Science and Technology Journal Vol. 7 Issue: 2 July 2019 ISSN: 2321-3388

Fuzzy Logic: An Easiest Technique to Predict Celiac Disease

Sunny Thukral[1]* and Jatinder Singh Bal[2]
[1,2]Sant Baba Bhag Singh University, Jalandhar–144030, India
E-mail *sunnythukral@davcollegeasr.org

Abstract—The need for the proposed system mounts due to expensive clinical cost, the prolonged period of Genetic testing and especially painful for an individual to perform all certain clinical tests to diagnose celiac disease. With this proposed method, an individual can foretell celiac disease by just input crisp values of varied symptoms using fuzzy logic. A case study was conducted using a questionnaire procedure to obtain out the requisite symptoms in Amritsar, Punjab on 700 individuals; having 303 females and 393 males. So, the proposed system will be implemented using Mamdani Model and forms the prediction output practicing de-fuzzification when correlated with computed values produced optimum correctness. The proposed system will have a disease prediction of 96.11% accuracy according to the input values given by an individual to authenticate the celiac disease. The proposed system will provide a fruitful outcome for individuals and physicians for celiac disease disclosure in few seconds without any painful testing strategy.

Keywords: *Abdominal Pain, Anemia, Celiac Disease, Fuzzy Logic, PyCharm*

INTRODUCTION

Several diseases have already been foretold with the fuzzy approach. Fuzzy logic deals with the multi-value approach which consists of complex crisp values according to input and output parameters. With the aid of a fuzzy inference system, the intact database that is in the form of fuzzy rules can be solidified by using Mamdani or Sugeno model depends upon the kind of application.

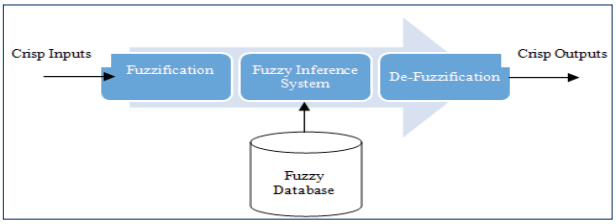

Fig. 1: Fuzzy System Architecture

Fuzzy logic is a type of technique to tackle the problem of uncertainty and ambiguity of the data. The input given to the system is based on the crisp values which should be formulated to fuzzy values depends upon the membership function i.e. fuzzification depicted in figure 1. The process of fuzzy values to convert them into fuzzy if-then rules using fuzzy database refers to fuzzy inference system. The evaluation process needs to de-fuzzify, fuzzy values to crisp outputs to generate single output value for the system. Celiac disease can be prophesied using fuzzy rules that should be accessible for individuals and physicians for recognizing the disease. Celiac disease is a class of chronic disease that vitiates the small intestine when the celiac patient engrosses gluten in the body. Gluten stays in wheat, barley, rye, etc. From the viewpoint of (Bascunun 2017), (Gee 1888) a few mm of gluten can be taken but more than that will harm small intestine ending in gut damage. (Dowd 1974) stated that the celiac disease can transpire at any age i.e. to a newborn baby or an old person. Marsh (1992) stated that the celiac disease is identified via tTG-IgA, Biopsy, Genetic testing, Gliadin clinical tests, etc. There are very rare peoples who aware of celiac disease due to similar symptoms with other diseases given by (Murry 2004). In additional words, the prescription of celiac disease does not come straight-forward because diarrhea, vomiting and stomach pain is very normal in other regular chronic diseases as these three are the basic symptoms of celiac disease as recommended by (Husby 2012) based on ESPGHAN guidelines. So, celiac patients require gluten-free nutrition to handle any type of intestine predicament from the disease. The role of the primary consumption of gluten and breast-feeding is significant; as this disease having 5% of genetic disease that comes from the parental background.

https://doi.org/10.22232/stj.2019.07.02.11

LITERATURE REVIEW ON FUZZY LOGIC AND CELIAC DISEASE

Fuzzy logic is consistently used in recognizing chronic diseases effectively and accurately. In 2009, Iris classification has been accomplished with different fuzzy parameters using the Mamdani model by (Moein 2009) and team members using the Netbox toolbox with 100% accuracy of the system. Chronic diseases having a genetic approach have been detected using the pattern recognition routine with fuzzy logic and neural network in 2011 by (Adeli 2011) with fetched samples from the UCI repository. The role of hybrid fuzzy logic originates with dental disease detection applying all major parameters of dental disease by (Parewe 2016) with accuracy achieved 82% . Cholera diagnosis using fuzzy logic has been offered by Uduak and Mfon (2013) with MATLAB tool to prophesy the disease.Liver diagnosis has been reported using fuzzy by Hashmi and Khan (2015) with three diverse types of liver diseases been realized by the fuzzy system. (Kaur 2016) proposed viral infection recognition using fuzzy logic with six different parameters to automate the system. The symptomatic study has been characterized by (Manikandan 2017) with the prediction of lung diseases using neural network and fuzzy logic with 95% accuracy of the fuzzy system. Recently (Zarandi 2018) aimed a fuzzy expert system for diagnosing kidney disease. The study was conveyed in Iran on 400 specimens to diagnose chronic kidney or non-chronic disease patients having 80% accuracy. Colorectal cancer detection was presented by (Chowdhury 2018) using a fuzzy logic approach. The implementation has been executed on Matlab with three input parameters to detect bowel cancer. On the additional side, Celiac disease has been wholly addressed by (Sood 2006) to unearth out the prevalence ratio of celiac disease on school children in Punjab. 1:310 prevalence consequences were proclaimed with an entirety conducted case study on 4347 children. Another related authenticity was proffered by (Makharia 2011) to commemorate the prevalence value in the northern region of India. More than 10,000 individuals were randomly selected for the diagnosis process of celiac disease. 1:96 prevalence outcomes were produced with 31 celiac patients.

STUDY CONDUCTED IN PUNJAB

The erudition of celiac or non-celiac selves has been assembled via Celiac Disease Awareness Camp organized in Amritsar, Punjab where 700 persons involved in the given camp. The data was collected through questionnaire technique with all possible symptoms. Persons that visited in the camp came from diverse sectors of Punjab including Ajnala, Amritsar, Baba-Bakala, Beas, Gurdaspur, Taran-Taran and their surroundings with distinct ages. The graphical depiction was executed in SPSS software for presenting frequency distribution with age-group as shown in Figure 2. The survey consists of data set with every gastro-intestinal symptom present in almost all celiac patients. The questionnaire also consists of height, weight, age, gender, Body Mass Index (BMI) with necessary family background history. It also defines first order and second-degree relative celiac patients if known which will be beneficial to collect necessary symptoms for the proposed system.

Age-Group	Frequency	Percent	Cumulative Percent
0-18	276	39.4	39.4
18-35	336	48.0	87.4
35-60	79	11.3	98.7
60-100	9	1.3	100.0
Total	700	100.0	

Fig. 2: Age-Group Description

Out of 700 persons, 303 and 393 persons proclaimed Females and Males respectively. Most of the individuals in Punjab are still unaware of Celiac disease because of the association of symptoms among other well-known diseases. The consequence of the camp was 134 celiac patients out of which 75 Females and 59 Males were chronicled and the recommendation was not to use any gluten products in the diet shown in the given Figure 3. The outcome from the study conducted in Punjab, indicates that the female celiac ratio is too much in comparison with male correspondents. The symptoms found in almost all celiac patients matched with equivocal symptoms with every celiac patient. Due to this common behavior, it is easy to think about to develop fuzzy system which can predict the fuzzy system based on similar symptoms among them.

		AGE_GROUP				
		0-18	18-35	35-60	60-100	Total
Gender Male	Count	163	210	16	4	393
	% within Gender	41.5%	53.4%	4.1%	1.0%	100.0%
	% within AGE_GROUP	59.1%	62.5%	20.3%	44.4%	56.1%
	% of Total	23.3%	30.0%	2.3%	.6%	56.1%
Female	Count	113	126	63	5	307
	% within Gender	36.8%	41.0%	20.5%	1.6%	100.0%
	% within AGE_GROUP	40.9%	37.5%	79.7%	55.6%	43.9%
	% of Total	16.1%	18.0%	9.0%	.7%	43.9%
Total	Count	276	336	79	9	700
	% within Gender	39.4%	48.0%	11.3%	1.3%	100.0%
	% within AGE_GROUP	100.0%	100.0%	100.0%	100.0%	100.0%
	% of Total	39.4%	48.0%	11.3%	1.3%	100.0%

Fig. 3: Gender Wise Report

So, in other words, 56% of female representation appears real while screening celiac records. The overall evaluation

concerning celiac disease principally comes to females through the world endures truly from the survey. It is manifest from the results that the replies of female participants (75) carrying celiac disease outnumbered male respondents (59).

PROPOSED SYSTEM IMPLEMENTATION

The proposed system implemented with numerous parameters among them Body Mass Index (BMI) considered to be an essential parameter with abdominal pain in Python. Mostly strengthened celiac patients have Body Mass Index (BMI) either Underweight or Overweight as contrasted to healthy individuals. Figure 4 represents all the basic six input parametrs given to the proposed fuzzy system with appropriate range of symptoms retrieved form the survey. The selection of symptoms for the fuzzy sytem needs principal component analysis for the final selective parameters. Every antecedent refers to fuzzy-if response with numpy variable applied in Python given in figure 4.

```
ap=ctrl.Antecedent(np.arange(0,11,1),'ap')
an=ctrl.Antecedent(np.arange(0,11,1),'an')
da=ctrl.Antecedent(np.arange(0,11,1),'da')
vom=ctrl.Antecedent(np.arange(0,11,1),'vom')
wl=ctrl.Antecedent(np.arange(0,11,1),'wl')
bmi = ctrl.Antecedent(np.arange(0, 41, 1), 'bmi')
```

Fig. 4: Celiac Input Parameters

The representation in fuzzy graph with one of the fuzzy parameter as vomiting is defined using triangular membership function with range according to weekly data given in figure 5. The upper value of y indicates the memebership value of the variable as fuzzy input.

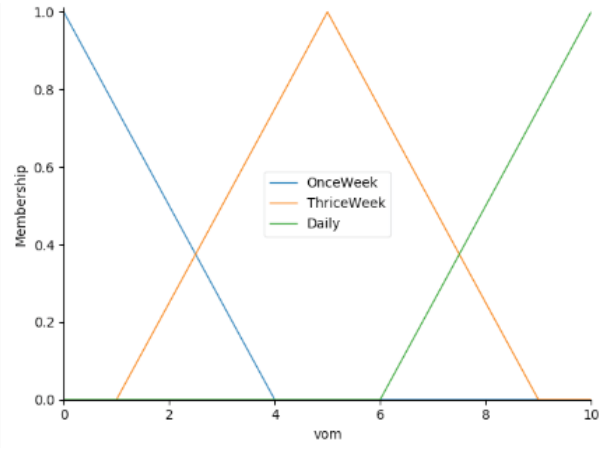

Fig. 5: Vomiting Fuzzy Graph

The system implemented with python using multiple crisp values to every input parameter whereas the disease prediction output parameter consists of eleven crisp values for the apprehension of celiac disease. The triangular membership function was applied to develop fuzzy system according to its range which differs with every symptom. The values vary according to symptom due to varied level in the format of daily, weekly or hourly report. The representation of vomiting parameter is defined according to three distinct values as once in a week, thrice in a week, and daily input with unique membership range. Similarly, every fuzzy input is defined using membership function to evaluate an output with distinct techniques.

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

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

$$\mu_{daily}(x)=\begin{Bmatrix}0 & x<6, x>10\\ (x-6)/4 & 6<x<10\end{Bmatrix}$$

where $a=6, b=10$ and $m=10$

Another crucial input of Body Mass Index (BMI) is defined using three different range as underweight, normal and overweight in the view of fuzzy graph. The representation of the crisp input parameter Body Mass Index (BMI) described in Figure 6.

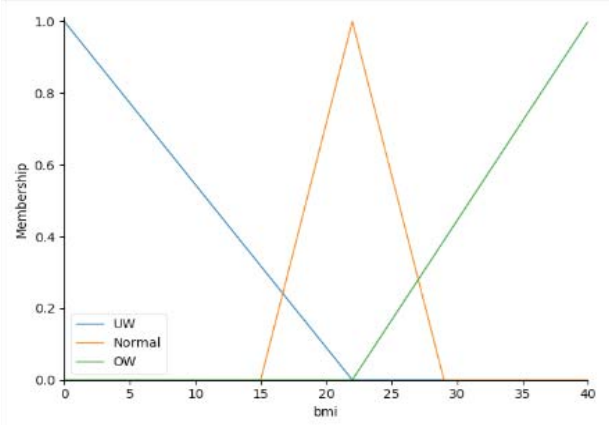

Fig. 6: Body Mass Index (BMI) Fuzzy Graph

The proposed system will have 486 fuzzy database rules that have been formulated based on the symptoms given in

ESPHAGN guidelines and existing studies in the world.

$$\mu_{uw}(x) = \begin{Bmatrix} 0 & x < 0, x > 22 \\ (22 - x)/22 & 0 < x < 22 \end{Bmatrix} \text{where } a = 0, b = 22 \text{ and } m = 0$$

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

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

Other parameters used in the proposed system as abdominal pain with mild, moderate and severe values. Abdominal pain generates in the celiac patients whenever any celiac patient consumes gluten in the diet. The range of abdominal pain depends upon domain which should be required to feed the data in the fuzzy system as crisp inputs. The intensity of the abdominal pain needs to be specified in the form of numerical value. Anemia parameter specifies the lack of blood in the body as another vital symptom for the predictive system. The range is as similar to the abdominal pain intensity with fuzzy crisp inputs. Diarrhea parameter is associated as intensity with never, once in a week, thrice in a week and on daily basis data. The range of the diarrhea parameter is 0-10 for the fuzzy system. Weight loss act as crucial parameter for the fuzzy system when any individual loss their weight abruptly in few months with values are underweight and static or underweight and losing.

RESULTS AND DISCUSSIONS

The rule viewer of the prediction of celiac disease produced output by differentiating 486 rules from the fuzzy engine using Mamdani Model given by (Mamdani 1975). From the given input, 8 different kinds of rules matched and comprise one single output using the de-fuzzification method. Every crisp input, when compared with its value, produces two indices that lie in different precincts to estimate a single output. Figure 7 specifies a common paradigm in which any individual submit the symptomatic value into the proposed fuzzy system. The inputs given by the individual based on fuzzy inputs that were defined from crisp values during the fuzzification process. Separate Body Mass Index (BMI) evaluator has already been evaluated using PyCharm software based on Python Language. The system also display every single symptom plot chart based on the input given by any user. The bar chart slider toolbar also provided for the graphical input rather than specific symptom input.

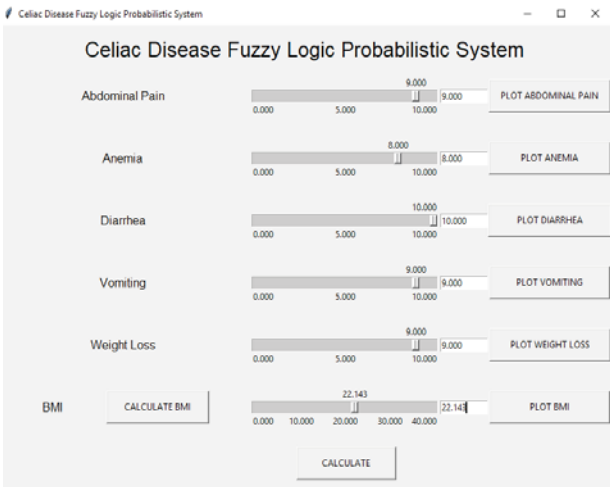

Fig. 7: Celiac Disease Input Symptoms with Crisp Inputs

The celiac disease system produces an output of 96.11% with graphical layout. It also recommends the clinical testing approach to confirm the celiac disease.

The above proposed system defines the output based on the symptomatic data given by one of the celiac patient. In traditional approach, the similar process was evaluated using de-fuzzification manual technique. To do this, all the rules that lie among the given input matched with all set of rules defined in the figure 8. The evaluation of singleton value with matched rule combination defines the centre of gravity de-fuzzification value. All the possible eight rules combination from the fuzzy database verified with same fuzzy input given to the fuzzy system. The evaluation approach to compute de-fuzzification value depends upon the membership function either trapezoidal or sigmoid function. Every given matched rules from the entire fuzzy database is required to be recorded to compare with the fuzzy input. The fuzzy inference system check every stored fuzzy rule in the database crosscheck with the fuzzy input an compute single value that should be accumulated together to define summation rule value of the given system.

Rules	Matched Rules	Evaluation (Singleton Value*Matched Rules)	Rules	Matched Rules	Evaluation (Singleton Value*Matched Rules)
R1	VVH(9.5)	0.05*9.5=0.475	R5	VVH(9.5)	0.05*9.5=0.475
R2	VVH(9.5)	0.05*9.5=0.475	R6	VVH(9.5)	0.05*9.5=0.475
R3	VVH(9.5)	0.225*9.5=2.1375	R7	VVH(9.5)	0.225*9.5=2.1375
R4	VVH(9.5)	0.225*9.5=2.1375	R8	VVH(9.5)	0.225*9.5=2.1375
Fuzzy Singleton Value =∑(Singleton Value*Matched Rules) / ∑R =>10.45/1.1=>95%					

Fig. 8: Rule-Input with De-fuzzification

The evaluation of de-fuzzification comes out to be 95% whereas the upshot of the proposed system will have a disease prediction of 96.11% accuracy according to the input values given by an individual to authenticate the celiac disease.

```
# If the membership function is a singleton fuzzy set:
if len(x) == 1:
   return x[0]*mfx[0] / np.fmax(mfx[0], np.finfo(float).eps).
astype(float)
# else return the sum of moment*area/sum of area
for i in range(1, len(x)):
   x1 = x[i - 1]
   x2 = x[i]
   y1 = mfx[i - 1]
   y2 = mfx[i]
   # if y1 == y2 == 0.0 or x1==x2: --> rectangle of zero height or width
   if not(y1 == y2 == 0.0 or x1 == x2):
      if y1 == y2:  # rectangle
         moment = 0.5 * (x1 + x2)
         area = (x2 - x1) * y1
      elif y1 == 0.0 and y2 != 0.0:  # triangle, height y2
         moment = 2.0 / 3.0 * (x2-x1) + x1
         area = 0.5 * (x2 - x1) * y2
      elif y2 == 0.0 and y1 != 0.0:  # triangle, height y1
         moment = 1.0 / 3.0 * (x2 - x1) + x1
         area = 0.5 * (x2 - x1) * y1
      else:
moment = (2.0 / 3.0 * (x2-x1) * (y2 + 0.5*y1)) / (y1+y2) + x1
         area = 0.5 * (x2 - x1) * (y1 + y2)
      sum_moment_area += moment * area
      sum_area += area
return sum_moment_area / np.fmax(sum_area,
                     np.finfo(float).eps).astype(float)
```

The code from the python is described with one module as de-fuzzification evaluation. The representation clearly describes sum of area method used in the proposed fuzzy system to compute its probable value. Similar types of different modules can be fetched from the fuzzy system including import external libraries as numpy, tkinter and skfuzzy. It indicates that the system when compared with traditional approach to de-fuzzification produces better outcome in terms of probability with lesser time to evaluate.

Fig. 9: Fuzzy Celiac Output with Re-commendation

The input given is in the framework of fuzzy system based on symptoms with the given scenario comes out to be 96.11% whereas the traditional method of producing similar outcome from de-fuzzification comes out to be 95% which shows the accuracy of the proposed system in a better way as depicted in Figure 9. So, the proposed system produces better outcome in terms of accuracy in comparison with traditional de-fuzzification evaluates mechanism given by (Thukral 2019).

CONCLUSION

The proposed system yielded excellent output accuracy of 96.111% in comparison with the computed de-fuzzification procedure of 95%. The collected set of data from the camp illuminates that female ratio carrying celiac disease is much more as correlated to males as depicted in ESPHAGN guidelines. The awareness level of celiac disease in the world is very miniature as received in the collected data. The evaluation of the system without python by practicing de-fuzzification admitted the accuracy of the system by crisp inputs supplied in the form of symptoms. Few parameters like abdominal pain and varied Body Mass Index (BMI) having vital inputs for the system as it seems optimum matched with all existing celiac patients. The projected outline is to increase some parameters by reconstructing fuzzy rules or by using distinct tools to appraise the accuracy of the system as well as to define the prevalence of the celiac disease.

CONFLICTS OF INTEREST

No conflict of interest was reported by the authors.

ACKNOWLEDGMENT

Author S. Thukral is grateful to Principal, DAV College, Amritsar for his kind support and for providing necessary facilities to carry out this work.

REFERENCES

Adeli M, Zarabadipour H (2011) Automatic disease diagnosis systems using pattern recognition based genetic algorithm and neural networks. International Journal of Physical Sciences 6: 6076-6081. doi:10.5897/IJPS11.1075

Aronsson CA, Lee HS, Liu E, Uusitalo (2015) Age at gluten introduction and risk of celiac disease. Pediatrics 135: 239-245. doi:10.1542/peds.2014-1787

Bascunan KA, Vespa MC (2017) Araya M Celiac disease: understanding the gluten-free diet. Eur J Nutr 6: 449-459. doi:10.1007/s00394-016-1238-5

Chowdhury T (2018) Fuzzy logic based expert system for detecting colorectal cancer. International Research Journal of Engineering and Technology 5: 389-393.

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

Gee SJ (1888) On the coeliac affection. St. Bartholomew's Hosp Rep. 24: 17-20.

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

Husby S, Koletzko S, Korponay-Szabo IR, Mearin ML, Phillips A, Shamir R (2012) European Society for Pediatric Gastroenterology, Hepatology, and Nutrition guidelines for the diagnosis of coeliac disease. J Pediatr Gastroenterol Nutr. 54: 136-160. doi:10.1097/MPG.0b013e31821a23d0

Kaur R, Kaur S, Rehani V (2016) Fuzzy based automation system for predicting viral infections. International Journal for innovative research in Multidisciplinary field 2: 426-434.

Makharia GK, Verma AK, Amarchand R, Bhatnagar S (2011) Prevalence of celiac disease in the northern part of India: a community based study. J Gastroenterol Hepatol 26: 894-900. doi:10.1111/j.1440-1746.2010.06606.x

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

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 8: 69-76

Marsh MN (1992) Gluten, major histocompatibility complex, and the small intestine. A molecular and immunobiologic approach to the spectrum of gluten sensitivity ('celiac sprue'). Gastroenterology 102: 330-354.

Moein S, Saraee MH, Moein M (2009) Iris disease classifying using neuro-fuzzy medical diagnosis machine. Advances in Intelligent and Soft Computing, Springer 56: 359-368, 2009. doi: 10.1007/978-3-642-01216-7-38

Murry JA, Watson T, Clearnnan B, Mitros F (2004) Effect of a gluten-free diet on gastrointestinal symptoms in celiac disease. Am J Clin Nutr. 79: 669-673. doi:10.10973/ajcn/79.4.669

Parewe AM, Mahmudy WF, Ramdhani F, Anggodo Y (2016) Dental disease detection using hybrid fuzzy logic and evolution strategies. Journal of Telecommunications, Electronic and Computer Engineering 10:10

Phuong NH, Kreinovich V (2001) Fuzzy logic and its applications in medicine. Int J Med Inform 62: 165-173

Revised criteria for diagnosis of coeliac disease. Report of Working Group of European Society of Paediatric Gastroenterology and Nutrition. Arch Dis Child 65: 909-911, 1990

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

Sood A, Midha V, Sood N, Avasthi G Sehgal A (2006) Prevalence of celiac disease among school children in Punjab, North India. J Gastroenterol Hepatol 21: 1622-1625. doi:10.1111/j.1440-1746.2006.04281.x

Stone ML, Bohane TD, Whitten KE, Tobias VH, Day AS (2005) Age related clinical features of childhood coeliac disease in Australia. BMC Pediatr 5: 11. doi:10.1186/1471-2431-5-11

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

Thukral S, Rana V (2019) Versatility of Fuzzy Logic in chronic diseases: A review. Medical Hypotheses 122: 150-156. doi:10.1016/j.mehy.2018.11.017

Uduak A, and Mfon M (2013) Proposed fuzzy framework for cholera diagnosis and monitoring. International Journal of Computer Applications 82: 1-10. doi:10.5120/14252-1626

Zadeh LA (1965) Fuzzy Sets. Elsevier, Information and Control 8:338-353. doi:10.1016/S0019-9958(65)90241-X

Zarandi MH, Abdolkarimzadeh M (2018) Fuzzy rule based expert system to diagnose chronic kidney disease. Advances in Intelligent Systems and Computing, Springer International Publishing 648: 323-327. doi:10.1007/978-3-319-67137-6-37