique with Bayesian has been used for the prediction of risk factors of this severe disease [15]. The decision tree algorithms are also used to propose a system which can analyze the disease from its symptoms and having better accuracy [16], [17].

An expert system by using the Generalized Regression Neural Network has been proposed for the early detection of Hepatitis B. This proposed system classified the infected patients and non-infected patients into two different classes [18], [19]. The other artificial intelligence approaches such as support vector machine and neural networks were also applied to propose a system which aids in the diagnosis of hepatitis B infection. This developed system classifies the patient into six distinct classes [20], [21].

The hybrid system like adaptive neuro-fuzzy inference system, which is a combination of two different approaches of artificial intelligence, i.e. fuzzy logic and neural network, is also used for the recognition of hepatitis B. Additionally, the comparison of Support vector machine and the neural network has been made [22]. The multi-layered fuzzy inference system has been developed by using numerous risk factors as the input variables and classify the disease into distinct classes [23].

The fuzzy logic is utilize to evaluate the values between 0 and 1 [24], [25]. It calculates the values which lie between the completely true and completely false [26]. This theory is used to deal with fuzzy values or imprecise values [27], [28]. The fuzzy logic is used to develop an expert system, and this system has the following blocks[29], [30]:

- Fuzzification: It converts the crips input given by the user into fuzzy values.
- Inference Engine: It assists in the mapping of suitable rules which are kept in the knowledge base to the given input and provide the output in a fuzzy set.
- Defuzzification: It transforms the output provided by the inference engine in the fuzzy set into the crisp set.

The composition of the rest of the paper is as section 2 elaborates the methodology used to develop the system, section 3 shows the result of the proposed system and the conclusion is presented in section 4.

2. Methodology

Figure 1 shows the methodology used to develop a multi-layered system by using fuzzy logic for the diagnosis of Hepatitis B.

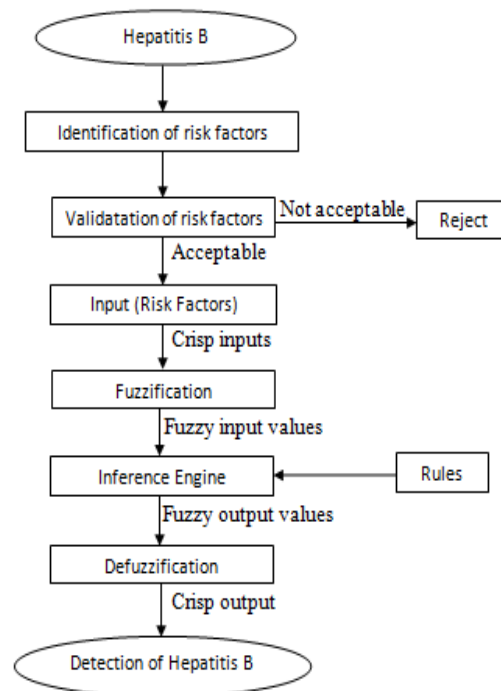


Figure 1: Methodology used to develop a system

Figure 2 presents the multi-layered expert system to diagnose the Hepatitis B. In this proposed system, the first layer, i.e. layer 1 used clinical symptoms as the input variables and give the output either yes or no which means this layer only detects whether the patient is suffering from the hepatitis B disease or not. Likewise, in the second layer, i.e., layer 2, the laboratory test values are used as the input variables which will detect the condition of the patient either no hepatitis B or chronic or acute. The several input variables used in layer 1 and layer 2 are given below:

Layer 1: Clinical symptoms

- Jaundice
- Dark Urine
- Abdominal Pain
- Vomiting

Layer 2: Laboratory test

- HBsAg
- Anti-HBs or HBsAb
- Anti-HBc or HBcAb
- HBV DNA
- Anti-HBcAg-IgM

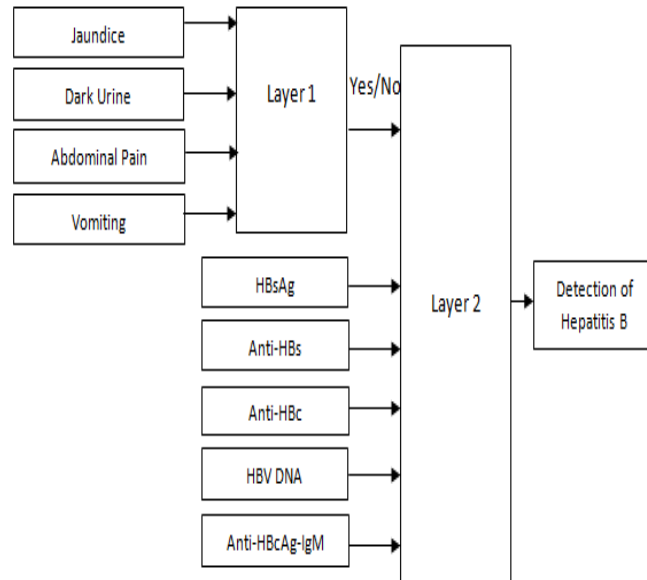


Figure 2: Development of Multi-layered Fuzzy inference system for the diagnosis of Hepatitis B

a. Input variables

In input variables with its membership functions used in layer 1 and layer 2 of the multi-layered fuzzy expert system to diagnose the Hepatitis B are shown in the figures. Figure 3-6 presents the input variables of layer 1 and similarly, figure 7-11 displays the layer 2's input variables of the medical diagnostic system.

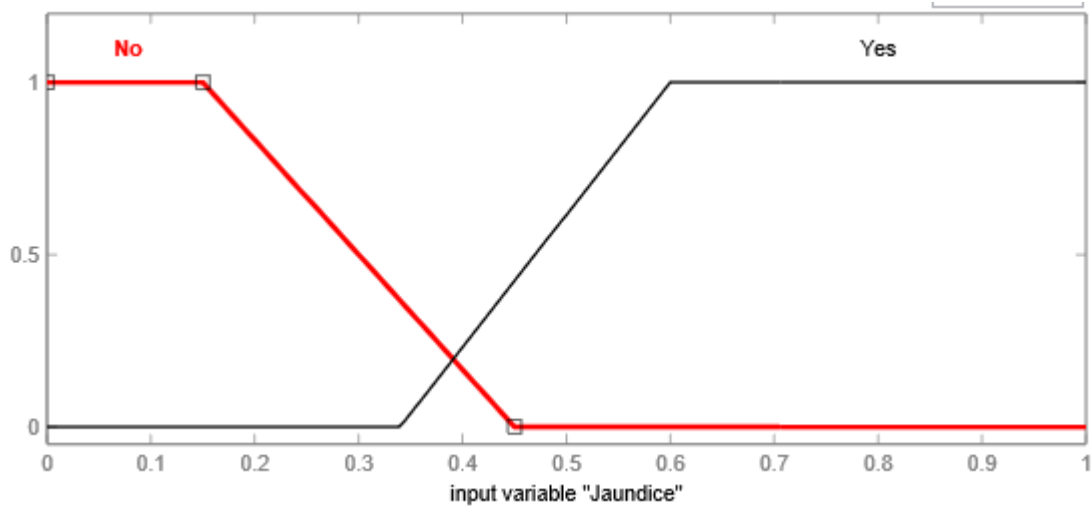


Figure 3: Input variable of layer 1, "Jaundice."

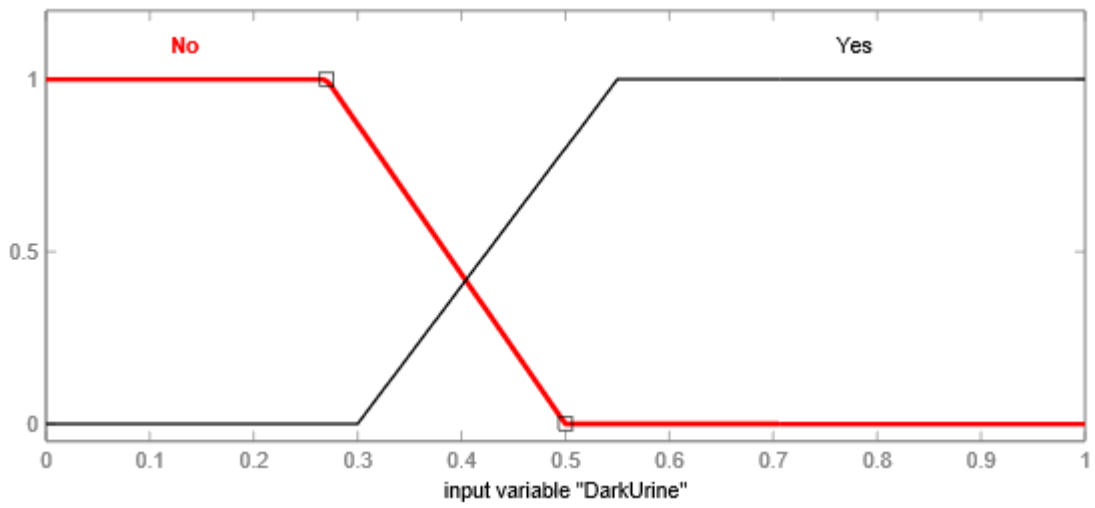


Figure 4: Input variable of layer 1, "Dark Urine."

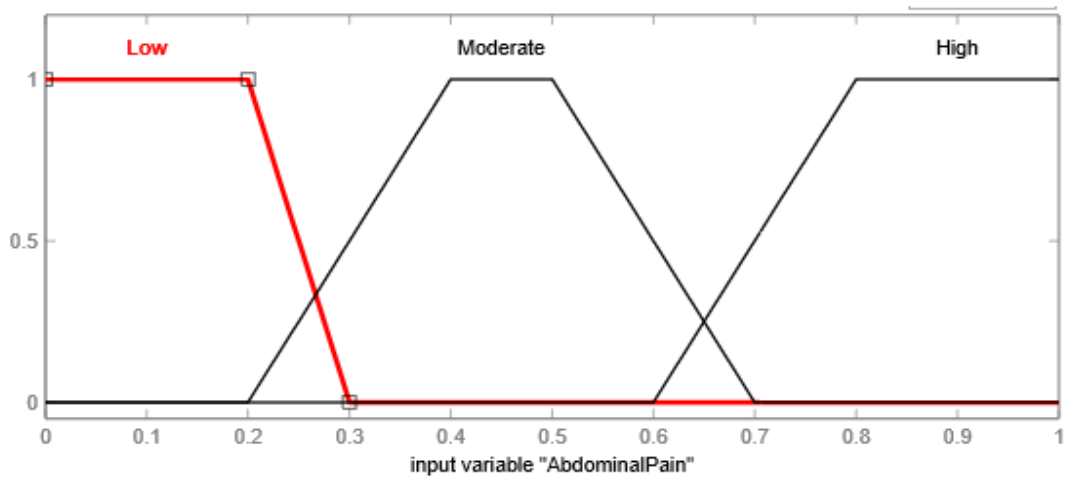


Figure 5: Input variable of layer 1, "Abdominal Pain."

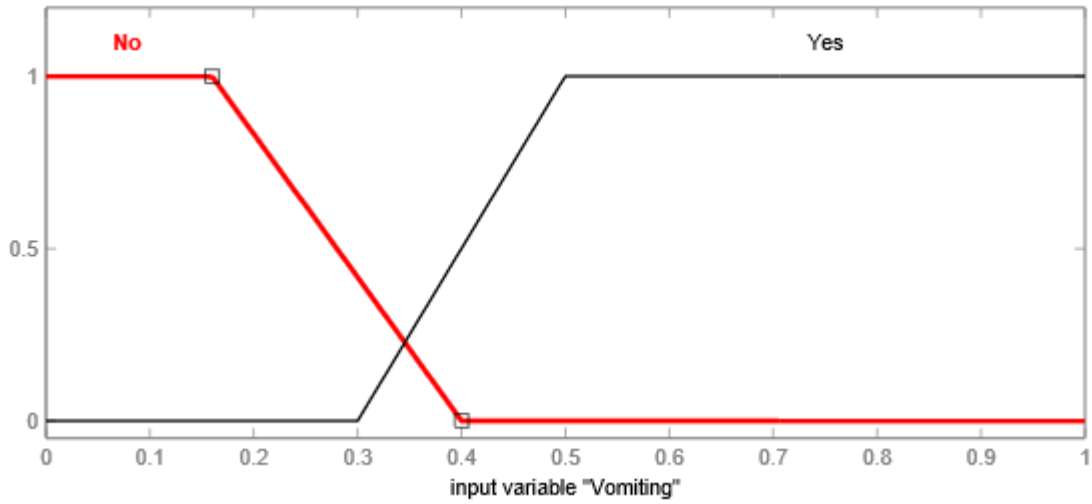


Figure 6: Input variable of layer 1, "Vomiting."

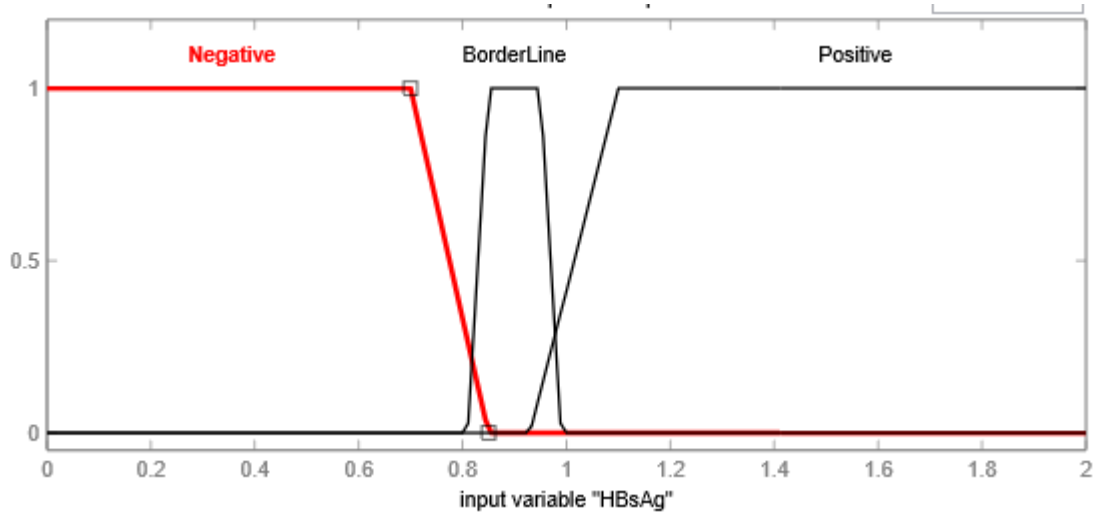


Figure 7: Input variable of Layer 2 "HBsAg."

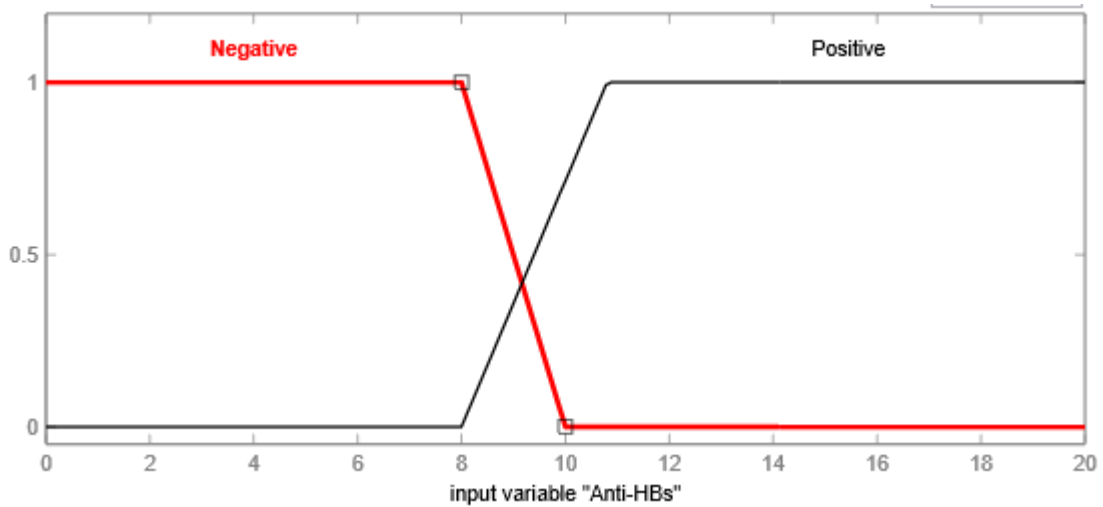


Figure 8: Input variable of Layer 2 "Anti-HBs."

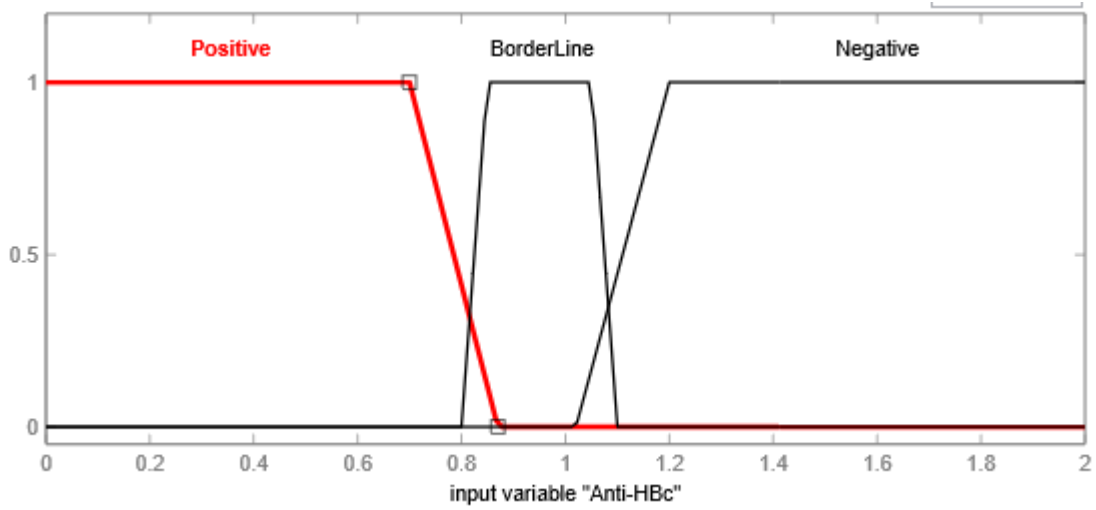


Figure 9: Input variable of Layer 2 "Anti-HBc."

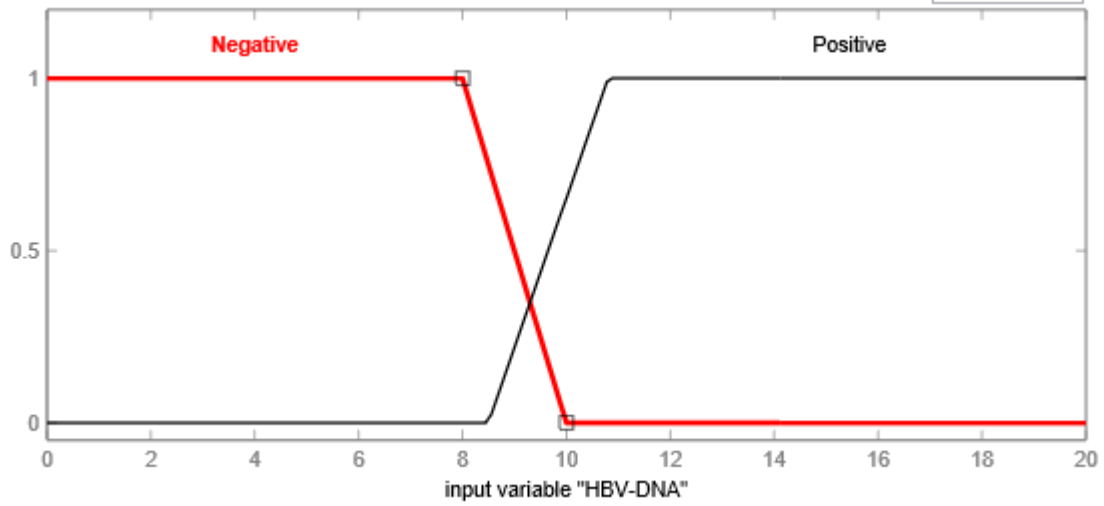


Figure 10: Input variable of Layer 2 "HBV DNA."

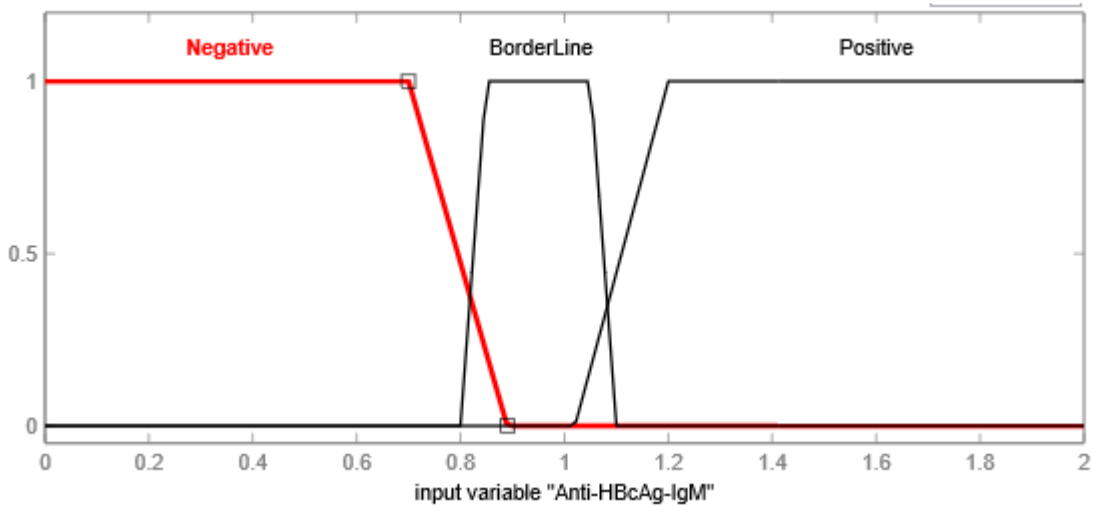


Figure 11: Input variable of Layer 2 "Anti-HBcAg-IgM."

b. Rules

The knowledge base of an expert system is used to store the rules. The information is gathered from the professionals or experts of the disease, and according to that information, the rules are generated to detect the disease. The framework of rules of layer 1 and layer 2 is represented in figure 12 and 13, respectively. The number of rules in layer 1 is 24, and likewise, the number of rules in layer 2 is 108.

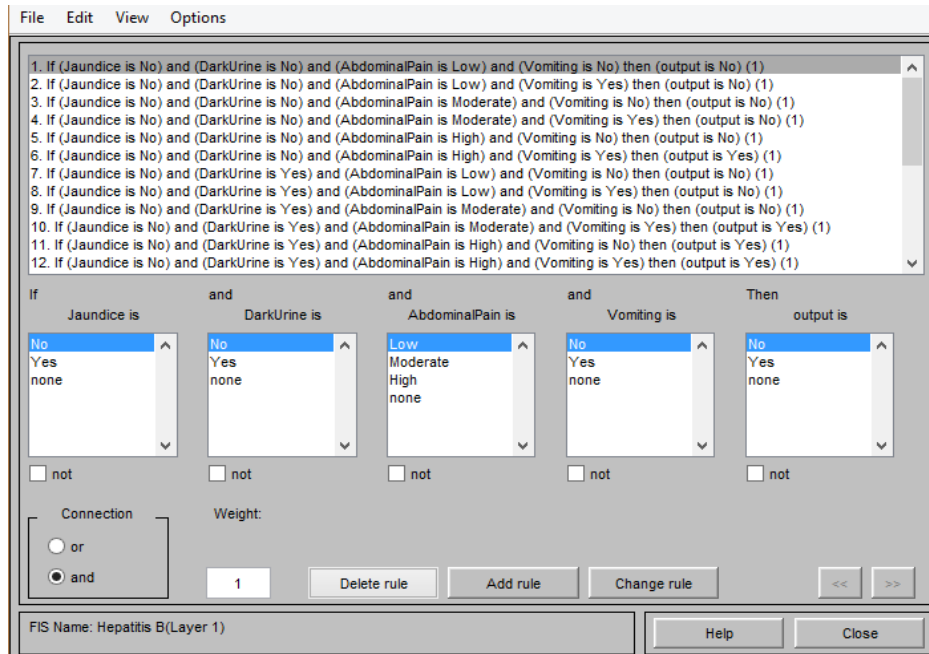


Figure 12: Framework of rules of layer 1

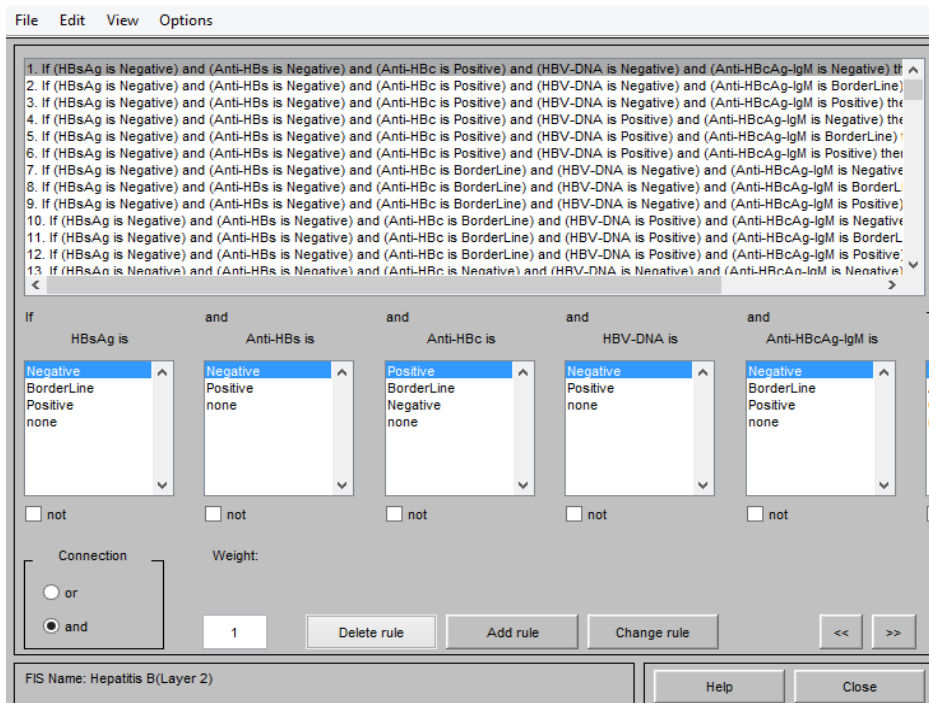


Figure 13: Framework of rules of layer 2

c. Output Variables

In the proposed medical diagnostic system, every layer has its individual output. Figure 14 and 15 shows the output variables of layer 1 as well as layer 2, respectively.

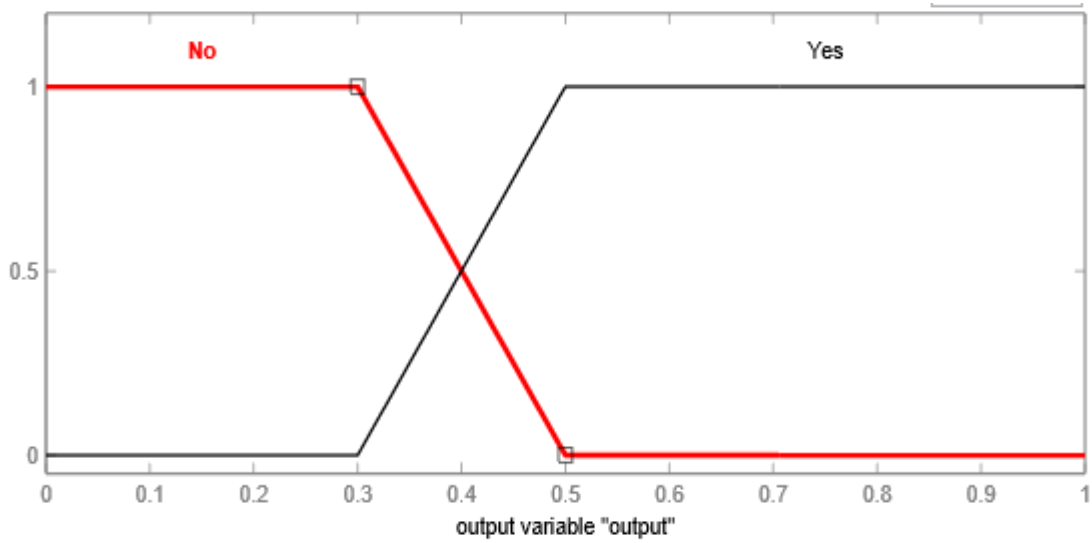


Figure 14: Output variables of layer 1

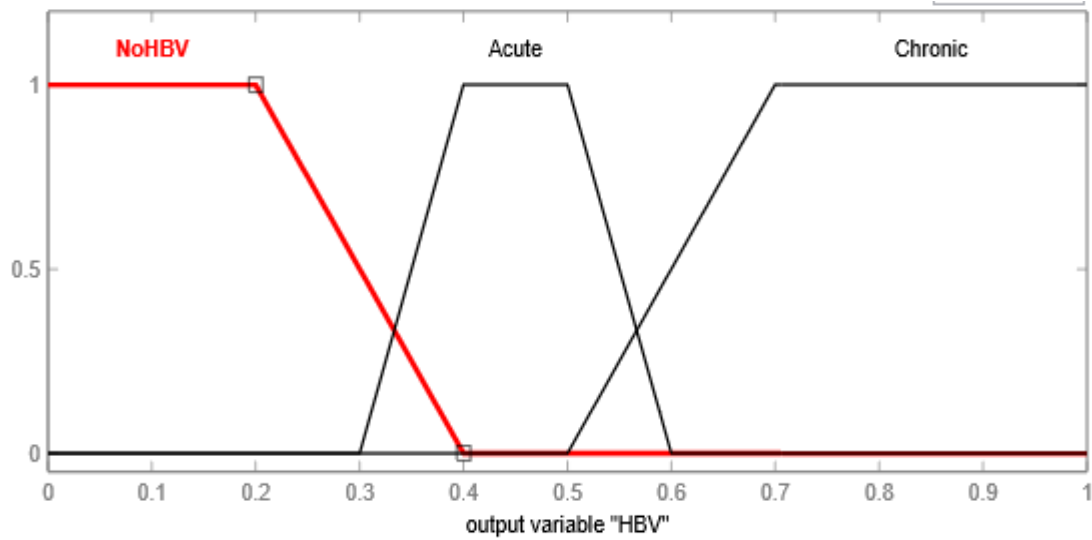


Figure 15: Output variables of layer 2

3. Result

Now, the performance of the proposed system is evaluated by comparing the outcome of the proposed system with the results given by the experts. If both results, i.e. from system and expert are same, then the system classifies the inputs correctly otherwise, not. Table 1 describes the percentage value of performance parameters of the proposed medical diagnostic system to diagnose the hepatitis B disease. Figure 16 represents the graphical form of performance parameters.

Table 1: Performace parameters

Sr. no.	Disease	Model	Classification Accuracy (%)	Specificity (%)	Sensitivity (%)	Precision (%)
1.	Hepatitis B	Multi-layered fuzzy logic	94	91.34	91.66	90.72

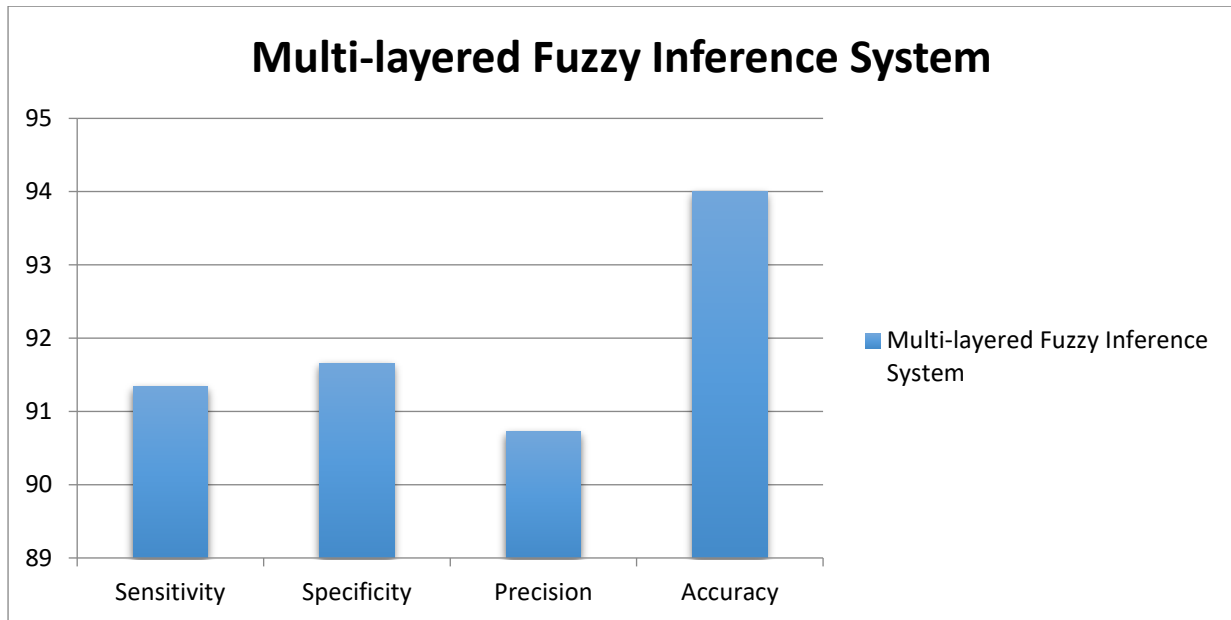


Figure 16: Graphical representation of performance parameters

4. Conclusion

The proposed multi-layered fuzzy inference system is a tool used to diagnose Hepatitis B disease. The system classifies the non-infected and infected patients into different classes. This system can be used by the fresher doctors as well as the experts. The classification accuracy of this developed system is 94%.

In future work, the input variables can be changed by researching the risk factor more accurately. The membership functions can also be replaced by other types of membership functions in order to increase the performance of the system.

5. References

- [1] C. Long, H. Qi, and W. Peng, "System Dynamics of Chronic Hepatitis B - Modeling the Virus and Immune System of Chronic Hepatitis B," *2010 2nd International Workshop on Intelligent Systems and Applications*, 2010.
- [2] Y.-F. Liaw and C.-M. Chu, "Hepatitis B virus infection," *The Lancet*, vol. 373, no. 9663, pp. 582–592, 2009.
- [3] L. S. Y. Tang, E. Covert, E. Wilson, and S. Kottlil, "Chronic Hepatitis B Infection," *Jama*, vol. 319, no. 17, p. 1802, 2018.
- [4] Y. Bai, X. Chen, C. Dong, Y. Liu, and Z. Zhang, "A Comparison of Multimodal Biomarkers for Chronic Hepatitis B Assessment Using Recursive Feature Elimination," *In 2016 38th Annual International Conference of the IEEE Engineering in Medicine and Biology Society (EMBC)* pp. 2448–2451, 2016.
- [5] C. Cheng *et al.*, "Discovering Clinical Biomarkers of Chronic Hepatitis B by Mining Mutation Hotspots," *2011 International Conference on Technologies and Applications of Artificial Intelligence*,

- Chung-Li, 2011, pp. 51-56, doi: 10.1109/TAAI.2011.17.
- [6] W. Shen, Z. Wei, Y. Li, H. Zhang and P. Liu, "Multiple Granular Analysis of TCM Data with Applications on Diagnosis of Hepatitis B," *2015 IEEE International Conference on Systems, Man, and Cybernetics, Kowloon*, 2015, pp. 2920-2925, doi: 10.1109/SMC.2015.508.
- [7] L. Du, D. Huang and Q. Xie, "A mathematical model for acute hepatitis B virus infection," *2010 3rd International Conference on Biomedical Engineering and Informatics, Yantai*, 2010, pp. 1109-1113.
- [8] S. U. Emon, "KStar and Naïve Bayes Classifier," *2019 10th International Conference on Computing, Communication and Networking Technologies (ICCCNT)*, pp. 1–7, 2019.
- [9] S. Liu, B. Zhou, J. D. Valdes, J. Sun, and H. Guo, "Serum Hepatitis B Virus RNA: A New Potential Biomarker for Chronic Hepatitis B Virus Infection," *Hepatology*, vol. 69, no. 4, pp. 1816–1827, 2019.
- [10] K. Leung et al., "Data Mining on DNA Sequences of Hepatitis B Virus," in *IEEE/ACM Transactions on Computational Biology and Bioinformatics*, vol. 8, no. 2, pp. 428-440, March-April 2011, doi: 10.1109/TCBB.2009.6.
- [11] H. Yasin, "Hepatitis-C Classification using Data Mining Techniques," *International Journal of Computer Applications*, vol. 24, no. 3, pp. 1–6, 2011.
- [12] L. Muflikhah, Widodo, W. F. Mahmudy and Solimun, "DNA Sequence of Hepatitis B Virus Clustering Using Hierarchical k-Means Algorithm," *2019 IEEE 6th International Conference on Engineering Technologies and Applied Sciences (ICETAS), Kuala Lumpur, Malaysia*, 2019, pp. 1-4.
- [13] A. Bustamam, H. Tasman, N. Yuniarti, and I. Mursidah, "Application of K-Means Clustering Algorithm in Grouping the DNA Sequences of Hepatitis B Virus (HBV)," In *AIP Conference Proceedings*, vol. 030134, 2017.
- [14] B. Liu, S. Feng, X. Guo and J. Zhang, "Bayesian analysis of complex mutations in HBV, HCV, and HIV studies," in *Big Data Mining and Analytics*, vol. 2, no. 3, pp. 145-158, September 2019, doi: 10.26599/BDMA.2019.9020005.
- [15] H. Wang and Y. Liu, "Random Forest and Bayesian Prediction for Hepatitis B Virus Reactivation," *2017 13th International Conference on Natural Computation, Fuzzy Systems and Knowledge Discovery (ICNC-FSKD)*, no. 81402538, pp. 2060–2064, 2017.
- [16] X. Chen, L. Ma, N. Chu and Y. Hu, "Diagnosis based on decision tree and discrimination analysis for chronic hepatitis b in TCM," *2011 IEEE International Conference on Bioinformatics and Biomedicine Workshops (BIBMW), Atlanta, GA*, 2011, pp. 817-822, doi: 10.1109/BIBMW.2011.6112478.
- [17] S. Uhm, D. Kim, S. W. Cho, J. Y. Cheong and J. Kim, "Chronic Hepatitis Classification Using SNP Data and Data Mining Techniques," *2007 Frontiers in the Convergence of Bioscience and Information Technologies, Jeju City*, 2007, pp. 81-86, doi: 10.1109/FBIT.2007.64.
- [18] C. Mahesh, K. Kiruthika and M. Dhilsathfathima, "Diagnosing hepatitis B using artificial neural network based expert system," *International Conference on Information Communication and Embedded Systems (ICICES2014), Chennai*, 2014, pp. 1-7, doi: 10.1109/ICICES.2014.7033938.
- [19] G. S. Uttreshwar and A. A. Ghatol, "Hepatitis B Diagnosis Using Logical Inference And Generalized Regression Neural Networks," *2009 IEEE International Advance Computing Conference, Patiala*, 2009, pp. 1587-1595, doi: 10.1109/IADCC.2009.4809255.
- [20] M. Rouhani and M. M. Haghighi, "The Diagnosis of Hepatitis Diseases by Support Vector Machines and Artificial Neural Networks," *2009 International Association of Computer Science and Information Technology - Spring Conference, Singapore*, 2009, pp. 456-458, doi: 10.1109/IACSIT-SC.2009.25.
- [21] H. Wang, Y. Liu and W. Huang, "The application of feature selection in Hepatitis B virus reactivation," *2017 IEEE 2nd International Conference on Big Data Analysis (ICBDA), Beijing*, 2017, pp. 893-896.
- [22] S. Shariati and M. M. Haghighi, "Comparison of anfis Neural Network with several other ANNs and Support Vector Machine for diagnosing hepatitis and thyroid diseases," *2010 International Conference on Computer Information Systems and Industrial Management Applications (CISIM), Krakow*, 2010, pp.

596-599, doi: 10.1109/CISIM.2010.5643520.

- [23] G. Ahmad, M. A. Khan, S. Abbas, A. Athar, B. S. Khan, and M. S. Aslam, "Automated Diagnosis of Hepatitis B Using Multilayer Mamdani Fuzzy Inference System," *Journal of healthcare engineering*, vol. 2019, no. i, 2019.
- [24] V. Bhandari, "Comparative Analysis of Fuzzy Expert Systems for Diabetic Diagnosis," *International Journal of Computer Applications*, vol. 132, no. 6, pp. 8–14.
- [25] D. Saikia and J. C. Dutta, "Early diagnosis of dengue disease using fuzzy inference system," *2016 International Conference on Microelectronics, Computing and Communications (MicroCom), Durgapur*, 2016, pp. 1-6, doi: 10.1109/MicroCom.2016.7522513.
- [26] R. Meza-Palacios, A. A. Aguilar-Lasserre, E. L. Ureña-Bogarín, C. F. Vázquez-Rodríguez, R. Posada-Gómez, and A. Trujillo-Mata, "Development of a fuzzy expert system for the nephropathy control assessment in patients with type 2 diabetes mellitus," *Expert Systems with Applications*, vol. 72, no. 1, pp. 335–343, 2017.
- [27] V. Novák, "Which logic is the real fuzzy logic?," *Fuzzy Sets and Systems*, vol. 157, pp. 635–641, 2006.
- [28] M. Jampour, M. Jampour, M. Ashourzadeh, and M. Yaghoobi, "A fuzzy expert system to diagnose diseases with neurological signs in domestic animal," *Proceedings - 2011 8th International Conference on Information Technology: New Generations, ITNG 2011*, pp. 1021–1024, 2010.
- [29] S. Ananthi and V. Bhuvaneshwari, "Prediction of heart and kidney risks in diabetic prone population using fuzzy classification," *2017 International Conference on Computer Communication and Informatics, ICCCI 2017*, vol. 48, 2017.
- [30] S. Ahmed, T. Kabir, N. T. Mahmood, and R. M. Rahman, "Diagnosis of Kidney Disease Using Fuzzy Expert System," *In The 8th International Conference on Software, Knowledge, Information Management and Applications (SKIMA 2014)*, pp.1-8, 2014.