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DESIGN OF AN INTELLIGENT FUZZY LOGIC PREDICTIVE SYSTEM FOR CELIAC DISEASE ASSESSMENT

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Abstract: Disease prediction can be attainable through fuzzy logic using relevant member functions with Mamdani model. Fuzzy logic has prophesied several diseases based on the symptoms in the form of existing predictions systems in almost every sphere of medicine. Celiac disease is a sort of auto-immune dysfunction which attacks small intestine after any celiac patient devours gluten in the nutrition. The disease can be diagnosed simply with clinical examinations like tTG-IgA, Biopsy, Genetic Testing etc. To conquer the sensitive process for the evidence of disease, the fuzzy logic celiac system has been proposed based on the symptoms. The proposed system implemented in PyCharm software accompanying with SPSS tool for the interpretation of the data. The system comprised of all the common symptoms transpired in celiac patients by using factor analysis procedure in SPSS. The most obvious symptoms grasped to be fuzzy inputs supplied to the system and offer de-fuzzification singleton value as celiac disease prognostication. The proposed system will be profitable for the surgeons to catch the celiac disease in a more reliable way outwardly any clinical testing strategy, which delivers cost and significant life.
Keywords: Body Mass Index, Celiac Disease, Fuzzy Logic, PyCharm

INTRODUCTION

The conception of fuzzy logic was coined by Lotfi Zadeh [1] in 1965, to tackle the problem of inconsistency. Through fuzzy logic, varying types of models can be adapted to deal with linear and non-linear real-life scenarios. Mamdani and Sugeno patterns respond according to the desired outcome of the system with footing on the specification of the problem [2-3]. Fuzzy logic has been utilised in the context of medicine to discover numerous diseases by formulating fuzzy rules applying member functions. So, Celiac disease fuzzy system can be thoughtful using fuzzy logic Mamdani method [4-5]. Celiac is a variety of chronic disease which afflicts intestine following the consumption of wheat by any celiac patient [6]. The genetic factor also worked a significant role because of halotype instant in celiac patients [7]. These halotypes when associating with gluten drives to various symptoms like vomiting, diarrhea, weight loss, skin rashes, dental problems, a stomach infection, abdominal pain etc. The symptoms varied with different patients with their intensity depend upon the gluten ppm taken by the celiac patient. The distinct diagnosis methods are possible to detect celiac disease in the frame of tTG-IgA, Biopsy or genetic procedure [8]. These clinical aspects require high cost and painful format for any celiac patient for its appropriate detection. So, it leads to thinking about celiac disease prediction with the fuzzy logic strategy by a useful combination of symptoms as similar retrieved from celiac patients. The essential benefit of this system will be for any physician to foretell celiac disease based on the symptoms with no need for any type of clinical testing for the analysis [4-5].

Section II of the paper designs the literature study based on diverse studies on multiple diseases using fuzzy logic methodology without any type of clinical tests. Section III illustrates the design model of fuzzy logic to predict celiac disease. Section IV concentrates on the implementation in Python using fuzzy input-output parameters with membership functions. Section V outlines on results achieved with a fuzzy logic system with appropriate discussions. Additionally, the conclusion of the fuzzy system related with all the benefits of the fuzzy system along with future paradigm.

LITERATURE REVIEW

Literature clarified that celiac disease diagnosis with computer terminologies is not up to the mark. But on the other aspect, fuzzy logic is consistently propagating helpful outcomes in the field of medicine as described in Table 1. In 2018, Heart disease diagnosis was achieved using fuzzy logic by Iancu [9] with just accomplished 44 distinct rules to develop software which showed much better results for heart disease prediction. Manikandan et al. [10] in 2017, focused on Lung diseases using the fuzzy logic scheme. The system was analyzed on 271 persons, clarified 95% accuracy of the fuzzy system by capturing data in the form of a questionnaire using SPSS software. Parwe [11] in 2016, worked on Dental disease using fuzzy logic in Indonesia with sparse common dental parameters. The system was validated using 100 dental patients with an outcome of 82% accuracy of the fuzzy system. Hashmi [12] in 2015 implemented liver disease with fuzzy logic with diagnosis procedure reciprocates with CBC tests and fuzzy inputs with similar input-output parameters. The sensitivity and specificity of the proposed system were essential to implement the fuzzy system in realtime diagnosis. In 2014, Rana [13] developed a combination of an intelligent fuzzy system which deals with Cardiac, Brain Tumor and Thyroid with fuzzy logic using the Mamdani model. The predication of the proposed system was exclusively based on symptoms supplied by personalities while getting disease data.

Table1: Literature Review on Diseases

Diseases/ Author	Methodology	Outcome
Heart Disease by Iancu (2018) [9]	Fuzzy Logic	Heart disease prediction system with minimal rules using the Mamdani model
Lung Diseases by Manikandan et al. (2017) [10]	Fuzzy Logic	Implemented on 271 patients, Accuracy achieved 95%
Dental Disease by Parwe (2016) [11]	Fuzzy Logic	Applied in Indonesia with 82% accuracy on 100 dental patients
Liver Disease by Hashmi (2015) [12]	Fuzzy Logic	Differentiates with the clinical testing approach and implemented with similar input-output parameters
Brain tumor, Cardiac and Thyroid disease by Rana (2014) [13]	Fuzzy Logic	Embedded fuzzy system diagnosis based on symptoms given by individuals
Cholera Disease by Uduak (2013) [14]	Fuzzy Logic	Accuracy up to the mark with an error rate of 0.15 using Mamdani Fuzzy Model
Asthma Disease by Zarandi (2010) [15]	Fuzzy Logic	Implemented with fuzzy rule-based approach concludes with the asthmatic and non-asthmatic outcome
Breast Cancer by Kovalerchuk et al. (1997) [16]	Fuzzy Logic	Achieved robustness outcome to detect breast cancer using image processing with fuzzy logic

Uduak [14] in 2013 proclaimed cholera fuzzy logic system for disease judgment. The accuracy of the system is preferred with an insignificant error rate. The Mamdani model was implemented using a fuzzy if-then rule-based structure with the centre of gravity as de-fuzzification technique. In 2010, Zarandi [15] accomplished the fuzzy system on Asthmatic disease by distinguishing with non-asthma patients. The inputs for the fuzzy rules were obtained through historical information from the patients, and clinical aspects are taken from the diagnosis test reports of asthmatic patients. Kovalerchuk et al. [16] in 1997 formulated breast cancer detection fuzzy system by using the image processing technique. The extraction of cancer was analyzed by using lobulated mass images taken from breast cancer patients. The system produced accuracy with minimum error rate for disease diagnosis.

So, these are the valuable contributions furnished by numerous researchers to deal with the prediction of diseases using fuzzy logic as given in Table 1. In a similar manner, it conveys an intention to predict celiac disease applying fuzzy logic with the proposed system.

DESIGN OF FUZZY LOGIC SYSTEM

The design of a fuzzy logic system to predict celiac disease necessitates appropriate member functions for the fuzzy values [17-19]. For hiring any membership function demands fuzzy inputs which should be as related to the celiac disease symptoms. The common symptoms gathered from the questionnaire manner among infrequent individuals to carry out the most common symptoms among all utilising SPSS software. To do this, 6 most common symptoms fitted to the fuzzy system to get the probabilistic value which acts as consequent of celiac disease. Triangular membership function was practised to formulate fuzzy inference system as in Figure 1. Every fuzzy value prevails in between 0 to 1 which expresses the maximum values of the fuzzy variable. The values and range of every symptom transformed into fuzzification procedure using multiple fuzzy inputs.

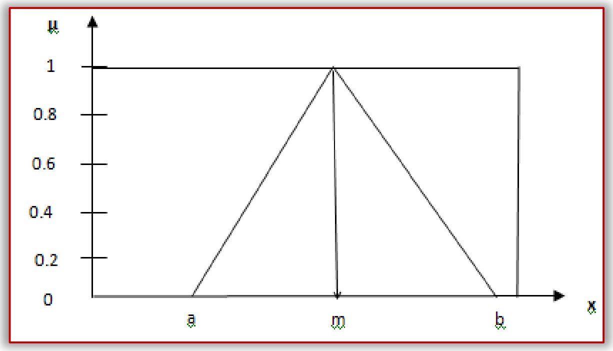

Figure 1: Triangular Fuzzification Structure

$$\mu_{mild}(x) = \begin{cases} 0 & x<0,\ x>4 \\ (4-x)/4 & 0 \le x \le 4 \end{cases} \quad \text{where } a=0,\ b=4 \text{ and } m=0$$

$$\mu_{mod}(x) = \begin{cases} 0 & x<1,\ x>9 \\ (x-1)/4 & 1 \le x \le 5 \\ (9-x)/4 & 5 \le x \le 9 \end{cases} \quad \text{where } a=1,\ b=9 \text{ and } m=5$$

$$\mu_{sev}(x) = \begin{cases} 0 & x<6,\ x>10 \\ (x-6)/4 & 6 \le x \le 10 \end{cases} \quad \text{where } a=6,\ b=10 \text{ and } m=10$$

Figure 2: Triangular Fuzzification Values of Symptom

There are some other membership functions available to design the fuzzy logic but triangular function comprised of three possible values with two ends of extreme nature. Below is the given form of triangular membership function with abdominal pain as input parameter having fuzzy values as Mild, Moderate and Severe in Figure 2. The stipulation of fuzzy values lies with a range as 0-10 with the mild range as 0-4, Moderate range as 1-9 and severe range as 6-10 depicted in the figure. There is an opportunity of intersection points develop because of ambiguous range values due to transition.

The fuzzy graph of abdominal pain is represented in figure 3 with all attainable outcomes as mild, moderate and severe [20-21]. The similar type of inputs in the form of symptoms with fuzzification can be accomplished similarly with similar membership function but different fuzzy values for each symptom according to its range.

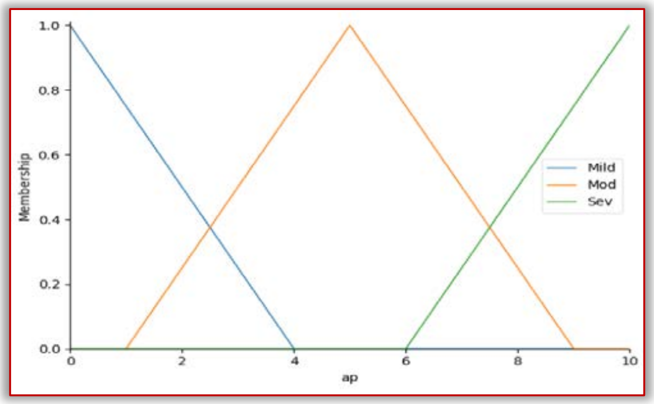

Figure 3: Abdominal Fuzzy Graph

The output membership function also executed using triangular membership values but further composed of 11 sub fuzzy values due to achieve optimum accuracy. The values varied according to its range with sub-division of its range that lies from 0-100 for disease prediction as manifested in figure 4.

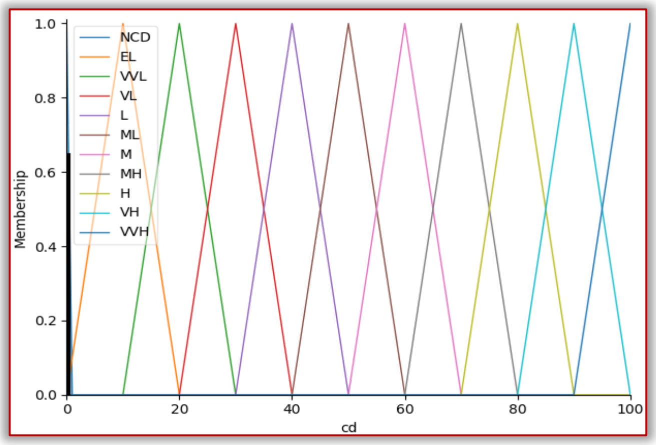

Figure 4: Celiac Fuzzy Outcome Graph

After receiving the input and output membership function, there is a requirement to develop fuzzy rules using if-then values. Fuzzy rules consist of multiple fuzzy operators to be required for the final formation of the fuzzy database. The purpose of the inference engine is to compare each and every symptom value to the fuzzy probabilistic system to get the de-fuzzification value [22-25].

IMPLEMENTATION OF FUZZY LOGIC SYSTEM

The proposed system completed in Python using sub-software as PyCharm for its evaluation. The system needs several sub-modules as matplotlib for fuzzy graph, numpy for fuzzy variables declaration and skfuzzy for the computation in the form of fuzzification and de-fuzzification. The values of fuzzy variables inputted in the form of numerical to concise the fuzzification using numpy variables. The figure 5 quoted here to implement one of the scenarios in which individual input the values of various symptoms as abdominal pain with 9.0, anemia factor with 8.0, diarrhea value with 10.0, vomiting input as 9.0, critical parameter weight loss as 10.0 and Body mass index as 22.143. All these inputs when tendered to a fuzzy system deliver a consequence in the form of de-fuzzification value as celiac disease prediction output.

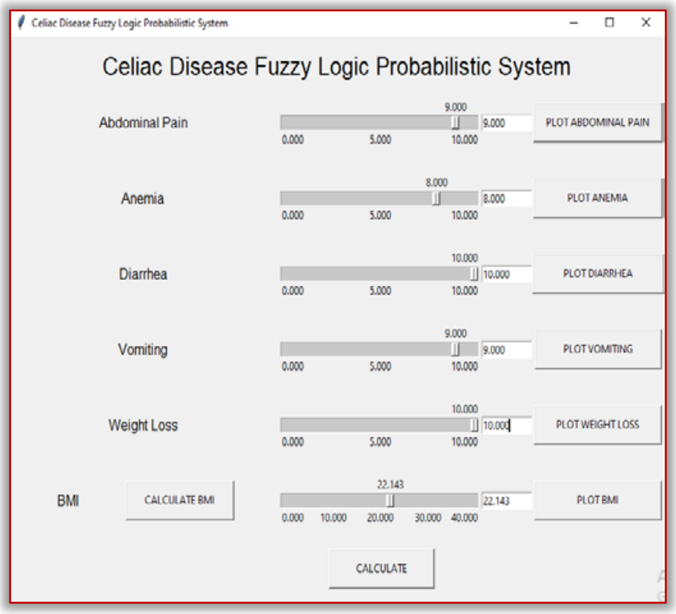

Figure 5: Scenario of a Fuzzy System

The sub-module of evaluating BMI is also determined independently using the height and weight of an individual. On the basis of supposed input, the fuzzy system will take evaluation time to compare every single input with all rules wrapped in the form of a fuzzy database. The process of de-fuzzification renders the outcome by evaluation using the centre of gravity or area of the maximum technique [26-28].

RESULTS

The system generated an output of 96.11%, which dispenses a strong chance of celiac disease with respect to a given input in the inputted scenario in figure 6. The system also blueprints recommendation should be taken to the assigned individual to perform tTG testing for the final confirmation of the disease. If the value appears out to be less than 40% then there will be no requirement to conduct any type of clinical testing.

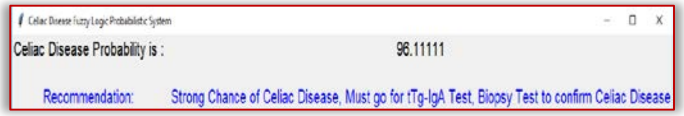

Figure 6: Outcome of Fuzzy Input Scenario

The graphical layout exposed in Figure 7 from the matplotlib indicates all rules matched from the de-fuzzification lies in between 90-100, which is an alarming situation for the submitted individual value. The evaluation method of de-fuzzification is based on the fuzzy inputs in comparison with fuzzy rules in the database [29-30]. Different operators like 'AND' and 'OR' for the conjunction of several consecutive inputs

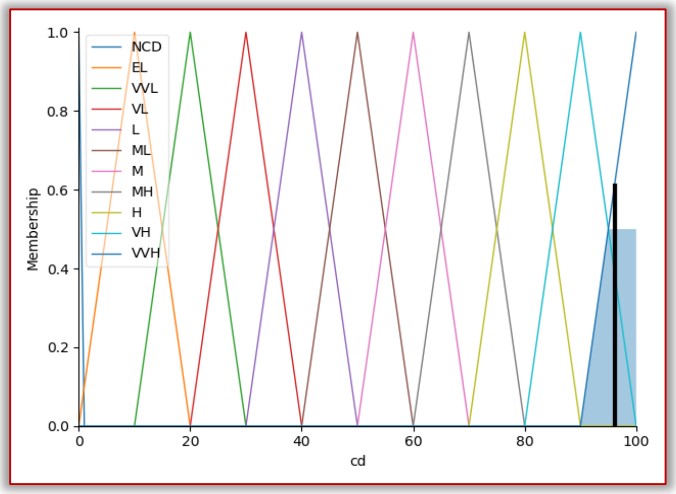

Figure: Fuzzy Outcome Graph

So, the proposed system is advantageous for evaluating celiac disease prediction outcome with certain inputs given by any individual. The time taken by the system is trivial in comparison with clinical testing time which resolves painful testing procedure.

CONCLUSION AND FUTURE SCOPE

The fuzzy system offers results with optimal accuracy and insignificant error rate. The implementation of the proposed system is as related to the given guidelines of ESPHAGN. The system delivers an output in the form of celiac disease foresight based on the symptoms. The system will be propitious for experts to foretell celiac disease and take urgent decision to tackle the disease by recommendation in the form of a gluten-free diet to save small intestine. With the aid of a fuzzy system, any person does not require a clinical test in the first endeavour which conserves painful procedure for the recognition of the disease. For the future perspective, a related type of systems can be formulated to divine unknown diseases with the cooperation of symptomatic study and presents recommendations to tackle diseases in a better way.

References

[1] Zadeh, L.A. (1965). Fuzzy Sets. Elsevier, Information and Control 1965, 8(3), 338-353

[2] Sadegh-Zadeh, K. (2000). Fuzzy Health, Illness, and Disease. Journal of Medicine and Philosophy, 25, 605–638.

[3] Mamdani, E.H., Assilian, S. (1975). An experiment in linguistic synthesis with a fuzzy logic controller. International Journal of Man-Machine Studies, 7(1), 1-13.

[4] Thukral, S., Rana, V. (2019). Versatility of Fuzzy Logic in chronic diseases: A review. Medical Hypotheses, Elsevier, 122, 150-156

[5] Thukral, S., Bal, J.S. (2019). Medical Applications on Fuzzy Logic Inference System: A review. Int J. Advanced Networking and Applications, 10(4), 3944-3950

[6] Gee, S.J. (1888). On the coeliac affection. St. Bartholomew's Hosp Rep., 24, 17-20.

[7] Dowd, B., Walker-Smith, J. (1974). Samuel Gee, Aretaeus, and the coeliac affection.Br Med J, 2(5909), 45-47.

[8] Husby, S., Koletzko, S., Korponay-Szabo, I. R., Mearin, M. L., Phillips, A., Shamir, R., Nutrition. (2012). European Society for Pediatric Gastroenterology, Hepatology, and Nutrition guidelines for the diagnosis of coeliac disease. J Pediatr Gastroenterol Nutr, 54(1), 136-160

[9] Iancu, I. (2018). Heart disease diagnosis based on mediative fuzzy logic. Artificial Intelligence in Medicine, 89, 51–60

[10] Manikandan, T., Bharathi, N., Satish, M., &Asokan, V. (2017). Hybrid neuro fuzzy system for prediction of lung diseases based on the observed symptom values. Journal of Chemical and Pharmaceutical Sciences, 28(2):69-76.

[11] Parewe, A.M., Mahmudy, W.F., Ramdhani, F., Anggodo, Y. (2016). Dental disease detection using hybrid fuzzy logic and evolution strategies.Journal of Telecommunications, Electronic and Computer Engineering 2016, 10(10

[12] Hashmi, A., Khan, M.S. (2015). Diagnosis blood test for liver disease using fuzzy logic. International Journal of Sciences: Basic and Applied Research, 20(1), 151-183.

[13] Rana, M., Sedamkar, R.R. (2013). Design of expert system for medical diagnosis using fuzzy logic. International Journal of Scientific and Engineering Research, 4(6):2914-2921.

[14] Uduak, A., Mfon, M. (2013). Proposed fuzzy framework for cholera diagnosis and monitoring. International Journal of Computer Applications, 82(17), 1-10

[15] Zarandi, M.H., Zolnoori, M., Moin, M., Heidarnejad H. (2010). A fuzzy rule based expert system for diagnosing asthma. Trans-action E: Industrial Engineering, 17(2), 129-142

[16] Kovalerchuk, B., Triantaphyllou, E., Ruiz, J. F., Clayton, J. (1997). Fuzzy logic in computer-aided breast cancer diagnosis: Analysis of lobulation. Artificial Intelligence in Medicine, 11(1), 75–85

[17] Marsh, M. N. (1992). Gluten, major histocompatibility complex, and the small intestine. A molecular and immunobiologic approach to the spectrum of gluten sensitivity ('celiac sprue').Gastroenterology, 102(1), 330-354.

[18] Bascunan, K. A., Vespa, M. C., Araya, M. (2017). Celiac disease: understanding the gluten-free diet. Eur J Nutr, 56(2), 449-459
[19] Murry, J.A., Watson, T., Clearnnan, B., Mitros, F. (2004). Effect of a gluten-free diet on gastrointestinal symptoms in celiac disease. Am J ClinNutr., 79(4), 669-673
[20] *** Revised criteria for diagnosis of coeliac disease. Report of Working Group of European Society of Paediatric Gastroenterology and Nutrition. (1990). Arch Dis Child, 65(8), 909-911.
[21] Falodia, S., Vyas, A., Joshi, A. (2019). Oral Manifestations of celiac disease in north western part of India: A case-control study. *International Journal of Scientific Research, 8*(4), 54-56.
[22] Gulseren, Y.D., Adiloglu, A.K., Yucel, M., Dag, Z., Caydere, M. (2019). Comparison of non-invasive tests with invasive tests in the diagnosis of celiac disease.J Clin Lab Anal. 2019; 33:e22722
[23] Senapati, S., Sood, A., Midha, V., Sood, N., Sharma, S., Kumar, L., Thelma, B. K. (2016). Shared and unique common genetic determinants between pediatric and adult celiac disease. BMC Medical Genomics, 9(1),44
[24] Koh, J. E. W., Hagiwara, Y., Oh, S. L., Tan, J. H., Ciaccio, E. J., Green, P. H., Rajendra Acharya, U. (2019). Automated diagnosis of celiac disease using DWT and nonlinear features with video capsule endoscopy images. Future Generation Computer Systems, 90, 86–93
[25] Kayali, I. (2018). Expert system for diagnosis of chest diseases using neural networks. Artificial Intelligence, arXiv:1802.06866v1
[26] Jesus, M.H., Manuel, Z.R., Faiyaz, D., Rosario, B.F., Carlos, L.R., Alfonso, R.D. (2018). Modeling independence and security in Alzheimer's patients using fuzzy logic. Intelligent Data Sensing and Processing for Health and Well-being Applications
[27] Satarkar, S.L., Ali, M.S. (2017). Fuzzy expert system for the diagnosis of common liver disease. International Engineering Journal for Research and Development, 1(1)
[28] Manikandan, T., Bharathi, N., Satish, M., Asokan, V. (2017). Hybrid neuro fuzzy system for prediction of lung diseases based on the observed symptom values. Journal of Chemical and Pharmaceutical Sciences, 28(2):69-76.
[29] Makharia, G. K., Verma, A. K., Amarchand, R., Bhatnagar, S., Das, P., Goswami, A., Anand, K. (2011). Prevalence of celiac disease in the northern part of India: a community based study. J Gastroenterol Hepatol, 26(5), 894-900
[30] Aronsson, C. A., Lee, H. S., Liu, E., Uusitalo, U., Hummel, S., Yang, J., Teddy Study, G. (2015). Age at gluten introduction and risk of celiac disease. Pediatrics, 135(2), 239-245
[31] Phuong, N. H., Kreinovich, V. (2001). Fuzzy logic and its applications in medicine.Int J Med Inform, 62(2-3), 165-173.

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