Diagnosing Oral Ulcers with Bayes Model

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Abstract. An oral ulcer is considered an ulcer that occurs on the mucous membrane of the oral cavity. Its treatment however poses a serious challenge as experts in this area of family health care are rare. In order to affirm this claim, questionnaire was designed and distributed to get up-to-date information concerning the ailment, particularly its treatment, causes, and solutions among others. An expert system seeks to mimic the functions and capabilities of a real life expert. This means that just as the expert is domain specific, the expert system as well is domain specific. It consists of a user interface, a knowledge-base, a fact-base, and an inference engine; all working together to mimic an expert. Bayesian inference was used in this work to factor in probability as it is well known that the fact that one is experiencing the symptoms of a disease does not absolutely mean that one has that disease. The domain of this expert system is oral ulcer and it focuses on four common oral ulcers which include: Cold sores, Gingivostomatitis, Herpangina as well as Neutropenia. The application which was designed with Object-Oriented Analysis and Design methodology was implemented with java programming language, provided on the Netbeans 8.0.2 IDE.

Keywords: Expert system · Oral ulcers · Diagnosis · Bayes' theorem

1 Introduction

Artificial intelligence [19] is the aspect of Computer Sciences that is concerned with solving problems using non-algorithmic, and symbolic methods. One of some of its branches is the Expert System. An expert system in itself is a system that is able to mimic an expert [23]. This implies that the system should be able to do what that expert can do. In other words, an expert system is an intelligent system that follows a theoretical knowledge of an expert, and gives inferences just like the expert does [13].

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Oral ulcers are common place disorders of the mouth. It is commonly referred to as a breach in the oral epithelium [24]. It exposes nerve endings in the underlying lamina propria which results in sores in the mouth preventing one from the want to eat something that contains pepper [20].

With advancement in technology, researchers, as well as industries, have been able to bring to us an advancement in artificial intelligence [29]. This work well done introduced expert systems into the world of dental informatics [22]. An era of advanced dentistry has now come upon us with the arrival of this new paradigm in the delivery of dental health care. The application of expert systems to dentistry cannot be overemphasized [30]. One of such is the subject of this work. This work aims at developing of an expert system that is capable of imitating the role of a dental expert in the diagnosis of oral ulcers.

With the advent of dental informatics, it is essential to begin improving dental research and treatment using information technology tools [27]. One of such tools is the expert system [25]. In the case of this project, the problem that is being solved is that of the development of an expert system that diagnoses common oral ulcers as well as provide useful information in treating them [26]. Also, the basic theories involved will be clearly expressed. Expert systems will be looked at closely vis a vis: history, basic concepts, techniques, as well as its application in the development of diagnostic systems.

The work is presented as follows. The background of oral ulcers and expert system are provided in next section. The methodology and data collection are given in Sect. 3. Implementation and testing is in Sect. 4 and finally conclusion drawn in Sect. 5.

2 Background of the Work

Oral ulcers – also known as mouth ulcers – are usually small, painful lesions that grow in the mouth or at the bottom of the gums [9, 15]. They are painful round or oval sores that appear in the mouth, commonly on the inside of the cheeks or lips [16]. They can make oral activities such as eating, talking, drinking, etc. uncomfortable [14]. Women (more likely than men), young adults, and people with family history of oral ulcers have a higher risk of mouth ulcers [9]. In this work, about four (4) different oral ulcers are considered. These ulcers include:

Cold Sores: Cold sores, are red blisters that are usually full of fluid that appear close to the mouth or on other parts of the face [21]. They are small blisters that develop on the lips or around the mouth [17]. In infrequent cases, they may appear on the finger, nose or inside the mouth. These sores are incurable, contagious and may reoccur without warning. The major cause of cold sores is the Herpes Simplex Virus type 1. Type 2 generally causes the genital herpes [21].

Gingivostomatitis: Gingivostomatitis (GM), is a common infection of the mouth and gums. This infection may be caused by a virus, bacteria, improper hygiene for the teeth and mouth [18]. It is a common condition among children. These children may drool and not eat or want any drink due to the discomfort that the sore causes [18]. Causes of

Gingivostomatitis include: Herpes Simplex Virus type 1, Coxsackie virus; often transmitted by touching a feces-contaminated surface and Poor oral hygiene [18].

Herpangina: Herpangina is an illness caused by virus that involves ulcers and sores inside the mouth, a sore throat, and fever [8].

Neutropenia
Neutropenia is a condition of the blood. This is caused by low neutrophil (type of white blood cell that fights infections) level [6]. This condition may be caused by any of the followings: Shwachman-Diamond syndrome, glycogen-storage disease type 1b, leukemia, viral illnesses [6].

Expert Systems: An expert system in itself is a system that is able to mimic the knowledge of an expert [5]. This implies that the system should be able to do what that expert can do. In other words, an expert system is an intelligent system that follows a theoretical knowledge of an expert, and gives inferences just like the expert does. Since these systems make use of knowledge, it is important to take a lot at what knowledge is [28].

Brief History of Expert Systems: In 1957, Herbert, Simon, Shaw, and Newell developed the first ever computer program that separated its knowledge of problems from its problem solving strategy. It was the general problem solver (G.P.S).

In the 1970s, expert systems began to surface [11]. Ted Shortliffe developed MYCIN, one of the first expert systems to demonstrate the power of rule-based architectures in 1974 [7]. Then in the 1980s, they began to go commercial encouraging more and more insight into the advances in the development of expert systems [4].

Concept and Design of Rule-Based Expert Systems: There are basically five main components for a rule-based expert system [3]. They are, the knowledge base, the inference engine, the database, the user interface and the explanation facilities [13]. This is depicted in Fig. 1 [13].

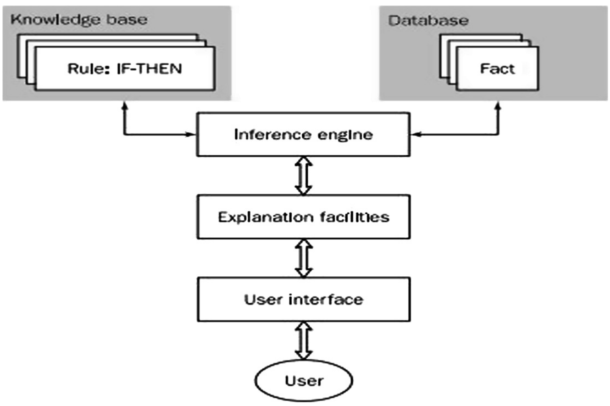

Fig. 1. Rule-based expert system architecture.

Bayes' Theorem-Bayes' theorem deals with conditional probabilities that are the reverse of themselves. It introduces the concept of prior probability and posterior probability; where the latter is the former, updated by information given from data [1]. Conditional probability refers to the probability of observing an event due to the observation of another event [12]. This is given in Eq. 1 [2].

$$P(B|A) = \frac{P(A\,and\,B)}{P(A)} \tag{1}$$

Having looked at conditional probability, Bayes' theorem can now be described. Bayes' theorem can be given as shown in Eq. 2.

Mathematically,

$$P(B|A) = \frac{P(A|B)P(A)}{P(A|B)P(A) + P(A|\neg B)P(\neg A)} \tag{2}$$

Using a simple Bayes' model, proposed by Ledley and Lusted [10], we follow two assumptions:

1. That all results are provisionally and conditionally independent, given an ulcer instance. This implies that, if the true ulcer state of a patient is known, the possibility and likelihood of having any observation doesn't rely on observations made on any other characteristics and features. In essence, from the rules of probability:

$$P(s_i, s_{i+1}, s_{i+2}, \ldots, s_n|D_i) = P(s_i|D_i)P(s_{i+1}|D_i)\ldots P(s_n|D_i) \tag{3}$$

2. That the traditional entities of the ulcer are mutually exclusive and exhaustive.

Given these two (2) assumptions, the expert system can now calculate the posterior probabilities of the ulcer using:

$$P(D_i|s_i, s_{i+1}, s_{i+2}, \ldots, s_n) = \frac{P(s_i|D_i)P(s_{i+1}|D_i)\ldots P(s_n|D_i)}{\sum_i P(s_i|D_i)P(s_{i+1}|D_i)\ldots P(s_n|D_i)} \tag{4}$$

After the expert system does this calculation, it can thenceforth choose the optimum diagnosis; referring to the most suitable diagnosis given the symptoms that the patient is experiencing.

3 Methodology and Data Collection

The methodology used for this project work is the object oriented analysis and design (OOAD). OOAD can be broken down into parts.

System Implementation
System implementation may be seen as the building or developing of the system and its delivery into full business or organization operations. The implementation phase has one major activity: deploying the system. At this point in the software development life cycle, every bit of theoretical and conceptual design is converted into a working system; implying that the given system specifications are used to come up with a new system.

In this work, a questionnaire was used to check for the relevance of this work. It was shared to twenty people. The detail about the interpretation of questionnaire is included in the appendix.

Data Used in Bayesian Inference
Sample data was collected from an anonymous source. The data of people who came in for consultation on any of the four types of oral ulcers considered in this work were collected. We considered 400 of them; that is 100 for each case of ulcer to see what happens. Each patient narrated his symptoms and then the medical [10] personnel checks if they match the case for the ulcer, he then goes ahead to make conclusive tests to determine specifically which oral ulcer the patient had. The Tables 1, 2, 3, and 4 were the recorded observation of this setup.

Activity diagram for the system implementation is given in Fig. 2.

Activity Diagram

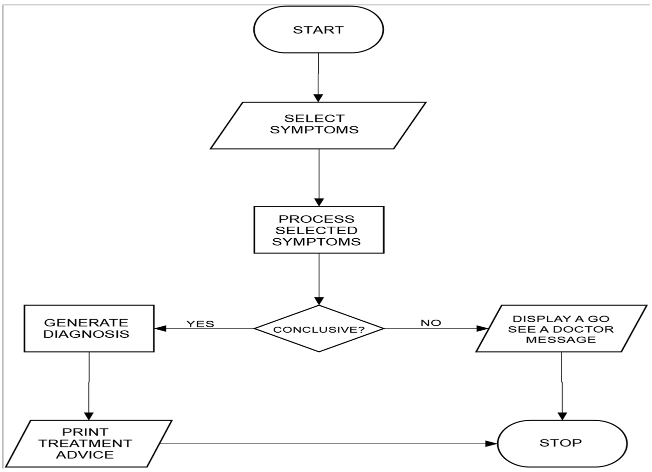

Fig. 2. Activity diagram for the implementation

Table 1. Statistics on Cold sores

Status	Cold sores (74%)	No cold sores (26%)
Tingling Sensation Positive	89.2%	15.2%
Tingling Sensation Negative	10.8%	84.8%
Red, fluid-filled blisters Positive	79.8%	5.4%
Red, fluid-filled blisters Negative	20.2%	94.6%
Fever Positive	99.24%	10.56%
Fever Negative	0.76%	89.44%
Muscle Aches Positive	69.25%	17.0%
Muscle Aches Negative	30.75%	83.0%
Swollen Lymph Nodes Positive	80.2%	15.4%
Swollen Lymph Nodes Negative	19.8%	84.6%

Table 2. Statistics on Gingivostomatitis

Status	Gingivostomatitis (79%)	No Gingivostomatitis (21%)
Tender Sores Positive	92.5%	19%
Tender Sores Negative	7.5%	81%
Bad Breath Positive	72%	21%
Bad Breath Negative	28%	79%
Fever Positive	91%	51%
Fever Negative	9%	49%
Bleeding Gum Positive	76.55%	21.23%
Bleeding Gum Negative	23.45%	78.77%
Swollen Lymph Nodes Positive	82%	15%
Swollen Lymph Nodes Negative	18%	85%
Drooling Positive	76.09%	11.04%
Drooling Negative	23.91%	88.96%
Malaise Positive	79.1%	12.1%
Malaise Negative	20.9%	87.9%
Discomfort in Mouth Positive	82.17%	0.91%
Discomfort in Mouth Negative	17.83%	99.09%

Table 3. Statistics on Herpangina

Status	Herpangina (70%)	No Herpangina (30%)
Fever Positive	99.7%	45.8%
Fever Negative	0.3%	54.2%
Headache Positive	89.6%	48.95%
Headache Negative	10.4%	51.05%
Appetite Loss Positive	88.6%	25.8%
Appetite Loss Negative	11.4%	74.2%
Sore Throat Positive	80.3%	44.2%
Sore Throat Negative	19.7%	55.8%
Similar Sores (HFB) Positive	78.6%	0.8%
Similar Sores (HFB) Negative	21.4%	99.2%

Table 4. Statistics on Neutropenia

Status	Neutropenia (71%)	No Neutropenia (29%)
Fever Positive	99.9%	67.5%
Fever Negative	0.1%	32.5%
Pneumonia Positive	78.65%	17.32%
Pneumonia Negative	21.35%	82.68%
Sinus Infection Positive	92.6%	1.5%
Sinus Infection Negative	7.4%	98.5%
Ear Infection Positive	88.6%	9.5%
Ear Infection Negative	11.4%	90.5%
Gum Inflammation Positive	92.53%	42.75%
Gum Inflammation Negative	7.47%	57.25%
Navel Infection Positive	98.6%	27.5%
Navel Infection Negative	1.4%	72.5%
Skin Abscesses Positive	90.6%	7.55%
Skin Abscesses Negative	9.4%	92.45%

4 Validation- Implementation and Testing

The implementation was done using java. The program starts by collecting data from the user. It collects the user's first name, last name, gender, as well as body temperature. With the body temperature, the system determines whether the patient has a fever (that is, temperature >37.5) or not. The other part of data collection involves the patient selecting the set of symptoms that he is experiencing. A screenshot of the input screen is demonstrated in Fig. 3.

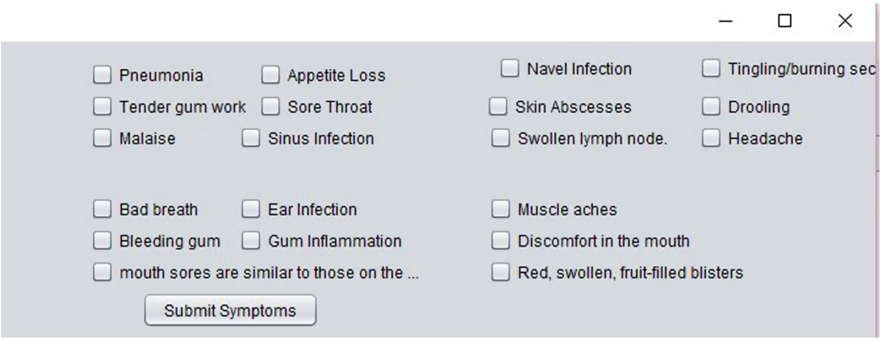

Fig. 3. Input screen

With the symptoms collected, the conditional probabilities of all the symptoms the user entered are aggregated and then converged using the assumptions proposed as the simple Bayes' model.

The expert system uses JEOPS, a java library that serves as an inference engine used in expert system. The rules were developed around the optimality of the probabilities. That implies that the ulcer with the highest probability is said to be the ulcer that the patient may be experiencing. The outcome of the test is then displayed on the outcome text area of the system. A screenshot of an example of an anonymous patient who used this system is given in Fig. 4.

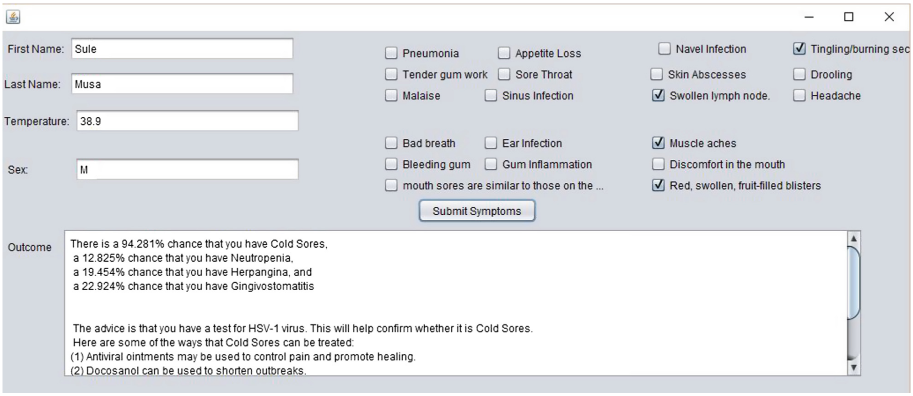

Fig. 4. Test case

The system also generates a printable Microsoft word document of the diagnosis which can be taken to the nearest oral health care specialist for confirmation and further examinations.

Recommendation

This work is a step in the right direction towards achieving good health care delivery system. With this system been made accessible to everyone to use, it could go on to reduce long incessant queues in the hospitals. Consequently, authors are of the following recommendations:

1. This system be made available to everyone so as to facilitate its use.
2. Workshops and training sessions should be set-up on the use of this system.
3. More systems be developed that can help bring medical care to the fingertips of the less privileged.
4. More research should be carried out on how artificial intelligence (in this case, expert systems) can be much more useful for the common good of man (especially in the medical fields).

5 Conclusion

This work has been able to demonstrate, to a large extent, that artificial intelligence can be a useful tool in the medical field. With the introduction of more expert systems, more people will be able to get access to health diagnosis without having to queue and wait long hours to see a physician. An efficient use of this system will result in reduction in cost and increase in the speed of oral health care delivery. Consequently, the application which was designed with the Object-Oriented Analysis and Design methodology was implemented with java programming language, provided on the Netbeans 8.0.2 IDE provides 98% degree of accuracy for diagnosing oral ulcers among the infected patients. It is the recommendation of the authors that its full scale implementation will assist medical personnel and experts in this domain of medical ailment.

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References

1. Azad, K.: An Intuitive (and Short) Explanation of Bayes' Theorem (n.d.). http://betterexplained.com/articles/an-intuitive-and-short-explanation-of-bayes-theorem/
2. Bayes, T., Price, R.: An Essay Towards Solving a Problem in the Doctrine of Chances. By the late Rev. Mr. Bayes, communicated by Mr. Price, in a letter to John Canton, MA. and F. R.S. Philosophical Transactions of the Royal Society of London, pp. 370–418 (1763)
3. Blereau, R.P.: Viral infections in children and adolescents. Consultant for pediatrcians 360 (2013). http://www.pediatricsconsultant360.com/sites/default/files/Screen%252520Shot%2525202013-04-30%252520at%2525202.17.46%252520PM.png
4. Elstein, A.S., Schwarz, A.: Clinical problem solving and diagnostic decision making. Chicago (2002)
5. Franco, J.: Primary Herpetic Gingivostomatitis (n.d.). http://janellef.weebly.com/primary-herpetic-gingivostomatitis.html. Accessed 10 Oct 2017
6. Giorgi, A.Z.: Neutropenia, 27 August 2017. http://www.healthline.com/health/neutropenia
7. Jones, M.T.: Artificial intelligence: a systems approach. Infinity Science Press LLC, Hingham (2008)
8. Kaneshiro, N.K.: Retrieved from MedlinePlus, 22 August 2017. https://www.nlm.nih.gov/medlineplus/ency/article/000969.htm
9. Krucik, G., Johnson, S.: What causes mouth ulcers? 25 possible conditions, 25 August 2015. http://www.healthline.com/symptom/mouth-ulcers
10. Ledley, R.S., Lusted, L.B.: Reasoning foundations of medical diagnosis. Science **130**, 9–21 (1959)
11. Matarasso, S., Daniele, V., Siciliano, V.I., Mignogna, M.D., Andreuccetti, G., Cafiero, C.: The effect of recombinant granulocyte colony-stimulating factor on oral and periodontal manifestations in a patient with cyclic neutropenia: a case report. Int. J. Dent. **2009**, 6 (2009)
12. Meagher, P.: Implement Bayesian inference using PHP, Part 1, 5 January 2005. http://www.devshed.com/c/a/php/implement-bayesian-inference-using-php-part-1/
13. Negnevitsky, M.: Artificial Intelligence: A Guide to Intelligent Systems. Addison-Wesley (Pearson Education) (2005)
14. Newell, A., Simon, H.A.: Human Problem Solving. Prentice Hall, Upper Saddle River (1972)
15. Newell, A., Simon, H.A., Shaw, J.C.: Report on a general problem-solving program (1959)
16. NHS: Cold sore (herpes simplex virus), 10 April 2014. http://www.nhs.uk/conditions/cold-sore/pages/introduction.aspx

17. NHS: Mouth ulcers. Retrieved from NHS, 6 March 2014
18. Phillips, N.: Gingivostomatitis, 16 July 2012. http://www.healthline.com/health/gingivostomatitis
19. Ramsay, G.G.: Noam Chomsky on Where Artificial Intelligence Went Wrong (n.d.). http://www.theatlantic.com/technology/archive/2012/11/noam-chomsky-on-where-artificial-intelligence-went-wrong/261637/. Accessed 7 October 2017
20. Saudi, H.I., Ali, S.A.: An expert system for the diagnosis and management of oral ulcers. Tanta Dent. J. **11**, 42–46 (2014)
21. Selner, M.: Retrieved from Healthline (2012). http://www.healthline.com/health/herpes-labialis
22. Whitten, J.L., Bentley, L.D.: System Analysis and Design Methods, 7th edn. McGraw-Hill Companies Inc., New York (2007)
23. Azeez, N.A., Ademolu, O.: CyberProtector: identifying compromised URLs in electronic mails with Bayesian classification. In: International Conference Computational Science and Computational Intelligence, pp. 959–965 (2016)
24. Azeez, N.A., Olayinka, A.F., Fasina, E.P., Venter, I.M.: Evaluation of a flexible column-based access control security model for medical-based information. J. Comput. Sci. Appl. **22** (1), 14–25 (2015)
25. Denning, E.D.: An intrusion-detection model. IEEE Trans. Softw. Eng. **SE-13**, 222–232 (1987)
26. Azeez, N.A., Babatope, A.B.: AANtID: an alternative approach to network intrusion detection. J. Comput. Sci. Appl. **23**(1), 129–143 (2016)
27. Azeez, N.A., Venter, I.M.: Towards ensuring scalability, interoperability and efficient access control in a multi-domain grid-based environment. SAIEE Afr. Res. **104**(2), 54–68 (2013)
28. Nureni, A.A., Irwin, B..: Cyber security: challenges and the way forward. GESJ: Comput. Sci. Telecommun. **29**(6), 56–69 (2010). ISSN 1512-1232. 14p. 2
29. Azeez, N.A., Iliyas, H.D.: Implementation of a 4-tier cloud-based architecture for collaborative health care delivery. Niger. J. Technol. Dev. **13**(1), 17–25 (2016)
30. Ayofe, A.N., Adebayo, S.B., Ajetola, A.R., Abdulwahab, A.F.: A framework for computer aided investigation of ATM fraud in Nigeria. Int. J. Soft Comput. **5**(3), 78–82 (2010)