# ENTDEx: ENT Diagnosis Expert System Using Bayesian Networks

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*Abstract*—**Before, if a person felt something unusual with their senses, their only choice is to go to a clinic or a hospital in order to know what they are feeling. But because of the continuous advancement in the technology, people are now able to know what their probable disease just by using their smart phones and an application capable of diagnosing diseases. This kind of innovation gave rise to the researchers in creating ENTDEx: ENT Diagnosis Expert System using Bayesian Networks, a system developed to help ENT patients and non-patients to diagnose common adult ENT diseases based on the given symptoms. This application uses Bayesian Networks in diagnosing the diseases. Based on the series of surveys and experiments conducted by the researchers, ENTDEx has a good feedback to its users as it provides the necessary information the users needed specifically in the field of otolaryngology.**

*Index Terms*—**Bayesian networks, expert systems, sensitivity, specificity.**

## I. Introduction

According to an article about early diagnosis, pre-diagnosis are more accurate early in the disease process. A more accurate diagnosis is possible when a complete history can be taken early in the disease process, while the person is still able to answer questions and recall the order in which symptoms first appeared. Individuals diagnosed early in the disease process can take advantage of early-stage support groups and learn tips and strategies to better manage the disease [1]. Otolaryngologists diagnose and cure Ears, Nose, Throat (ENT) disorders. At the present time, there are certain ways to identify ENT ailments. One of those can be old-style way or ENT diagnosis and because of the application of technology and gadgets available today, the idea of expert system had arouse.

With more research being done, and greater worldwide interest in expert systems and mobile applications about medicine, the proponents motivated to develop an ENT diagnosis expert system because people nowadays have been more health conscious. It causes the self-diagnosis tool (e.g. website, application, device etc.,) to be increasingly demanded by the public. Besides that, the doctor consultation fee is increasing which is a burden to patients with low income though dealing with only ENT common diseases. The developed system will be able to diagnose ENT common disorders based on the symptoms and will provide the suitable treatment based on the diagnosis result.

Expert systems are knowledge-based systems and are computer programs that simulate the chain of reasoning of an expert in a specific problem domain, or clarify uncertainties where normally one or more human experts would need to be consulted [2]. Expert systems are not only helping us, but acting as a smart human full of knowledge and giving us advice in many areas, where it is impossible to have many humans do the same thing. The main purpose of an expert system is to provide the solution to a problem when it is needed, sometimes in a matter of seconds. Because of this use, performance has increased in business, science, government and other fields. Expert systems due to their knowledge can take accurate and quick decisions and can provide assistance to all professionals [3].

According to a book entitled Encyclopedia of Statistics in Quality and Reliability, Bayesian Networks are graphical structures that are used to represent knowledge about an uncertain domain. In particular, each node in the graph represents a random variable, while the edges between the nodes represent probabilistic dependencies among the corresponding random variables. These conditional dependencies in the graph are often estimated by using known statistical and computational methods. Hence, Bayesian Networks combine principles from graph theory, probability theory, computer science, and statistics [4].

The impressive performances of expert systems and Bayesian Network in the field of medicine have become a factor that leads the researchers in an idea of piecing the two ideas together.

## II. Background of the Study

Expert systems are computer programs that are derived from a branch of computer science research called Artificial Intelligence [5]. These programs use a collection of facts, rules of thumb, and other knowledge about limited field to help make inferences in the field. This differ substantially from conventional computer programs in their goals may have no algorithm solution, and they must make inferences based on incomplete or uncertain information. They are called expert systems because they address problems that normally require human specialists and knowledge for solution.

There are three basic components in the expert system structure which are Knowledge Base, Inference Engine and User Interface. Knowledge base has a description of the elements in the process along with their characteristic, function, and relationships. These are set out in logical statements. It may also contain rules about the actions to be

Manuscript received February 9, 2014; revised March 20, 2014.

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DOI: 10.7763/JACN.2014.V2.108

set into motion as a result of certain events. The knowledge base can also obtain its information from external programs and databases. When dealing with a particular task or problem, the system constructs a number of hypotheses based on the external information supplied, its own knowledge, and the rules in the knowledge base. Inference engine is the software which uses the knowledge represented in the knowledge base to draw its conclusions. The design of the inference engine may limit the ways in which knowledge can be represented in the knowledge base so that certain shells are only suitable for particular types of application. User interface varies widely according to the application. The basic criterion for the user interface is that the user should be able to interrogate the system about the reason for its conclusion [6].

Expert systems in medicine are the computer programs used to support clinical decision making. They deal with medical data about patients and the relative medical knowledge that is necessary to interpret such data. These systems are divided into three types: systems for information management, systems for focusing attention, and systems for patient-specific consultation [7]. An example of this is MYCIN that used artificial intelligence to identify bacteria causing severe infections, such as bacteremia and meningitis, and to recommend antibiotics, with the dosage adjusted for patient's body weight [8]. Another is Heart Disease Program (HDP) that covered most areas of heart diseases. Its purpose is to assist physicians in the diagnosis of patients with heart disease [9]. Automated Health Diagnosis and Medical Record System is also an example of expert system wherein the user will input what's wrong about he/she feels and it will then show the possible sickness and if possible, output the possible cause/s [10]. Banggad *et al*. developed a mobile skin disease detector and solution provider for patients who have common types of skin. It presents the information about the skin disease, together with its proper name, the percentage of how definite the diagnosis is and gives proper tips on how to cure and prevent the disease [11].

Since the beginning of expert systems technology, knowledge acquisition and representation have been considered the major constraint in the development of expert systems in the medical field [12]. Thus, diagnosis is based on a causal explanation of what is happening to the patient, and therapy is based on predictions about how the disease process can be modified. One of the knowledge models people have used in medicine is Bayesian Networks.

Bayesian network is a mechanism to calculate the probability of a disease, in light of specified evidence, from the a priori probability of the disease and the conditional probabilities relating the observations to the diseases in which they may occur. The main advantages of Bayesian networks 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 [13]. In relation to medical expert systems, this means they can state the probability that a patient has a disease based upon personal information, existing symptoms, and the results from tests. Additionally, Bayesian networks can encode expert information and patient data unlike early methods used in medical expert system [14].

ENTDEx mainly uses the Bayes' Theorem (1) which expresses the posterior probability that is expressed on some prior knowledge.

$$P(H|E) = \frac{P(E|H)*P(H)}{P(E)} \tag{1}$$

The formula is shown above, where in:

$P(H|E)$ =Probability of the hypothesis given the evidence.

$P(E|H)$ =Probability of the evidence given the hypothesis.

$P(E)$ =Marginal Probability or the Probability of the evidence.

$P(H)$ =Probability of the hypothesis.

$H$ =Hypothesis.

$E$ =Evidence.

Mobile computing systems are computing systems that may be easily moved physically and may be used while users are on the move. Examples of mobile devices are such as laptops, personal digital assistants (PDAs), mobile phones and smart phones. As devices become smaller and more portable, the demand for computing and networking solutions while on the move has increased steadily. Recently, with the wide acceptable usage of smart phones on the cellular phone market makes individual person to carry their personal computing device everywhere. It is estimated that currently over one quarter of the world's population owns a cell phone. Thus, the dissemination of knowledge within the mobile computing is widely accepted which makes information accessible without geographical barrier. The easy access to the information is important to accommodate the needs in this new technology era [6].

Nureize Arbaiy and Chong See Tong developed a Medical Diagnosis Expert System (MDES) based on Traditional Chinese Medicine (TCM) to help users to identify common disease based on the observed symptoms. This system is able to perform diagnosis in order to identify disease infection based on given symptoms. It is chosen to be developed in android platform because people can reach it easily since many people in most countries have android phones; also installation of this application is quick and easy. This system used Forward Chain Technique that works from the fact IF to the information THEN [6].

On the other hand, ENTDEx also diagnoses diseases by asking a set of questions that were frequently asked by the otolaryngologist or ENT experts when they do an actual check-up to a patient. Once the diagnosing is done, it gives the user the information they needed to know more about the disease. Aside from that, it also gives the user some recommendations that they can do in the comfort of their own home. This will be implemented on a mobile platform so that it will be more accessible for more users, particularly the ENT patients.

## III. The Developed System

ENTDEx: Ears, Nose, Throat Diagnosis Expert System using Bayesian Networks can diagnose the probable disease based on the answers given by the user in each question.

The system gives information and recommendation about the result of the diagnosis. Take note that ENTDEx will not give any branded medicine for the medication of the patients; it will only recommend simple approaches on how to deal with the disease on a day to day basis.

The system also has an ENT dictionary for uncommon words (e.g. drooling, tripod position, diaphoresis, pinna, otitis externa). There will be no retrieval of records for the reason that the study will only focus on the diagnosis of ENT diseases. ENTDEx can be implemented in Android OS with versions 2.3 up to the latest version.

### *A. System Architecture*

The flow of the system is divided into three sections, namely **Word Help** that functions as a dictionary for the uncommon terms that is found on the application, **Diagnosis Section** that composed of questions and choices that serve as the data to be processed by the algorithm used, and the **Bayesian Network Process** for the detailed procedure on how the answers are calculated in order to have the diagnosis results.

ENTDEx starts with a menu wherein the user should choose among Word Help, Start Diagnosis, Instructions, or about button. Start Diagnosis function is explained in the second section of the system's process. Instructions part shows the step-by-step process on how to use the system while about portion displays information about the application itself and its developers.

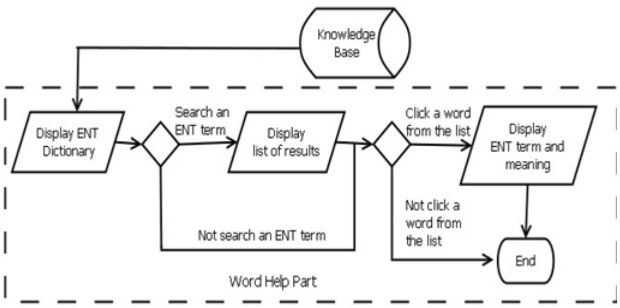


Fig. 1. Word help.

Word Help is an ENT dictionary that contains different ears, nose, and throat terms and other related terms.

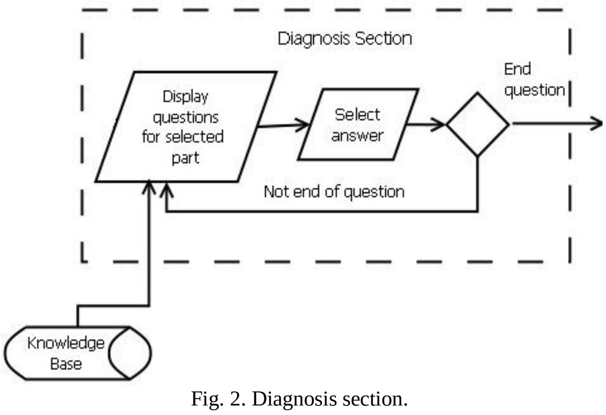


Fig. 2. Diagnosis section.

In Fig. 2 which shows the Diagnosis Section, the list of ENT disorders, ENT symptoms, causes, description of the disorder and recommendation are populated in the database for android phones (SQLite). There are (14) fourteen common ENT diseases stored in the knowledge base such as Presbycusis, Meniere's disease, Otitis Media, Otitis Externa, Labyrinthitis for ears, Acute Sinusitis, Chronic Sinusitis, Allergic Rhinitis for the nose and Mononucleosis, Laryngopharyngeal Reflux Disease, Epiglottitis, Acute Tonsilo Pharyngitis, Laryngitis, Pharyngitis for the throat. All of these are common adult (18 and above) ENT diseases. The questions and its corresponding choices are also stored in the database. The questions for each part will be fetched from the knowledge base and then displayed in the screen. User must select the answer from the questions displayed on the screen. He/she cannot go back to the previous question. This will continue until the last question is asked. Once all the questions are answered, the process will then go to another section, the Bayesian Network Process which is shown in Fig. 3.

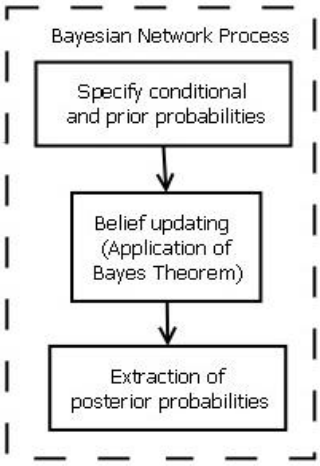


Fig. 3. Bayesian network process.

In the Bayesian Network Process, the first step is to specify the conditional and prior probabilities. Prior probability is the probability of the event computed before the collection of new data while conditional probability is the probability that an event will occur, when another event is known to occur.

Fig. 4-Fig. 6 show the network structure for the ears, nose and throat respectively. The nodes represent the symptoms to each diseases and every node corresponds to a probability that the user will answer a yes and a probability that the user will answer a no.

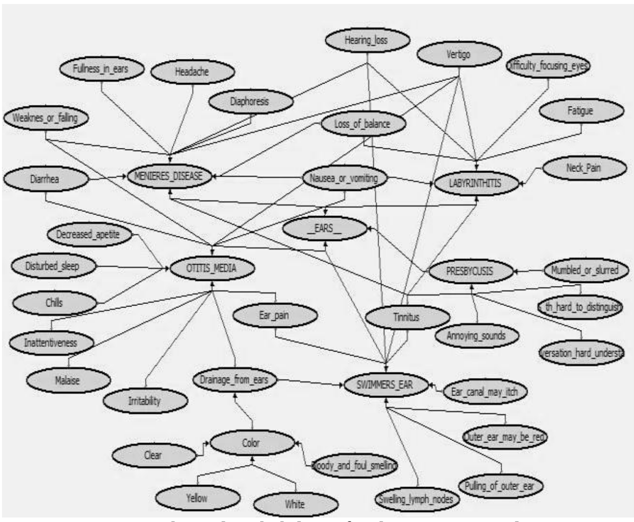


Fig. 4. Networks and probabilities for diagnosing ear diseases.

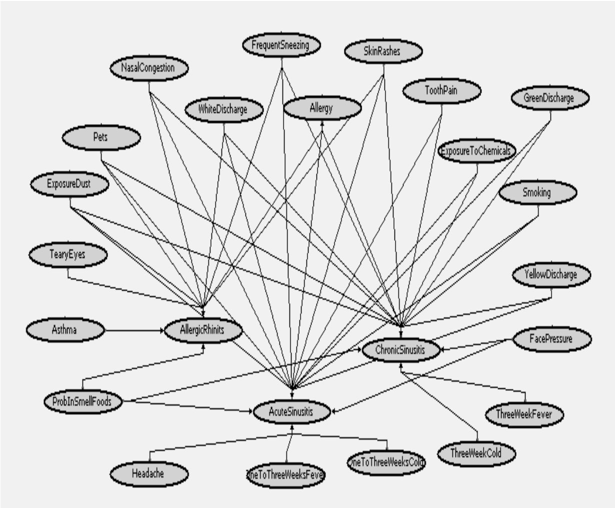


Fig. 5. Networks and probabilities for diagnosing nose diseases

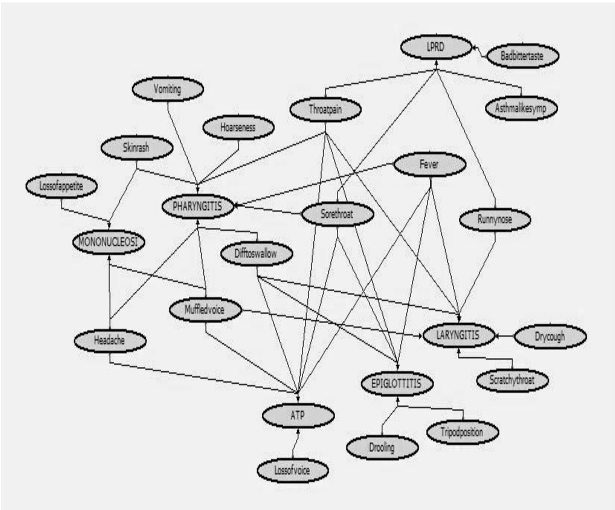


Fig. 5. Networks and probabilities for diagnosing throat diseases

Most of the questions in the system are answerable by YES or NO. But at some point in the diagnosis part, the user is presented with different choices. The user must choose on which of those symptoms the user actually felt. The answers from each question (symptoms) corresponds a probability to detect the disease. The links between the symptoms specifies conditional and prior probabilities. Each question and answer depends on each other.

Once all questions are answered, the Belief Updating Process will be the next step. In particular, when we observe the value of some variable, we would like to condition upon the new information. The process of conditioning (also called probability propagation or inference or belief updating) is performed via a "flow of information" through the network. In the probabilistic system, this becomes the task of computing the posterior probability distribution for a set of query nodes, given values for some evidence (or observation) nodes [15]. Marginal Probability (2) or $P(X)$ will be needed that can be computed by summing joint probabilities over $X$ or $Y$. Marginal Probability as shown in (1) can be computed as follows:

$$P(X) = P(X|Y)P(Y) + P(X|{\sim}Y)P({\sim}Y) \qquad (2)$$

where:

$P(X)$ = Marginal probability or the Probability of the disease

$P(X|Y)$= Probability of the disease given the symptom

$P(Y)$ = Probability of the symptom

$P(X|{\sim}Y)$ = Probability of the disease given that the symptom is not really the symptom

$P({\sim}Y)$= Probability that the symptom is not really the symptom

After getting the Marginal Probability, the system will go to the computation of the probability of the disease using the Bayes' Theorem (3).

$$P(Y|X) = \frac{P(X|Y)P(Y)}{P(X)} \qquad (3)$$

where:

$P(Y \mid X)$ = Probability of the symptoms given the disease

$P(X \mid Y)$ = Probability of the disease given the symptom

$P(X)$ = Marginal Probability or the Probability of the disease

$P(Y)$ = Probability of the symptom

$X$ = Disease

$Y$ = Symptom

The computation between the conditional probability of the two events (ENT symptoms and causes) and (ENT disorders) is divided by the prior probability; the probabilities that are not conditioned on other answers. The posterior probability or the result will be extracted until it reaches the correct disorder. The belief updated result would be the possible percentage of how certain the disorder is.

After the computations by the Bayes' Theorem, the name of that ear, nose, or throat disorder with the highest probability based on the computation using the Bayes' rule will be the possible ENT disease of the user.

## IV. System Implementation and Testing

The target users of this application are otolaryngologists or ENT experts and its patients, and other people (non-patients) who want to diagnose their ears, nose, or throat. The proponents chose to use the selected population of the otolaryngologists in University of the East Ramon Magsaysay Memorial Medical Center, Incoporated (UERMMMCI) to assist the evaluation of system's performance in terms of correctness and adequacy of contents. The proponents also worked with patients from said hospitals to assess the user-friendliness and usefulness of the mobile application. The researchers also used experimentation for sensitivity and specificity of ENTDEx.

A survey was conducted to five (5) resident doctors and thirty-seven (37) ENT patients from UERMMMCI. The researchers also conducted the sensitivity and specificity experiment in the said hospital.

On the the implementation and testing of ENTDEx, various statistical methods and computations are provided and conducted to achieve the desire ouput. First is the Likert Scale that is primarily used in questionnaires to obtain participant's preferences or degree of agreement with a statement or set of statements [16]. The respondents evaluated the developed system using the five-point rating scale which is based on the Likert scale on Table I.

TABLE I: LIKERT SCALE

| Scale | Range | Description |
|---|---|---|
| 5 | 4.50 – 5.0 | Strongly Agree |
| 4 | 3.50 – 4.49 | Agree |
| 3 | 2.50 – 3.49 | Neutral |
| 2 | 1.50 – 2.49 | Disagree |
| 1 | 1.0 – 1-49 | Strongly Disagree |

Second, sensitivity and specificity were used to determine the effectiveness of a test, especially medical tests in the diagnosis of a disease. Sensitivity shows the test's ability to diagnose correctly the patients with the disease, while specificity determines the test's ability to determine the patients who do not have the disease, or are disease-free [17]. Fifty-two trials (52) were conducted to test the sensitivity and specificity of ENTDEx.

TABLE II: ASSESSMENT OF ENT PATIENTS FOR USER-FRIENDLINESS AND USEFULNESS OF ENTDEX

| Criteria | Average Weighted Mean | Rating |
|---|---|---|
| User-friendliness | 4.31 | Agree |
| Usefulness | 4.42 | Agree |

Table II shows the assessment of ENT patients from UERMMMCI on the developed system. ENTDEx got an Agree rating in user-friendliness and usefulness.

TABLE III: ASSESSMENT OF OTOLARYNGOLOGISTS FROM UERMMMCI PER CRITERIA FOR EARS, NOSE, THROAT AND OTHER SPECIFICATIONS OF ENTDEX

| Criteria | Ears | | Nose | | Throat | | Others | |
|---|---|---|---|---|---|---|---|---|
| | M | DC | M | DC | M | DC | M | DC |
| Correctness of Results | 2.53 | N | 2.67 | N | 2.47 | D | 2.67 | N |
| Adequacy of Contents | 2.47 | D | 2.60 | N | 2.67 | N | 2.53 | N |

Legend: M = Average Weighted Mean
DC = Decision
N = Neutral
D = Disagree

Table III presents the assessment of the otolaryngologists from UERMMMCI on the developed system. ENTDEx got Neutral and Disagree ratings in terms of correctness and adequacy of contents respectively; specifically in ears and throat part for the reason that ENTDEx did not satisfy the standards of the experts.

TABLE IV: SUMMARY OF TESTING FOR SENSITIVITY OF ENTDEX

| True Positive | False Negative | Sensitivity Result | Sensitivity Result |
|---|---|---|---|
| 23 | 3 | 88.46% | 11.54% |

Table IV displays the summary of results in sensitivity testing based on the experimentation done. The test is true positive when the patient has a disease and ENTDEx diagnosed it positively while a false negative test result is when the patient has a disease but ENTDEx didn't diagnose the disease. The researchers obtained 88.46% sensitivity. This implies that ENTDEx is capable of diagnosing the right disease that the patient has.

TABLE V: SUMMARY OF TESTING FOR SPECIFICITY OF ENTDEX

| True Negative | False Positive | Specificity Result | Specificity Result |
|---|---|---|---|
| 11 | 15 | 42.31% | 57.69% |

Table V shows the summary of results in specificity testing based on the experimentation done. The test is true negative when the patient doesn't have a disease and ENTDEx diagnosed it correctly while a false positive test result is when the patient doesn't have a disease but ENTDEx didn't diagnose it. By using the formula to get the specificity, the researchers got 42.31% which implies that ENTDEx is not capable enough to identify whether the user doesn't have a disease.

TABLE VI: ACCURACY OF ENTDEX

| True Positive | True Negative | False Positive | False Negative | Accuracy |
|---|---|---|---|---|
| 23 | 11 | 15 | 3 | 65.38% |

Table VI presents the overall accuracy of the system based on true positive, true negative, false positive, and false negative. The researchers calculated the accuracy based on the number of correct assessments which is thirty-four (34) over the total number of assessments which is fifty-two (52). ENTDEx is capable in detecting ENT diseases and sensing that the person doesn't have the certain disease is 65.38%.

## V. CONCLUSION AND FUTURE WORKS

ENTDEx: ENT Diagnosis Expert System using Bayesian Networks is developed to diagnose common adult ENT disorders based on the given symptoms and to help people to know more about ENT diseases. After series of experimentations and calculations, the researchers therefore conclude that ENTDEx is able to identify a person with an ENT disorder and detect a person with no disorder. In terms of correctness of results, ENTDEx needs to be more certain in diagnosing diseases based on the gathered data. In terms of the adequacy of contents of the system, ENTDEx needs to provide more adept information and explanation about the disease. In terms of user-friendliness and usefulness, ENT patients find it attractive and an interesting mobile application based on the facts that were shown to them.

For future works, ENT doctors recommended to make the questions in the database more specific for each ENT part. In addition, the proponents suggested to add more medical or Ears, Nose, Throat terms for the Word help, improvement of the performance by using other algorithms to diagnose diseases, implement this mobile application in other operating systems like iOs and Windows, improve the Graphical User Interface (GUI) of the application to provide more appropriate look in relation to medical field and add more illustration, put additional features in the application (e.g. the user can save the diagnosed results), improve on the field of specificity wherein the system should not be able to detect a person without any ENT disorder, and make a Tagalog version of ENTDEx to help other user to understand it very well.

## ACKNOWLEDGMENT

The researchers would like to express their deepest gratitude to Prof. Renato Apa-ap, Prof. Patrick Sta. Maria and Prof. Rhea Bernardino of the faculty of College of Science for guiding the proponents to evaluate the data gathered from the respondents and to calculate the probabilities using Bayes' Theorem. The authors would also like to convey thanks to Dr. Alonso of University of the East Ramon Magsaysay Memorial Medical Center, Incorporated for guiding the proponents on making the questions and choices in the application for easier understanding of the patients and other users of the system, and providing references for the ENT diseases, details, and recommendation despite of her toxic schedule. In addition, the proponents acknowledge University of the East Ramon Magsaysay Memorial Medical Center, Incorporated (UERMMMCI) for letting the researchers implement ENTDEx to their ENT patients and otolaryngologists.


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