

# Naïve Bayes Based Diagnostic System for Ear, Nose and Throat (ENT) Diseases

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**Abstract:** Diseases are aberrant health disorders that makes living uncomfortable and need to be properly addressed when they do occur. Otolaryngology/Ear, Nose, and Throat (ENT) illness problems can impair a person's ability to smell, hear, speak, learn, or perform crucial functions in life. The services of ENT specialists are not always easily accessible in some parts of the country. Therefore, effectiveness and efficiency of this healthcare system can be improved by using a Computer-Aided App that can help Otolaryngologists and patients diagnose and treat ENT related diseases. This study proposes a Multi-Class ENT Medical Diagnostic System (MCEMDS) that can help experts and non-experts to diagnose ENT-related disorders using the Naïve Bayes Algorithm. The system was implemented using PHP, Java script, and MySQL. The findings of the App's testing revealed that the system was capable of diagnosing a number of ear, nose, and throat conditions indicating the likelihood of their occurrence. The system has high accuracy (>90%) and it is consistent and reliable for ENT diseases detection.

**Keywords:** Diagnostic system; ENT diseases; Intelligence; Naïve Bayes; Otolaryngology.

## 1. INTRODUCTION

Challenges related to human health are inevitable while life exists. Human health challenges have been in existence since the creation of man on planet earth and will last as long as man is not extinct from the earth [1]. The uneasiness that these problems cause to man has led to the discovery and emergence of countless diseases that have threatened the existence of man and the ecosystem at large which can no longer be overlooked. There is therefore the need for early diagnosis of ailments so that early treatment can commence. Diagnosis is used in many different disciplines like in computing, tools, logic and experience to determine cause-and-effect relationships. Medical diagnosis refers both to the process of attempting to determine the identity of a possible disease or disorder and to the opinion reached by this process [2]. In the medical place, the diagnosis of sicknesses is a vital task intended to aid Physicians/Clinician in informed decision making when treating a patient. Diagnosis is a difficult task in medical domain due to influence of medical uncertainties that arises from confusion in disease symptomatic presentation between two or more diseases which makes the first stage of therapeutic actions towards eventual management of diseases difficult [1]. Otolaryngology/Ear, nose and throat (ENT) related diseases can cause disorders in the human body which may affect the sense organs of speech, hearing, smell and etc. The loss of any of these senses can be of a catastrophic effect to an individual and must be avoided.

Due to the shortage of medical specialists and relatively low diagnostic accuracy calls for a new way of diagnostic strategy [3]. This gap has been perfectly bridged by the automation of several medical processes and procedures. Computerization overtime has greatly changed the ways things are done in the medical domain as it had to the development of several computer aided medical systems such as MYCIN [4], PUFF [5], Oncology protocol management system (ONCOCIN) [6] and recently, expert system for diabetes diagnosis [7], mobile expert system on febrile diseases [2] and decision support system for detection of skin diseases in smart health development planning [8] amongst several others.

This paper presents Multi-Class ENT Medical Diagnostic System (MCEMDS) for ENT diseases using Naive Bayes algorithm which has the capability of detecting ENT diseases based on the inputs/symptoms supplied. It also provides explanation subsystem, allows addition of new knowledge to the knowledge-based repository and make recommendation with useful remarks for further actions. The system developed can be used by Physicians, medical students and even patients in dealing with ENT related cases.

## 2. OVERVIEW OF MEDICAL DIAGNOSTIC SYSTEMS AND ENT

### 2.1 Overview of Medical Diagnostic Systems

Medical diagnosis is the process of determining the cause of a patient's illness or condition by investigating information acquired from various sources including physical examination, patient interview, laboratory tests, patient's and the patient's family medical record, and existing medical knowledge of the cause of observed signs and symptoms [9]. To ascertain correct diagnosis is the most crucial step in treating a patient as it allows medical experts to find the best treatment for the patient's condition, this complicated process requires lots of human effort and time. According to Gagliano *et al.* [9], diagnosis of a disease or a condition relies on information which contains factors that makes getting it correct a challenge. These factors include ambiguity, uncertainty, conflicts, and resource and organizational constraints. A lot of symptoms are nonspecific and variable, depending on the person. Many diagnostic tests are expensive, not regularly done and often do not give a precise result. This usually prone physicians to cognitive bias and incorrect applications of heuristics during the diagnosis stage. They are more biased towards disease or conditions which they have diagnosed in the past.

The rapid development in the fields of artificial intelligence, especially expert systems, machine learning (ML) and data mining allow technology and healthcare innovators to create intelligent systems to optimize and improve the current processes. Expert system has the ability to model the problem-solving ability of a human experts in a specific domain. It encodes human expertise in specific domains by using If-Then rules, and accordingly advise and provide solutions to different problems [10]. Expert systems support clinical decision makings. ML has been applied in a variety of area within the healthcare industry such as diagnosis, personalized treatment, drug discovery, clinical trial research, radiology and radiotherapy, smart electronic health record, and epidemic outbreak prediction. In medical diagnosis, ML and data mining algorithms are particularly useful [11]. ML techniques can be applied to the analysis of medical data and are useful for identifying various specialized diagnostic issues in medical diagnosis. Systems that use ML produce reliable diagnosis results from patient data such as symptoms, test data, and some key traits. The computer will determine which data will be used as training and trained dataset for reference in the future based on the correctness of the output [12]. The use of artificial intelligence (AI) and ML in the field of otolaryngology is in its infancy; most current initiatives are in the research stage. But the benefits of employing these technologies show great promise [13].

ML algorithms have aided the development of several assistive technologies that can help patients to overcome or lessen disabilities [14]. Automatic classification of auditory brainstem responses [15], estimation of audiometric thresholds [16], automatic delineation of important anatomy and quantification of sinus opacification in rhinology [17, 18] are examples of applications of ML. Deep learning a type of ML that allows deep neural networks to be trained so as to identify patterns in data [19]. To expedite radiotherapy planning, deep learning networks have been employed in head and neck oncology to autonomously segment anatomical components [20-25]. Given that ML classifiers outperform conventional rule-based algorithms, laryngologists will probably use voice analysis software that uses them to detect disease [26].

### 2.2 Analysis of Ear, Nose and Throat (ENT) Diseases

ENT experts often called otolaryngology or otorhinolaryngology has diversified into several subspecialties namely: Otology/neurotology, Rhinology, Laryngology, Pediatric Otolaryngology, Head and neck oncology and microvascular surgery, skull base surgery/facial plastic and reconstructive surgery, and now an emerging subspecialty of neuro-rhinology where the brain tumors related to skull base are being treated by endoscopic nasal approaches [27, 28].

Otolaryngology is a surgical specialty involved with pathologies of the head and neck. Pathologies vary from very aggressive malignancies to benign, yet vastly functionally detrimental diseases for patients [29]. ENT surgeons treat a very wide range of conditions which includes but not limited to ear, nose, throat, head and neck conditions and facial cosmetic surgery. Table 1 shows some of these conditions with regard to the organs according to [30, 31].

Table 1. ENT conditions/diseases

Ear	Nose	Throat
a) Otosclerosis (a condition of the middle ear that causes hearing loss and other problems with hearing and deafness)	a) Sinus infection and rhino-sinusitis	a) Adenoid problems - surgical removal of these small glands in the throat at the back of the nose is sometimes needed and is usually performed in childhood.
b) Otitis media with effusion – a common condition of childhood (also known as glue ear) in which the middle ear becomes blocked with fluid.	b) Nasal discharge	b) Tonsillitis/Esophagitis: sometimes requiring surgical removal of the tonsils, usually in childhood.
c) Age related hearing loss	c) Nasal injuries	c) Hoarseness and laryngitis
d) Tinnitus (ringing in the ears) and eustachian tube dysfunction	d) Nasal polyps/tumors	d) Swallowing problems
e) Dizziness and vertigo	e) Nasal obstruction	e) Upper airway breathing problems
f) Ear infections	f) Disorders of the sense of smell	f) Snoring and obstructive sleep apnea (when breathing stops during sleep)
g) Perforated ear drum and cholesteatoma	g) Allergic rhinids/catarrh	g) Cancer of larynx/vocal code
h) Presbycusis	h) Bloody discharge or epistaxis	
i) Mener's syndrome		
j) Vestibular neuronitis		
k) Acoustic neuroma		

## 2.3 Related Work

Several works have been carried out in ENT related diseases diagnosis using computational intelligence. The Artificial Neural Network (ANN) and other methods were applied. Dunmade et al. [32] designed software system for diagnosis and classification of deafness, developed using a numerical scheme. The software helps otolaryngologist in determining the severity of deafness in each individual patient case. Igbinsosa [33] proposed an algorithm based on the neural network self-organizing map (SOM) and the traditional image processing to develop a technique for the extraction of healthy maxillary and ethmoid sinuses. The performance results illustrated that their work, Sinus extraction system (SES) performs reasonably well in extracting the region of interest. Its major advantage is that it is automatic, and the users have the choice of selecting any class in sampling.

Alonzo et al. [34] developed ENTDEX: ENT Diagnosis Expert System using Bayesian Networks to diagnose common ENT diseases based on the given symptoms and to help people to know more about ENT diseases. This system used Bayesian Networks in the diagnosis phase. The authors conclude that ENTDEX can identify the person if he/she has an ENT disorder and detect a person with no disorder. Yoganathan and Kajanan [30] proposed “Virtual Doctor” which is an ENT diagnostic system that uses rule-base for knowledge representation and has five core subsystems which enhance the physician’s ability in reaching a diagnosis decision with confidence. Symptoms are initially captured through the user interfaces as inputs thereafter the symptoms are matched with inference rules in the knowledge base and finally a diagnosis is made by the inference engine.

Naim et al. [35] presented another “Virtual Doctor” a diagnostic expert for the management ENT related diseases. It uses rule-based system for knowledge representation and has sub-systems which can enhance the physician’s ability in reaching a diagnosis decision with assurance. Livingstone and Chau [36] employed an automated ML approach to develop a computer vision algorithm that on average matches the accuracy of the doctors they evaluated. Images of otoscopes were retrieved from Google Images. The algorithm’s accuracy of 88.7% in analyzing fourteen different otologic diagnoses was higher than the average physician accuracy of 58.9%. Cha et al. [3] offered a large otoendoscopy image database and ensemble deep learning for an automated diagnosis of ear condition. Nine publicly available convolution-based deep neural network models were trained in their work using a total of 10,544 otoendoscopic pictures to classify eardrum and external auditory canal features into six categories of ear illnesses, representing the majority of ear diseases. Their work showed that for the 5-folds cross-validation is on average 93.67%. They concluded that their work is unparalleled in terms of illness diversity and diagnostic precision, and it matches or exceeds the performance of a typical otolaryngologist. Zeng et al. [37] presented an efficient and accurate diagnosis system of ear disorders using an ensemble deep learning model. The ML model was able to classify eight different types of ear disorders by using 20,542 plentiful otoscope image data collected from clinical cases to obtain an automatic diagnosis of ear diseases in real time. The developed model proved extremely helpful in the early diagnosis and treatment of ear disorders.

This research proposes a system that represents a medical decision support system (MDSS) for ENT diseases with multi-class diagnosis based on Naïve Bayes algorithm which gives results with high accuracy, description of the disease detected, information about causes of disease, an explanation subsystem, and a final recommendation for therapy.

## 3. MATERIAL AND METHODS

### 3.1 Modelling of the Proposed System

The proposed system was modelled using two standard unified modeling language (UML) tools, use case and class diagram as shown in Figures 1 and 2.

### 3.2 Proposed System Architecture

The proposed system is a collection of facts and rules and other knowledge about ENT disease which is used to make inferences in the field based on Naïve Bayes rules. The components in the system structure includes knowledge base, inference engine user interface and the explanation subsystem. The explanation Subsystem explains the system actions results and recommendations. The system diagnosis is based on a causal explanation of what is happening to the patient, and therapy is based on predictions about the disease.

Naïve Bayes is an algorithm that uses probability-based checks to discover diseases using the class conditional probability. It determines which disease of probability high than its bias on the disease and gives the result of the highly probable disease [12]. Wasyluk and Druzdzal [38] further stated that it is used in calculating the probability of a disease in light of specific evidence from a prior probability of the disease and the conditional probabilities relating the observations to the diseases in which they may occur. The main advantages of Naïve Bayes over other artificial intelligence schemes for reasoning under uncertainty is that they readily combine existing frequency data with expert judgment within the probabilistic framework and they readily model simultaneous presence of multiple disorders. Chandrasekhar et al [39] presented the Bayes rule in Equation (1).

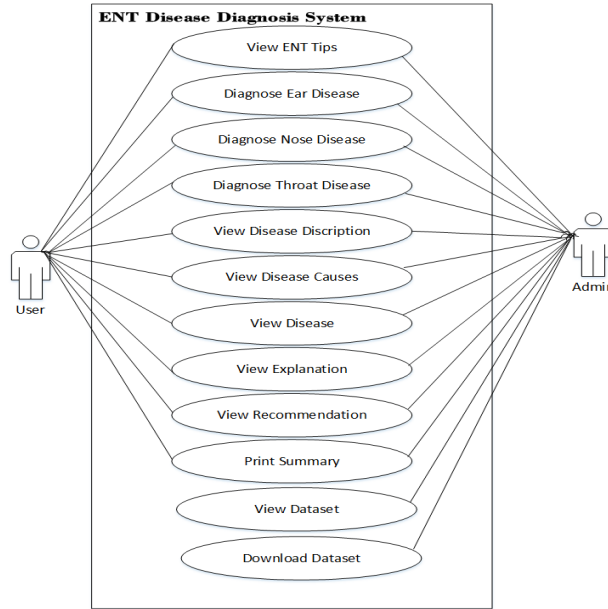


Figure 1. ENT system use case

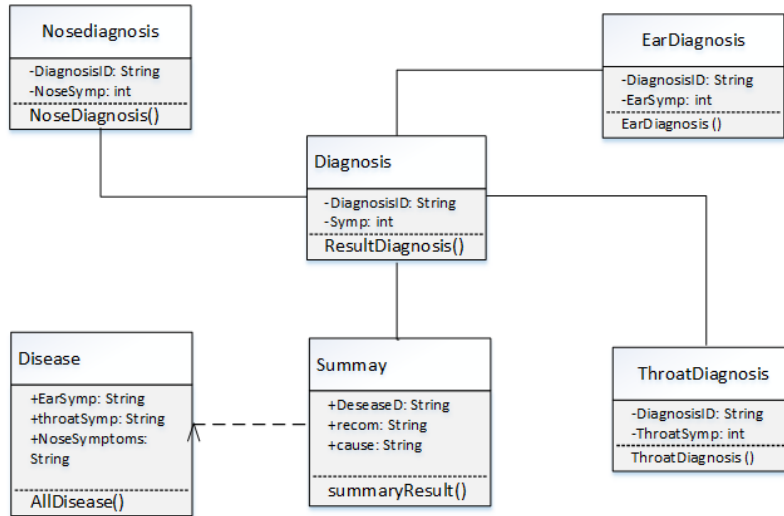


Figure 2. Proposed ENT system class diagram

$$P(a\backslash b) = \frac{P(b\backslash a) \times P(a)}{P(b)} \tag{1}$$

where  $P(a\backslash b)$  is the posterior,  $P(b\backslash a)$  is the likelihood,  $P(a)$  is the prior and  $P(b)$  is the normalization. Useful for assessing diagnostic probability from causal probability shown in Equations (2) and (3).

$$P(Cause|Effect) = \frac{P(Effect|Cause) \times P(Cause)}{P(Effect)} \tag{2}$$

It is applicable in medical diagnosis as depicted in Equation (3).

$$P(Disease|Sympton) = \frac{P(Sympton|Disease) \times P(Disease)}{P(Sympton)} \tag{3}$$

Figure 3 shows the Naïve Bayes algorithm. The flow of the proposed system was divided into three sections, namely Ear, Nose, and Throat disease diagnosis. Each section encompasses questions and choices that serve as the data to be processed by the Naïve Bayes algorithm used in order to have the diagnosis results. Figure 4 shows the proposed system architecture. Hypertext pre-processor (PHP), Java script and MySQL were the programming technologies used to implement the system.

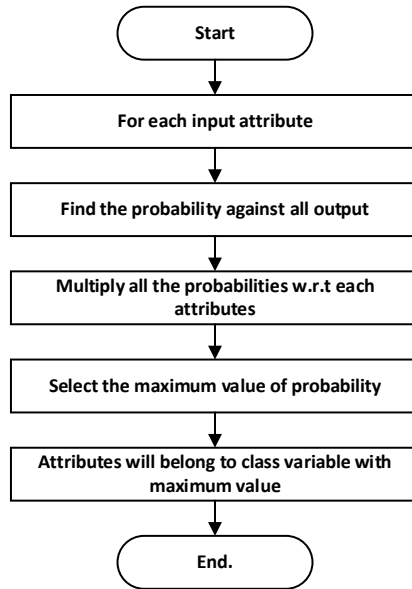


Figure 3. Naïve Bayes algorithm [12]

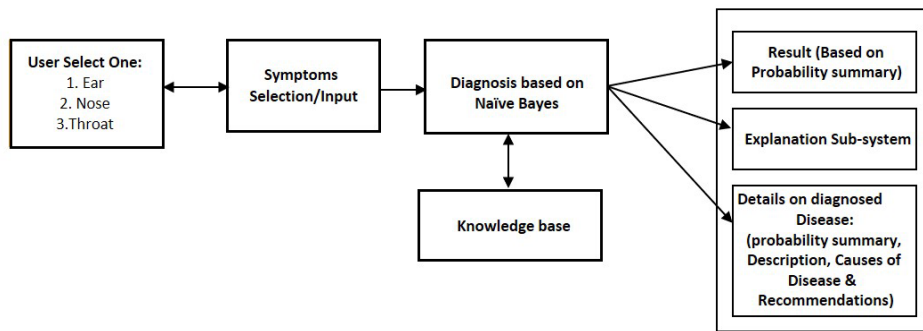


Figure 4. Proposed ENT diagnostic system

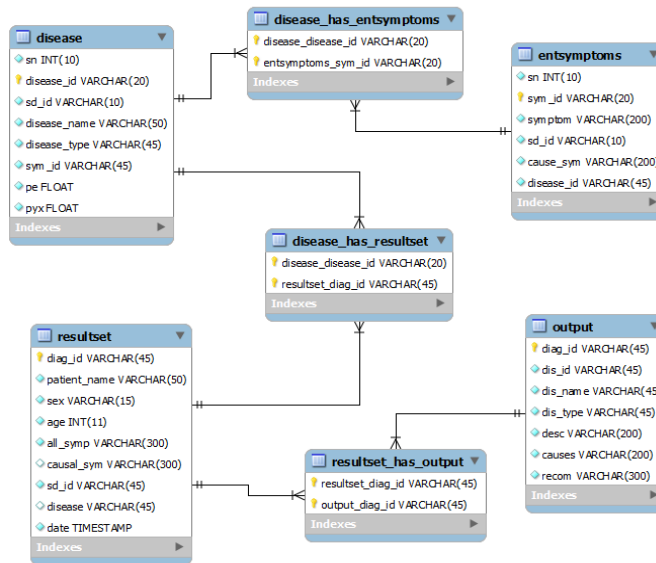


Figure 5. Entity relationship diagram for the proposed ENT system

### 3.3 System Design

This phase develops the technical blueprint and specification required to implement the final solution. The blueprint is then used in implementing the system required inputs, outputs, processes and databases. Entity-Relationship (E-R) model design for the proposed system which defines the conceptual view of a database is shown in Figure 5.

Table 2. Samples test cases

Test Case ID	Test Objectives	Description	Expected Outcome
Diag1	Hearing loss ear disease	Testing the system to diagnose hearing loss ear disease	Hearing loss ear disease diagnosed.
Diag2	Presbycusis ear disease	Testing to diagnose Presbycusis ear disease	Presbycusis ear disease diagnosed.
Diag3	Otitis media ear disease	To test if the system can diagnosis specifically Otitis media ear disease	Otitis media ear disease diagnosed.
Diag4	Labyrinthitis Ear Disease	Testing to diagnose Labyrinthitis ear disease	Labyrinthitis ear disease diagnosed.
Diag5	Acute Sinusitis nose disease	Testing the system to detect Acute Sinusitis nose disease	Acute Sinusitis nose disease detected.
Diag6	Chronic Sinusitis nose disease	Testing to diagnose Chronic Sinusitis nose disease	Chronic Sinusitis nose disease diagnosed.
Diag7	Snoring nose disease	Testing to detect Snoring nose disease	Snoring nose disease detected
Diag8	Gastroesophageal Reflux (GERD) throat disease	Testing to detect Gastroesophageal Reflux (GERD) throat disease.	GERD throat disease detected.
Diag9	Laryngitis throat disease	Testing to diagnose Laryngitis throat disease.	Laryngitis throat disease diagnosed.
Diag10	Sore throat disease	Testing to diagnose Sore throat disease	Sore throat disease diagnosed.
Diag11	Laryngopharyngeal reflux (LPR) throat disease	To test if the system can diagnose Laryngopharyngeal reflux (LPR) throat disease	LPR throat disease diagnosed.
Diag12	To test for invalid/incomplete selection of system.	Testing to determine if the system can give an error message when incomplete symptoms are selected.	Error message displayed.
Diag13	To get explanation for the diagnosed disease	Test if the system can diagnosis any ENT disease and show explanation for the result.	To get explanation for the detected disease.
Diag14	Get information about ENT disease from the system.	To test if the system can offer useful ENT information to the user	Get general information about ENT disease from the system.

## 4. TESTING AND RESULTS

### 4.1 Program Testing

Testing is the process of evaluating a system or its component(s) within the intent to find whether it satisfies the specified requirements or not. The developed system was extensively tested with several test cases developed of which a sample of it is shown in Table 2.

### 4.2 Results

The testing carried out showed that the application was able to diagnose numerous Ear, Nose and Throat related diseases. Table 2 is a sample test case of the various testing carried out on the system. Figures 6, 7 and 8 show sample displays when ear, nose and throat diseases were diagnosed respectively. The system was also able to provide detailed explanation on each diagnosed disease and equally made available useful information about ENT diseases. Figures 9 and 10 show examples with the GERD disease.

The developed system could identify any ENT condition based on chosen symptoms, according to the test findings shown in the results obtained based on the sample test cases listed in Table 2 using the Naïve Bayes algorithm. The probability of the occurrence of each disease was also specified. The results showed that the system was able to diagnose the diseases with probability as in Table 3. The developed system also supplied helpful information on ENT disorders, displayed information about gastroesophageal reflux disease (LPR) throat disease discovered, and explained why the outcome occurred using backward chaining to identify the precise causal symptoms from the user-selected symptoms. Following the system's ability to diagnose ENT diseases, recommendations for treatment were also made available. The system has high accuracy (>90%) and it is consistent and reliable for ENT diseases detections.

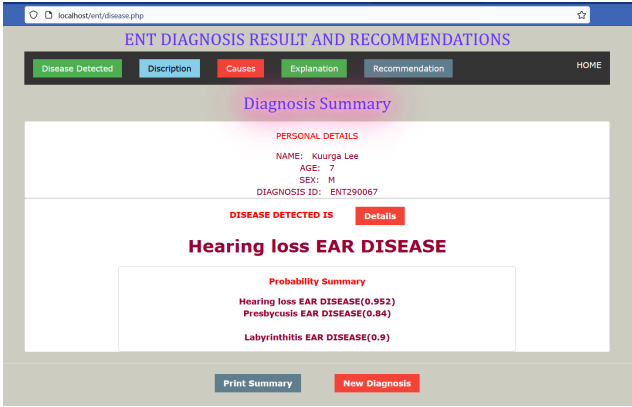


Figure 6. Ear disease (hearing loss) tested

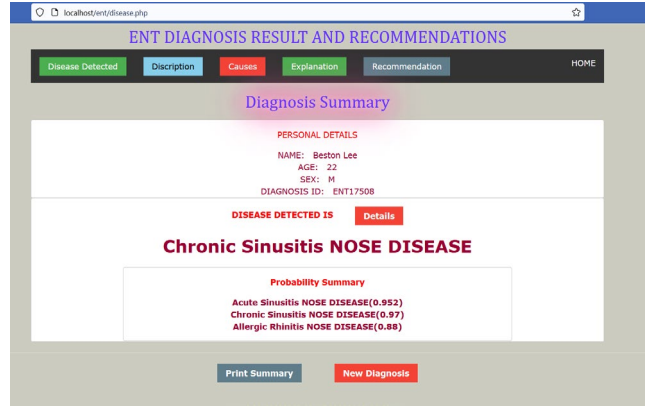


Figure 7. Nose disease (Chronic sinusitis) tested

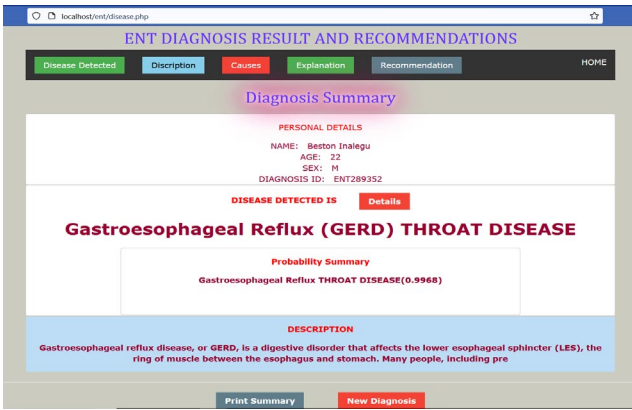


Figure 8. Throat disease (GERD) tested

Table 3. Probability of diagnose

	Disease	Probability
Ear disease	Hearing loss	0.952
	Presbycusis	0.960
	Otitis media	0.980
	Labyrinthitis	0.982
Nose disease	Acute Sinusitis	0.990
	Chronic Sinusitis	0.970
	Snoring	0.980
Throat disease	GERD	0.996
	Laryngitis	0.990
	Sore throat	0.940
	LPR	0.988



Figure 18. GERD throat disease

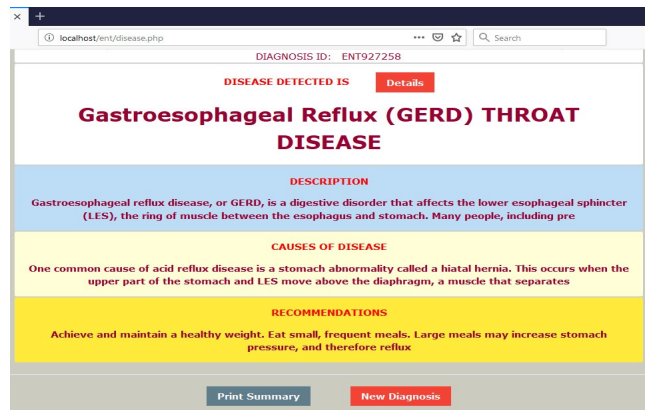


Figure 19. GERD throat disease details

## 5. CONCLUSION

To identify common adult ENT problems based on the provided symptoms and to educate individuals about ENT diseases, the ENT disease diagnosis system employing Naive Bayes algorithm was developed. Additionally, the research was designed to aid ENT patients and professionals in the diagnosis of ENT related diseases. The developed app was tested, and it was able to diagnose several ENT diseases while indicating the probabilities of occurrences. The ongoing system usage expands the knowledge base producing a data set for further test cases. Explanation system was also an added advantage to this system. As some ENT diseases can affect other parts of the human body which can also result in myriad diseases, more research be done in the future to create a system that may output more combinations of these diseases. To determine how best to implement such a system for improved output, additional ML techniques can be used, including Artificial Immune Systems, Neuro-Fuzzy, Support Vector Machine, Genetic Algorithms, and Decision Trees.

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