Gastroenteritis Disease in Pediatrics Detection System using Fuzzy Logic Type 2

Kingsley Ezebunwo Igbudu
Department of Computer Science
Rivers State University
Port Harcourt, Nigeria

Olukunle Oladipupo Amoo
Department of Cyber Security
University of Nebraska, Omaha
United State of America

Obot Israel Emaekop
Codetemple ICT center
Port Harcourt, Nigeria

ABSTRACT
The prevention of gastroenteritis disease in pediatrics is essential as it has the potential to prevent prolonged treatment with unbearable financial implications and in some cases which leads to death of patients. Early methods for detecting Gastroenteritis signs and symptoms may not have been effective in the sense that they lack the ability to detect the précised degree of the presence of Gastroenteritis signs and symptoms, which can lead to inappropriate treatment. To avoid prescribing the wrong treatment in an uncertain situation, an intelligent Gastroenteritis Detective System is required. This research work proposes a Fuzzy Logic Type 2 Detective Intelligent Technology for the detection of Gastroenteritis disease in Pediatrics. The System uses post-infection reviews to predict and give analytical reports of gastroenteritis in pediatrics using the global data set from the AVIN repository of machine learning. It also employs the Fuzzy Logic rule for the determination of the degree with 4-degree levels, namely, Mild, Moderate, Severe, and Very Severe levels. These levels were chosen in other to determine the degree of the disease and the expected output from the post-infection review. Apart from post-infection review and degree other inputs used in the system are the vital signs and the symptoms review, however, with the combination of the post-infection reviews, degree, duration, and vital signs in this new model, we also chose 4 high performing classifiers like Logistic Regression (LR), Random Forests, XGBoost and Naïve Bayes (NB). The Fuzzy Logic Type 2 Based detection system performance evaluation was tested in two ways; the evaluation of the presence of gastroenteritis based on training and testing accuracies and the fuzzy logic analysis model for gastroenteritis in pediatrics based on parameters such as training accuracy and testing accuracy against the acute gastroenteritis system. The overall accuracy of the fuzzy logic-based analysis model for gastroenteritis in the pediatric system was gotten as 90.5%, while that of the acute gastroenteritis system was gotten as 87.4%.

General Terms
Gastroenteritis Disease Detection System, Fuzzy Logic Detective System

Keywords
Gastroenteritis, Pediatrics, Fuzzy logic Type 2, Gastroenteritis Disease in Pediatrics Detection System using Fuzzy Logic Type 2

1. INTRODUCTION
Most children will complain of a stomachache once in a while because it is one of the most common childhood pain experiences. Complaints can range from a vague queasy feeling in the stomach to doubling over in pain accompanied by vomiting, diarrhea, or constipation. Children are vulnerable to acute gastroenteritis (AG), one of the most common children's diseases. Acute gastroenteritis is a disease state that occurs when food or water that is contaminated with pathogenic microorganisms (such as Clostridium perfringens, Vibrio cholera, E. coli) or their toxins are consumed. Some of its symptoms are loss of appetite, bloating, nausea, vomiting, abdominal cramps, abdominal pain, diarrhea, etc. In children under 5 years of age acute gastroenteritis (AG) is the major cause of their death. In some cases, diarrhea is usually severe enough to require hospitalization, with 1.87 million deaths cases in children before the age of 5 years [1]. In Nigeria, reports have shown that rotavirus is a very common etiologic agent of diarrhea in children under 5 years of age and causes more than 315,000 deaths of preschool-age children annually (5,7-14). In Ebonyi State of Nigeria, diarrhea is among the leading causes of pediatric emergency visits and one of the major causes of infant morbidity and mortality [2].

Early intervention in the prevention of gastroenteritis disease in pediatrics is essential as this has the potential to prevent prolonged treatment with unbearable financial implications and in some cases which leads to the death of patients, especially when the patient's sensitivity to treatment is low [3]. Choosing the appropriate preventive method is key in the analysis of gastroenteritis signs and symptoms. Conventional methods for detecting gastroenteritis signs and symptoms may not have been effective in the sense that they lack the ability to detect the précised degree of the presence of gastroenteritis signs and symptoms which can lead to inappropriate treatment. The aim of the research is to optimize the prediction of the presence of gastroenteritis in pediatrics using fuzzy logic.

2. RELATED WORKS
In [4] an ensemble proposition for categorization and forecasting of gastroenteritis employing mushy voting categorizer was proposed. Their suggested ensemble mushy voting categorizer allow binary categorization and accustom the ensemble to three machine learning instructions viz. logistic regression, random forest, and Naive Bayes for the categorization. Experimental estimation of the suggested course was administered with state-of-the-art techniques and base classifiers such as Logistic Regression, AdaBoost, Support Vector Machine, Random Forest, Naïve Bayes, Bagging, GradientBoost, XGBoost, CatBoost by collecting accuracy, precision, recall, F1-score as the assessment standard.

Another set of scholars suggested a categorization structure for gastroenteritis patients with an expert system approach as seen in [5]. In their research, five approaches established on expert systems particularly, RobustBoost, AdaBoost, LogicBoost, Naïve Bayes, and Bagging were suggested for the analysis and forecasting of DM patients. The suggested approach was engaged in the set of data for Redar gastroenteritis patients.

Azian and Zulkarnay [6] proposed research on the fuzzy expert system (FES) aiming at analyzing acute gastroenteritis in pediatrics within the age range of 1 and 4 years was suggested. The input data was gathered from a total of 10 kids, including boys and girls from various backgrounds. This fuzzy expert system's inputs included bio data, symptoms, and vital indicators including body temperature, pulse, and breathing rate. If the body temperature is 380C or above, the pulse is 72b/m, and the respiratory rate is 25cmp, gastroenteritis is considered to be present. When a kid exhibits the following symptoms, gastroenteritis is also determined to be present: fever, diarrhea, nausea, stomach discomfort, loss of weight, and lack of appetite. Here, the suggested model made use of a machine-learning method and a large data set from the AVIN repository. The suggested model used a highly accurate and quickly developed algorithm to predict gastroenteritis. Their suggested model yielded a training accuracy of 68.8%, testing accuracy of 79.2%, and total accuracy of 87.04% for diagnosing gastroenteritis with lower error rates based on symptoms. Gastroenteritis is referred to as a killer illness because it causes symptoms that, if ignored for a long time, might result in a child's death. So, to protect the gastroenteritis patient, a sophisticated and precise diagnostic technique is required. It was anticipated that the fuzzy system would ascertain the level of the feature familiar with the number of medications to be given to complete recovery based, but this never happened. Their approach, however, was unable to examine the numerous post-analysis infections.

Aziel and Paul [7] presented a study about rehabilitation and death through diarrhea and rotavirus in pediatrics. Infections linked to gastrointestinal illnesses are mostly ascribed to viruses associated with gastroenteritis. The population's most vulnerable members, such as small children and newborns, those with weakened immune systems, and the elderly, are most at risk of getting viral gastroenteritis and experiencing life-threatening symptoms or even passing away. Even though determining the causative relationship between viral causes of diarrhea and symptoms is sometimes challenging, gastric toxins such as rotavirus, sapovirus, norovirus, and gastric adenovirus, alongside astrovirus have been demonstrated to contribute to the total burden of diarrheal disorders.

3. METHODOLOGY

The Object-Oriented Analysis and Design Methodology (OOADM) was adopted in the study. The methodology promises to reduce development time, reduce the time and resources required to maintain existing applications, increase code reuse, and provide a competitive advantage to organizations that use it. In OOADM the life cycle of software includes analysis, design, and implementation of the software. Object-oriented development focuses on identifying and organizing the application concept instead of the implementation of the software.

Analysis Phase:

Requirements Gathering: The information was collected at some medical centers here in Nigeria. different symptoms of the patient.

Use Case Modeling: Analysts create use case diagrams to depict system functionalities from the user's perspective. Use cases represent interactions between users and the system.

Object Modeling: Object modeling involves identifying and defining the key objects in the system. Analysts describe object classes, attributes, methods, and relationships using class diagrams and object diagrams.

4. FUZZY LOGIC-BASED MODEL FOR GASTROENTERITIS IN PEDIATRICS

The proposed Fuzzy Logic Model improves the conventional detective models in two different areas. The first is in the scope of the system, our system's scope is to use post-infection reviews to predict and give analytical reports of gastroenteritis in pediatrics using the global data set from the AVIN repository of machine learning. The second enhancement is in the choice of the fuzzy logic rule used for the determination of the degrees. We chose 4 degrees namely mild level, moderate level, severe level, and very severe level (Table 1 and 2). These levels were chosen to determine the degree of the disease and the expected output from the post-infection review. Apart from post-infection review and degree other inputs used in the system are the vital signs and the symptoms review, however, with the combination of the post-infection reviews, degree, duration, and vital signs in this new model, we also chose 4 high performing classifiers like Logistic Regression (LR), Random Forests, XGBoost and Naïve Bayes (NB) (Figure 1), better accuracy without overfitting and low margins or noise are guaranteed for a more accurate analysis. The fuzzy logic-based analysis model for gastroenteritis in pediatrics is one of the best software that can guarantee training accuracy of up to 90.0% and testing accuracy of 91.5%. A fuzzy logic-based model for gastroenteritis pediatric is also very flexible and very suitable for handling missing data. Data regularization is also best performed using this new model. AVIN repository was also chosen because it works excellently with large clinical datasets especially when it relates to multi-class prediction. The outcome of the new system will show the presence of the disease and the degree if the disease is mild, moderate, severe, or very severe. User-friendliness in the visualization process of the new system is one of the improvements of our system. Our new system also accommodates retroviral screening tests to be carried out to check the status of the pediatric if positive for HIV or negative. The design and conceptual models of the fuzzy logic-based analysis model for gastroenteritis in pediatrics design is shown in figure1 and 2. The algorithm and the mathematical description of the model are given below.

4.1 The Fuzzy Logic-Based Model Algorithm

Step 1: Start

Step 2: Login, Authenticate Account.

Step 3: If Authentication fails, go to Step 4 Else go to Step 5

Step 4: Display Login Error, Go to End

Step 5: Check Account Logged in.

Step 6: If Logged User is Front desk officer, Register Pediatric Else go to Step 7.

Step 7: If Logged User is Nurse, Register Vital Signs Else go to Step 8.

Step 8: If Logged User is Doctor, Symptoms Else go to Step 9.

Step 9: If Logged User is Lab technician, Input the Stool Analysis Test Report,

MP Widal Test Report, Full Blood Count Test Report with Degree of illness, Else go to Step 10.

Step 10: User not found, go to Step 4.

Step 11: End.

4.2 Mathematical Model

Here, we study the behavior of a system's n entities (objects), $n \geq 2$, during a process involving vagueness and/or uncertainty. Denote by Si , i=1,2,3 the main stages of this process and by (a),Fever), (b), Nausea),(c), Diarrhea),(d), Abdominal cramps), (g), Vomiting), and e the linguistic labels of mild, moderate, severe and very sever respectively of a system's entity in each of the Si's. Set **U = {a, b, c, d, g}.**

We are going to attach to each stage S_i a fuzzy subset, A_i of U. For this, if n_{ia}, n_{ib}, n_{ic}, n_{ig} **and** n_{ie} denote the number of entities that faced mild, moderate, sever and very sever success at stage S_i respectively, i=1,2,3, we define the membership function m_{Ai} for each x in U, as follows:

1, if $\frac{4n}{5} < niX \leq \frac{4n}{5}$

0.75, if $\frac{3n}{5} < niX \leq \frac{4n}{5}$

0.5, if $\frac{2n}{5} < niX \leq \frac{3n}{5}$

0.25, if $\frac{2n}{5} < niX \leq \frac{3n}{5}$

0, if $0 \leq niX \leq 5$

Then the fuzzy subset A_i of U corresponding to S_i has the form:

Ai = {(x, mAi(x)): x∈U}, i=1, 2, 3.

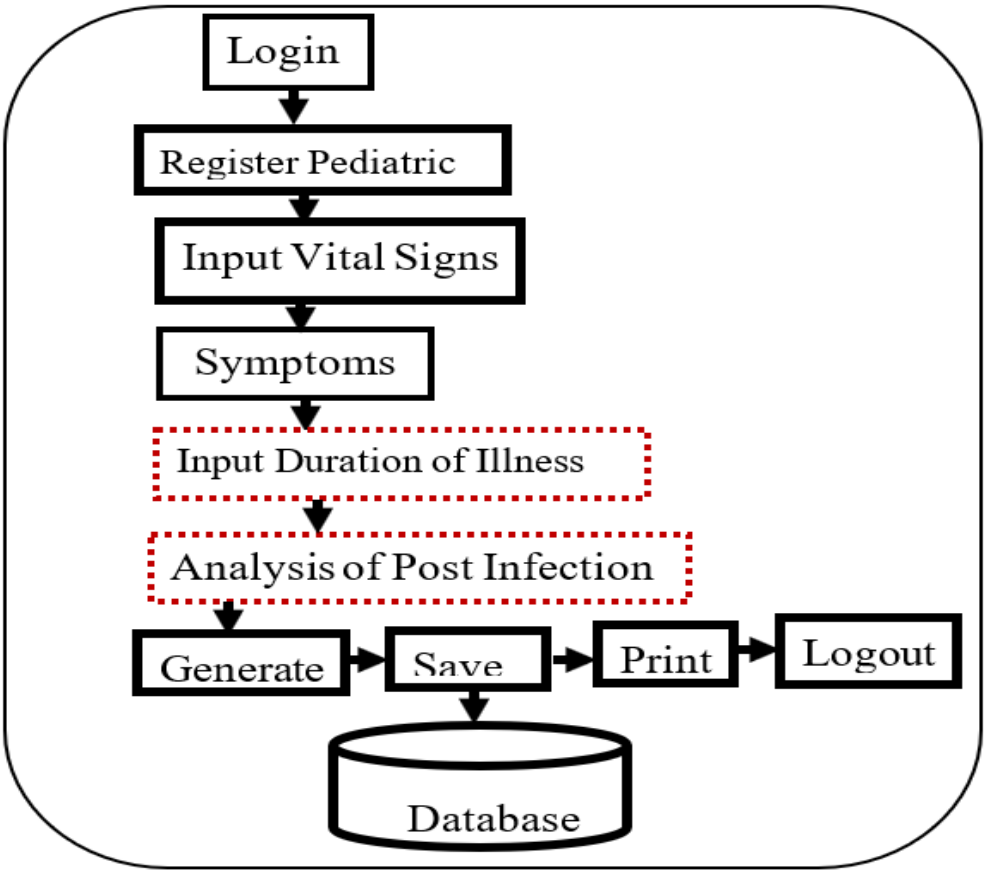

Figure 1: Fuzzy Logic-Based Model for Gastroenteritis in Pediatrics

The Fuzzy system contains the following components:

i. **Login:** The first login is being done by user 1 (front-desk office)

ii. **Register Pediatric:** The pediatric is being registered by the front-desk officer, the front-desk officer takes in the bio data of the pediatric and inputs the information into the system with the aid of the keyboard, the bio-data including full name, Sex, Age, Address, Phone No of the parents/guardians, card no. and religion. The front desk officer saves the details and then logs out.

iii. **Vital Signs:** The second login is done by the nurse, once the nurse logs in with the given email and password given by the admin/allocation, the nurse then see's awaiting pediatric whose vital signs need to be checked. The duties of the nurse are to check for the vital signs of the pediatric which includes, checking the temperature with a thermometer (mercury), pulse with a stethoscope, and respiratory of the pediatric, the nurse inputs the reading into the system with the aid of a keyboard and then saves the result and logout.

iv. **Symptoms:** The third login is being done by the doctor, the doctor logins in and sees the awaiting result from the nurse, he then clicks on it which is the result of the vital signs of the pediatric, after that the doctor proceeds to the symptoms checkbox table to check the symptoms experienced by the pediatric. The doctor then sends the pediatric to the lab technician for post infection diagnosis after which the doctor clicks on save and

waits for the lab technician to forward back his/her lab review/report.

v. **Input Duration of Illness:** the doctor inputs the duration of the illness by asking the parents/guidance on how long the pediatric has been ill.

vi. **Analysis of Post Infection:** The fourth to login is the lab technician, the lab technician signs in with the mail address and unauthorized code given to him/her by the admin/allocation, the lab technician then sees the awaiting pediatric for laboratory review, he/she then clicks on the waiting list and click on the pediatric name and sees the report from the doctor on the test to be carried out, the laboratory investigation is then being carried out which includes: stool analysis, full blood count (Fbc) and MP widal. Retrovirus Screening further diagnoses of post-infection are being made to check for retroviral screening (HIV), a blood sample is being taken by the lab-technician to test for the status of the pediatric to know if the pediatric is seropositive or sero-negative on HIV, after the investigations are being done the lab-technician then inputs the result into the system with the aid of a keyboard and then logout.

vii. **Generate:** the system automatically generates the degrees of the presence of gastroenteritis, the whole details

viii. entered into the system by the different users ranging from the front-desk officer to the nurse followed by the doctor to the lab-technician review are then being generated,

ix. **Save:** The doctor saves the report to the database.

x. **Print:** the analysis report is then printed out for documentation, given to the parents, or used to prescribe the dosage of drugs to be given.

xi. **Logout:** the doctor logs out

Table 1: Fuzzy Values (Value Representation for infections of Gastroenteritis)

Rule No.	Fever	Nausea	Diarrhea	Abdominal Cramps	Vomiting	Conclusion
1.	0.01	0.01	0.01	0.01	0.01	0.05(mild)
2.	0.02	0.01	0.02	0.02	0.01	0.08(moderate)
3.	0.03	0.03	0.03	0.02	0.01	0.12(severe)
4.	0.04	0.01	0.01	0.03	0.04	0.13(very severe)

Table 2: Fuzzy Rule for Gastroenteritis

Rule No.	Fever	Nausea	Diarrhea	Abdominal Cramps	Vomiting	Conclusion
1.	Mild	Mild	Mild	Mild	Mild	0.5(w)
2.	Moderate	Mild	Moderate	Moderate	Mild	0.8(x)
3.	Severe	Severe	Severe	Moderate	Mild	0.12(y)
4.	Very Severe	Mild	Mild	Severe	Very Severe	0.13(z)

Based on the symptoms entered into the system, the fuzzy logic system diagnoses based on its knowledge, adds a catalyst factor (if any), and does ranking and gives results in fuzzy form. This stores the permanent knowledge of the domain of the application and allows the system to act as an expert in the domain under consideration. It is this module which depends on the domain of the application. it holds a set of rules of inference (production rules) that are used in reasoning. These rules form the form; if <condition>, then <action>. The knowledge base contains knowledge belonging to the domain of the system; it stimulates the activity of an expert in his/her deductive and explanatory capacity. gastroenteritis pediatric disease whose symptoms are Fever (Fs) Nasal congestion (Ns) Diarrhea (Ds) Abdomerra (Ac) Vomiting (Vs). So it will be stored in the knowledge base in the form of a rule which is as follows: -

Disease (Patient, gastroenteritis): -

Symptom Fever (Fs)

Symptom Nasal congestion (Ns)

Symptom Diarrhea (Ds)

Symptom Abdominal (Ac)

Symptom Vomiting (Vs). are stored in the knowledge based before the inference engine will make it prediction based on the degree like mild, moderate, severe or very severe. Diagram of the fuzzy logic-based analysis model for gastroenteritis in pediatrics design is shown in figure 2

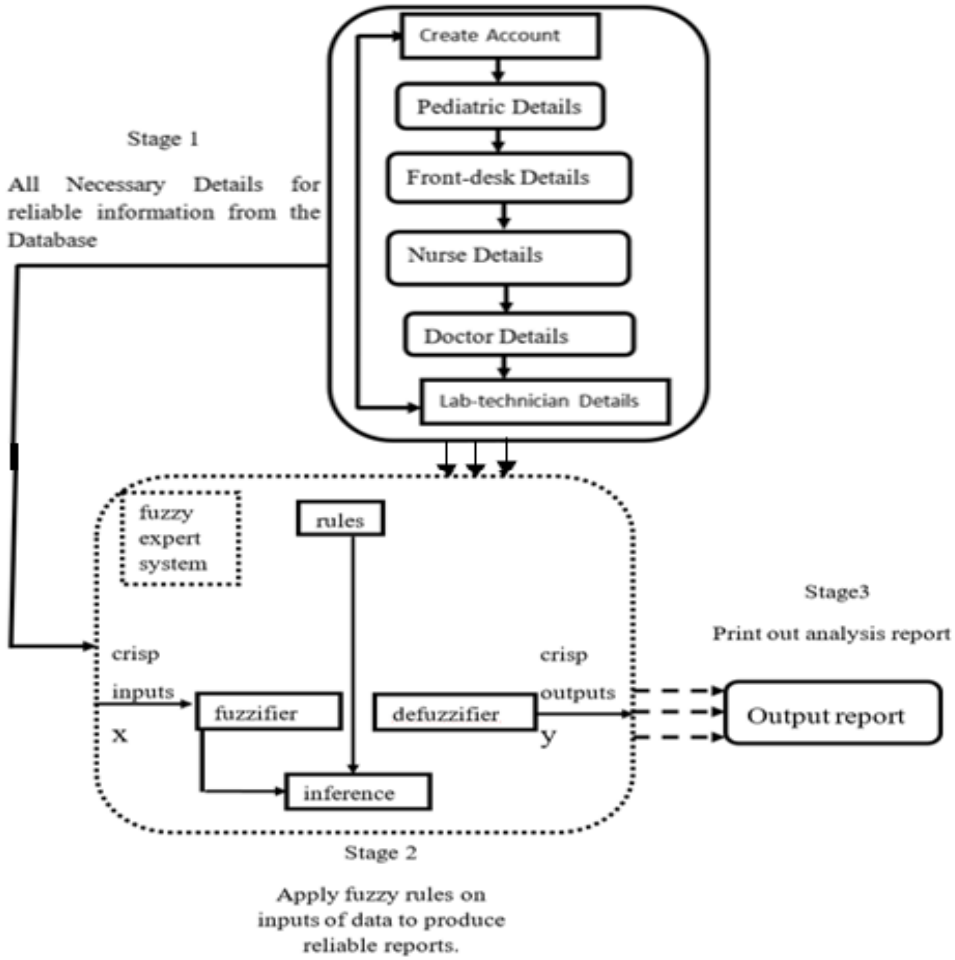

Figure 2: Fuzzy Logic-Based Analysis Model For Gastroenteritis In Pediatrics

5. RESULT AND DISCUSSION

The system was built using Hypertext Preprocessor programming language: there are 4 levels of users in the system, the administrator, font-desk officer, nurse, laboratory-technician, and the doctor. The doctor does the diagnosis of symptoms, the front desk does the registration of the pediatric, the nurse inputs the vital signs of the pediatric, and the lab technician inputs the laboratory results into the system, the script

for the development of the fuzzy logic Type 2 -based analysis for gastroenteritis in pediatrics was written in JavaScript. In figure 3 the vital signs of the pediatric is being displayed, the nurse inputs the vital signs reading of the pediatric which includes the pulse reading, the temperature and the respiratory readings.

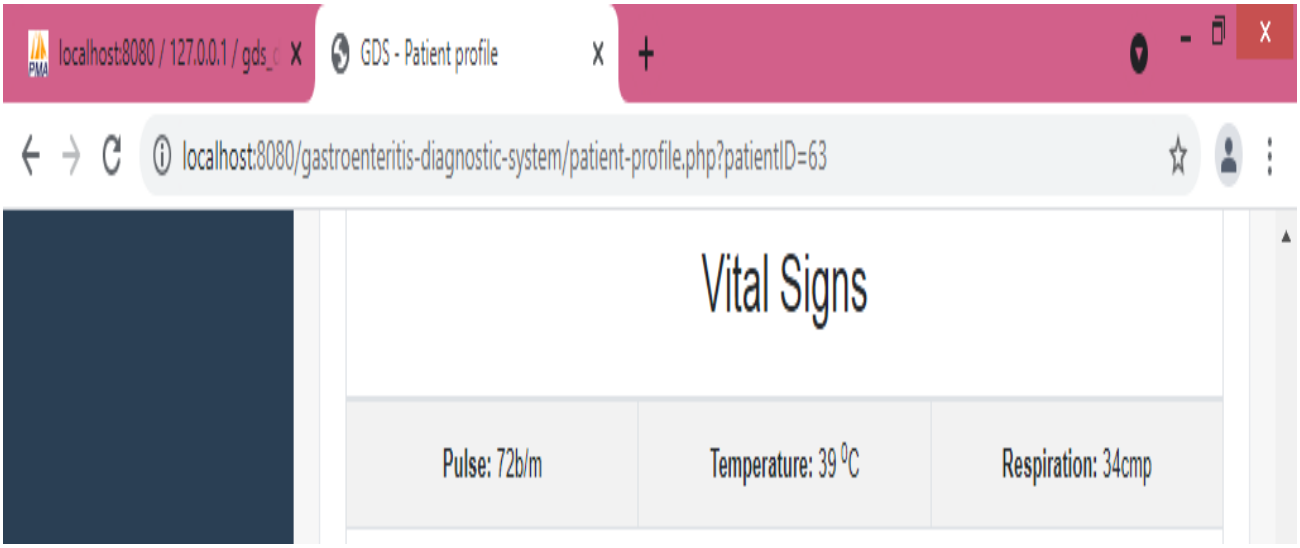

Figure 3: Vital Signs

Figure 4 shows the symptoms report of a pediatric, the symptom report is being ticked by the doctor in accordance to the symptoms experienced by the pediatric, if the symptoms are seen, it is displayed as plus (++) but if not seen it is displayed as negative (--), the reports shown reads diarrhea seen (++), vomiting seen (++), coughing not seen (--), fever seen (++), abdominal pain seen (++), loss of appetite seen (++), nausea seen(++) and skin irritation not seen(--). In Figure 5 the stool analysis report of a pediatric is displayed, the stool analysis is being investigated by a lab technician, the lab-technician checks for the presence of some parasites, and the stool analysis reads seen(++) if the parasites are present and read not seen(--) if the parasites are not seen, the screen shoot stool report in figure 5 reads pull cell seen (++), Cyst/vegetative form of Entamoaeba Histolytica seen (++), Iodamoaeba Butchilli seen (++),Gardia Lanblia not seen(--), Intestinal Flagellates seen (++), Yeast Cells not seen(--) and Red Blood Cells seen (++). In Figure 5 the full blood count report of a pediatric is being displayed, the full blood count reads the presence of the bacteria's degree in the blood sample taken by the lab technician. For the report reads: Hemoglobin (Hb). Hb: 11.3 g/dl, Widal Blood Cell (Wbc) 60,000 mm'3, Neutrophils 105% (Nr. 50-76), Lymphocytes 60% (Nr. 70-105), Eosinophils 7% (Nr. Monocytes 4% (Nr5. 12-16) and Basophils if present or not present. In Figure 5 the MP widal tire report of a pediatric. The MP widal tire test is being done by the lab technician, the lab technician takes a blood sample from the pediatric to check for the presence of bacteria in the blood the report reads: Salmonella Typhi O 1:80 H 1:100, Salmonella Paratyphi A 1:40 H 1:40, Salmonella Paratyphi B1:100 H 1:40 and Salmonella Paratyphi C 1:40 H 1:100.

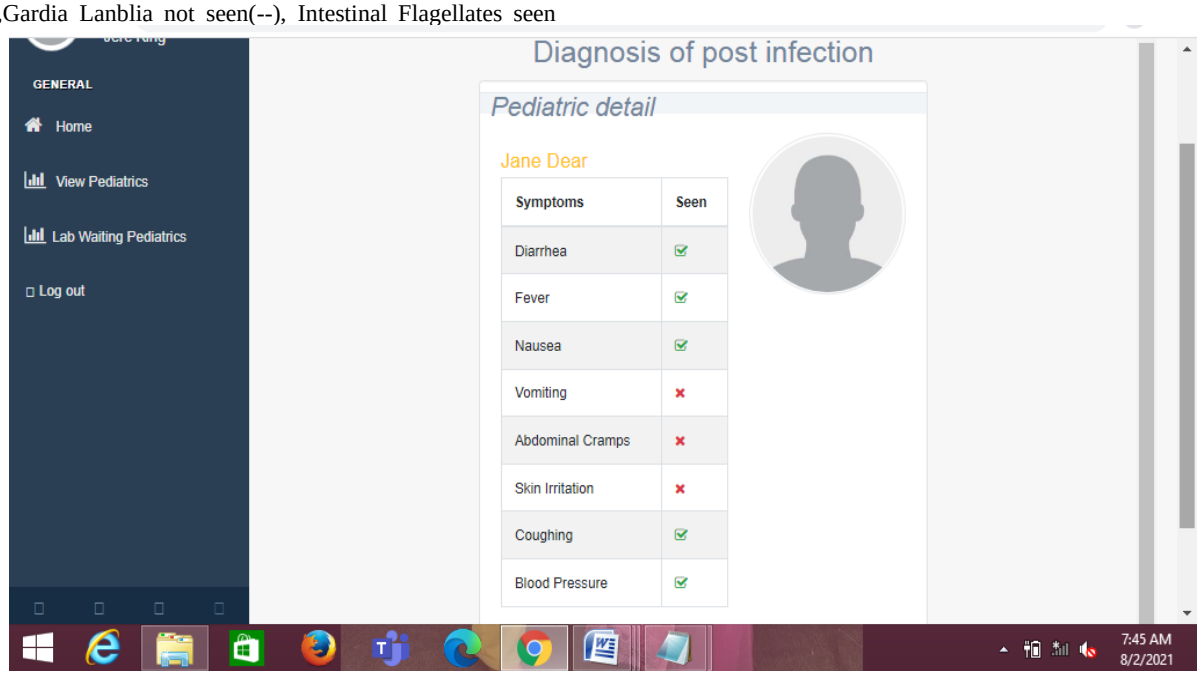

Figure 4: Symptoms Report of Gastroenteritis in a Pediatric

Figure 5 shows the report of a pediatric at a severe level of the presence of gastroenteritis, the severe level report reads: Microscope: Watery/Mucoid Stool, reading for full blood count: Marked hypochromasia and poikilocytosis observed. Marked neutrophilia. Platelets appear severe on film, reads for MP widal: severe agglutination reaction and reading for retroviral screening: seronegative. It shows the report of a pediatric at a very severe level of the presence of gastroenteritis, the very severe level reading for stool: Microscope: Watery / Mucoid Stool, reading for full blood count: Marked hypochromasia and poikilocytosis observed. Marked neutrophilia. Platelets appear very severe on film, reading for MP widal: very severe agglutination reaction and reads for retroviral screening: seronegative.

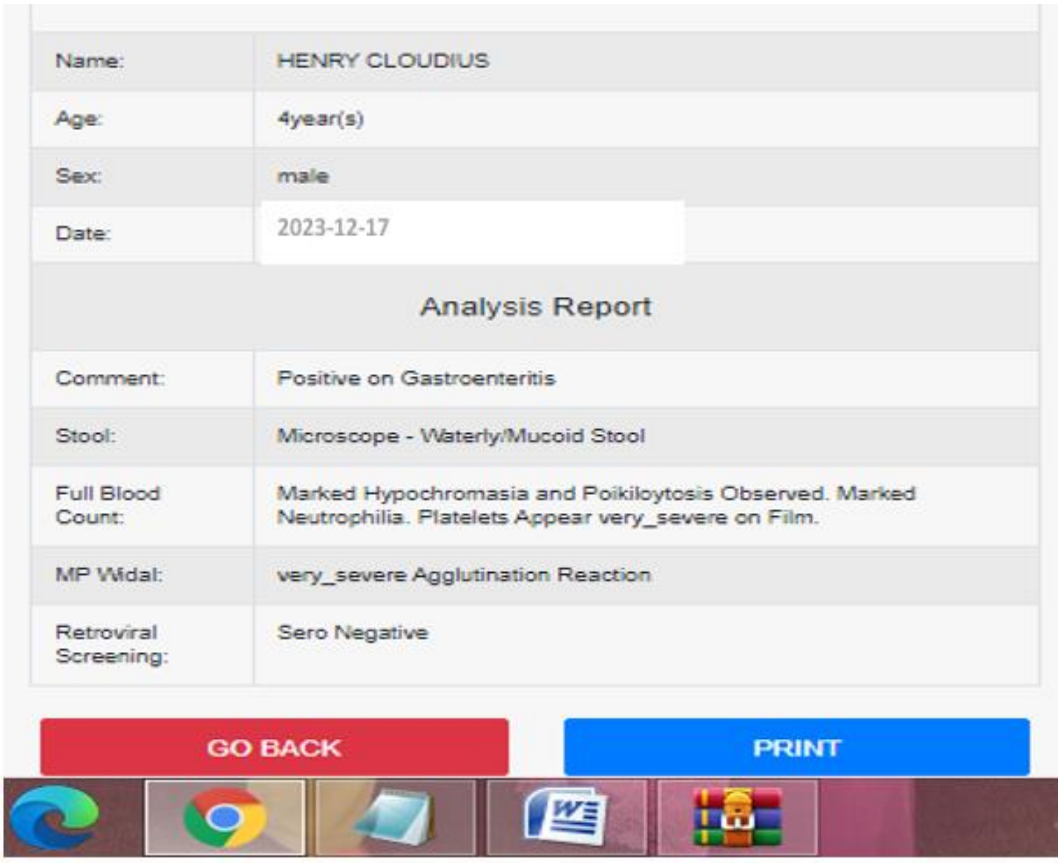

Fig 5: Very Severe presence of Gastroenteritis in a Pediatric

5.1 Performance Evaluation

Fuzzy logic- Type 2 based analysis model for gastroenteritis in pediatric outperformed the other analysis in both training and testing accuracy. The second evaluation is for the fuzzy logic-based analysis model for gastroenteritis in pediatrics based on parameters such as training accuracy and testing accuracy against the acute gastroenteritis system. This is shown in Figure 8 and Table 3. In this figure, it is shown that the fuzzy logic-based analysis model for gastroenteritis in the pediatrics system outperformed the acute gastroenteritis system in all the parameters used for the evaluation. The overall accuracy of the fuzzy logic- Type 2 based analysis model for gastroenteritis in the pediatric system was gotten as 90.5%, while that of the acute gastroenteritis system was gotten as 87.4%.

Accuracy: Measure the system's ability to correctly diagnose gastroenteritis in pediatric patients. Evaluate its sensitivity, specificity, positive predictive value, and negative predictive value compared to traditional diagnostic methods.

Clinical Validation: Validate the system's performance against established clinical standards and expert diagnoses. Conduct clinical trials or retrospective studies to assess its effectiveness in real-world scenarios.

Efficiency:

Computational Efficiency: Evaluate the computational resources required for diagnosis, including processing time and memory usage. Compare the system's efficiency with alternative diagnostic methods to ensure it meets acceptable performance standards.

Scalability: Assess the system's ability to handle varying patient loads and data volumes without compromising performance. Determine if it can scale effectively to meet the demands of different healthcare settings

Table 3: Ensemble Classifier Evaluation

Classifier	Training Score	Testing Score
Logistic Regression	75.8%	79.2%
Naïve Bayes	74.5%	78.5%
Random Forest	100%	81.1%
XGBoost	100%	68.8%

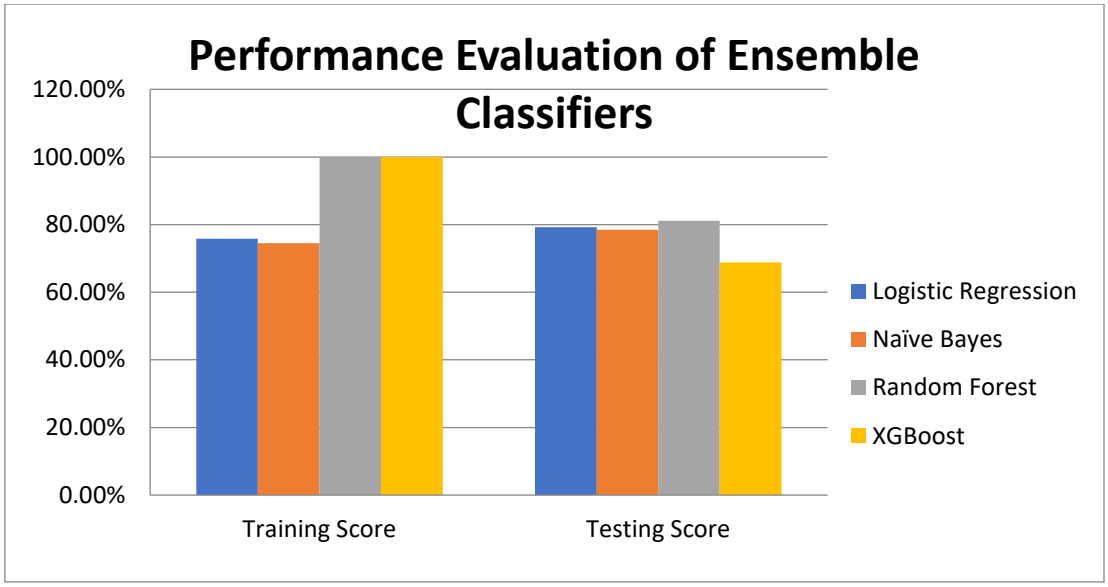

Figure 6: Graph of the Performance Evaluation

6. CONCLUSION

The Fuzzy logic Type 2 -Based Detective Model for Gastroenteritis in the Pediatrics system handles inaccurate analysis, imprecision, and absence of post-infection review of the acute gastroenteritis system. The system provides a scalable symptoms database and also determines the degree of the presence of gastroenteritis symptoms concerning very severe stages which then generates the analysis report of the disease. Accurate analysis of post-infection is one of the greatest advantages of the system. The doctor can analyze the pediatric without being a pediatrician who is a specialist in pediatrics or a gastroenterologist, the users can perform analysis in the hospital without any prior knowledge of programming or having to visit a programmer with the help of this system. Fuzzy logic- Type 2 based analysis model for gastroenteritis in pediatric system outperforms the acute gastroenteritis system with the post-analysis reviews to get an accurate prediction and its degree. Also, in terms of generating reports the fuzzy logic-based analysis model for gastroenteritis in the pediatric system outperforms the acute gastroenteritis system. This makes it the best analytical system for determining the degree of the presence of gastroenteritis.

7. REFERENCES

[1] WHO/United Nation Inter-Agency Group for Child Mortality Estimation (UN IGME). Levels and trends in child mortality. Report 2017. https://www.unicef.org/media/47626/file/UNIGME-Child-Mortality-Report-2018. (Accessed Nov 8, 2018)

[2] Mathers, C. D., Boerma, T., and Fat, D. M. Global and regional causes of death. Br Med Bull. 2009; 92 (1): 7-32.

[3] Ijaz, M. K., and Rubino, J. R. Impact of infectious diseases on cognitive development in childhood and beyond: Potential mitigation role of hygiene. The Open Infect Dis J. 2012; 6: 65–70.

[4] Ahmed, A., & Sherif, E. (2011). A Fuzzy Decision Support System for Management of Breast Cancer: *International Journal of Advanced Computer Science and Applications*, 23(3), 381-392.

[5] Alies, L. O., José, A., Liesbeth, M., Elisabeth, S., & Hester, M. (2017). Intention to vaccinate universally against varicella, rotavirus gastroenteritis, meningococcal B disease and seasonal influenza among parents in the Netherlands: An internet survey.*BMC research notes* 10 (1), 1-6.

[6] Azian, A., Zulkarnay, Z., & Nur-Farahiyah, M. (2011). Design and development of fuzzy expert system for diagnosis of hypertension *Second International Conference on Intelligent Systems*, 4(6), 113-117.

[7] Aziel, A., & Paul, N. (2020). IoT based health care monitoring kit. In Fourth international conference on computing methodologies and communication (ICCMC), IEEE; 6(23) 363–368.