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A Bayesian Network Expert System For Diagnosing Hormone Imbalance

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***Abstract**: In the overall health of women, hormones play significant roles. A fluctuation in hormone level leads to imbalance which at the end may have a negative impact on the health of the individual affected. Most diagnostic errors occur as a result of uncertainty, missing information and miscommunication. The lack of certainty about an outcome of diagnosis may lead to wrong medication, and this may lead to death of a patient or an irreversible medical condition. Providing correct information and making accurate diagnosis at the right time has the potential to prevent these unfavorable circumstances. This research proposes a web-based interactive expert system for the diagnosis and prediction of hormone imbalance using Bayesian Networks. Based upon the accuracy measure, all the classifiers used in the modeling process performed well. The selected model used for hormone imbalance expert system (Bayesian Networks) has an accuracy value of 98.33% with 0.98 precision and 0.98 recall values. Furthermore, the expert system was evaluated through usability testing (efficiency, few errors, learnability, memorability and satisfaction). The overall experience value of 4.29 was obtained after the usability testing. The expert system in this study was designed in such a way that a user can make use of the application remotely by installing it on an android device. This research discovered that expert system could be a more efficient method in addressing hormone imbalance diagnosis. Also, adoption of experts system could help save time in the diagnostic procedure of patients.*

Keywords— web-based; diagnosis; expert system; hormone imbalance; usability testing

1. INTRODUCTION

Medical diagnosis being the first and most important step in medical procedures play a major role in saving the life of patients and improving their state of health. An error at this stage may lead to serious medical problem or even result in the death of a patient. Most diagnostic errors occur as a result of uncertainty, missing information and miscommunication. Providing correct information and making accurate diagnosis at the right time have the potential to prevent these unfavourable circumstances [1]. Medical practitioners most times go through a stressful process to diagnose a patient. Manual diagnostic process can be tedious, time consuming and may require more resources. In addition, not every hospital may have an endocrinologists, gynaecologists and obstetricians. Hospitals that have the specialists have limited consultation time for patients. Considering certain issues such as number of patients to be treated by one or two specialist, the lack of interoperability between primary and specialty health care are factors that may lead to medical errors [2]. In this way, expert systems that have the ability to diagnose and predict diseases accurately in patients are needed to assist the clinicians in making decisions. Over the years, different innovations are been made to reduce human effort. The recent focus and demand of intelligent systems has helped the collaboration between various domains. It is evident that the current success from Artificial Intelligence (AI) has captured the imagination both the public and the research community [3]. The field of AI has evolved over the years with many sub-fields building models and developing artificial systems that are solving real world problems. AI has sub-fields, each of these sub-fields can be distinguished based on different techniques i.e. Neural Networks, e.g. brain modelling, time series prediction, classification, Expert Systems, e.g. decision support systems, teaching systems, Machine Learning, e.g. decision tree learning, version space learning. Most of these have both engineering and scientific aspects [4].

Today machine learning which is a subset of artificial intelligence has brought a fast and easy way to handle crucial health challenges for both medical professionals and patients affected. The availability of different techniques for developing expert systems capable of diagnosing and predicting the health level or diseases affecting a patient has shown the progress of modern technology solving medical related problems. Many people assume that only top hospitals and individuals can integrate machine learning in to their services but that is not actually the case. In fact, most likely people interact with many machine learning applications on daily basis without actually knowing. Most people including individual affected may be so busy due to their busy schedules and they hardly have time for routine medical check-up. Online diagnosis expert systems would match the need and bring support in medical diagnosis for medical professionals and affected patients at home, office and hospitals.

An expert system (ES) is a computer program designed using a set of rules and information with the aim to emulate the actions and judgments of human expert in a particular field to solve a particular problem [5], [6], [7], [8], [9]. With the recent development, physicians make use of different systems made for diagnosis to find out the health status of their patients. The system due to the relevant advantages they bring in the domain; efficiency, dealing with uncertainty and giving remarkable results in determining the effects of many variables on an outcome etc. Currently, hormonal imbalances and other medical diseases can be managed even at home as different e-health applications are being developed [10].

This paper proposes an interactive expert system in a medical decision making process by applying a Bayesian rule to data. Bayesian Networks generally is being recognised for its efficiency in the development of graphical models has significant capabilities for investigating biomedical data. It has progressed immensely over the years providing applications in different fields, and also performed remarkably in decision making in areas of reasoning under uncertainty [11].

2. RELATED WORK

In response to the challenges faced by medical practitioners, expert systems are considered as a supplement of traditional medical diagnosis. In the last few years, the use of techniques such as; fuzzy logic, neural networks, rule-based have greatly improved the expert systems used for diagnosis and prediction of diseases due to evolution in this area of research. Moreover, several languages (e.g., LISP, OWL, MySQL, e.t.c) and new tools have been developed and are currently being used for various studies and research in different fields. Some of the recent research works performed on expert systems used for diagnosis are presented here. Research [12] worked on a fuzzy expert system (FES) for diagnosis of back pain disease. User's selects a region from the five regions of the backbone human shown on the system interface, and then the system makes use of Knowledge Base (K.B) to display symptoms that the user may experience. Based on the selected observed symptoms, the Inference Engine (I.E) makes us of fuzzy logic to give an output of the possible disease the user may have and the treatment of that particular disease. The system was tested using the data of 20 patients with back pain. Diagnosis accuracy of cases tested was 90% as evaluated by comparing it with that of specialist. Sukar [13] adopted linear methodology to design and develop a web-based infertility expert system (IES) to diagnose symptoms that cause and contribute to infertility and also provide a possible solution with logical reasons. Modules in the system were divided in to two sub-modules. Users were required to answer questions for the system to diagnose and present result. Conclusion is drawn base on the answers given by the users and presented in the result sub-module. The second sub-module described as the prescription module, presents brief prescription and recommendation of solutions. The system focused on the most common infertility related problems and symptoms of women such as reproductive aging, infectious diseases, behavioural factors, damage to fallopian tubes, cervical, uterine causes and few hormonal factors. The system is limited to identify the exact type of symptoms and result laying emphasis on information the expert. Rawte and Roy [14] developed an ontology based system for diagnosing thyroid disease (both hyperthyroidism and hypothyroidism). The system made use of a database in storing patient information. The system was later improved by [15], improving the ontology design and adding the ability to diagnose testosterone deficiency and cortisol imbalance to their system, and also performs statistical analysis on the data collected from the patients. The system uses three related hormones (Testosterone, Thyroid Hormone, and Cortisol Hormone) for the diagnosis. The system does not deal with uncertainties in descriptions of symptoms by users. Abu Naser and Alhabbash [16] implemented a similar expert system for male infertility diagnosis using Simpler Level 5 Object (SL5 O). The system was made up of 46 rules that include basically symptoms, diseases and causes of male infertility. All sources of knowledge acquired were converted in to SL5 object knowledge base syntax and rules. Evaluation of the system was done by testing it on patients suffering from infertility diseases. The expert system is limited to male infertility diseases such as; Aspermia, Azoosperm, O.T.A syndrome (Oligoterato-astheno), Spermia, and Sexual transmitted disease.

The literature reviews show the works done on expert system used for medical diagnosis. Most of the techniques used may have high level of diagnosis accuracy but limited or may have constraints. For example, the fuzzy approach covers a wide range of operating conditions, but it lacks creative response and uses an uncommon way in making decisions. In OWL, data are specified on how they should be constructed and prevent adding inconsistent data to it.

3. PROPOSED EXPERT SYSTEM

3.1 Knowledge Acquisition of Hormone Imbalance

The sources of knowledge on hormone imbalance and symptoms used for the system were obtained primarily from the case notes of patients. Also, other sources of knowledge related to hormone imbalance diseases used in the expert system were solicited from medical experts duly acknowledged. The following medical conditions were used for diagnoses hormone imbalance by the system: Addison disease, Congenital Adrenal Hyperplasia, Cushing syndrome, Hyperprolactinemia, Hyperthyroidism, Hypothyroidism, Polycystic Ovary Syndrome (PCOS).

3.2 Materials and Research Tools

Case study was carried in Ahmadu Bello University Teaching Hospital (ABUTH), Zaria to obtain the necessary information needed. A total number of 600 case notes of married female patients were obtained from a five year period (July 2015-February 2021).

3.3 Data Description, Pre-processing and Analysis

Case notes of women of child-bearing age between the ages of 20 and 50 years were reviewed for hormone imbalance in this study. Information extracted for this study were selected from the case notes of patients with hormone imbalance related health conditions who had been registered in Ahmadu Bello University teaching hospital. Data obtained during the investigation includes: age of the patient, clinical symptoms and diagnosis result. Only cases with positive result were used. The age range was 20 – 50 years with a mean of 35 years as shown in Table 1. Table 2 shows the common hormone imbalances found in patients. The hormone imbalances are given as follows: Polycystic Ovary Syndrome (43%), Hypothyroidism (20%), Thyroiditis (15%), Hyperthyroidism (9%). Less common hormone imbalances are; Grave's disease (4%), Hyperprolactinemia (3%), Cushing syndrome (3%), Congenital Adrenal Hyperplasia (2%) and Addison disease (1%).

Table 1: Age distribution of patients

Age range (years)	**Frequency (n=600)**	**Percentage (%)**
20-24	78	13
25-29	168`	28
30-35	138	23
36-40	114	19
41-45	72	12
46-50	30	5

Table 2: Distribution of medical conditions as a result of hormone imbalance

Hormonal Diseases	**Frequency (n=600)**	**Percentage (%)**
Addison Disease	6	1
Congenital Adrenal Hyperplasia	12	2
Cushing Syndrome	18	3
Graves's Disease	24	4
Hyperprolactinemi a	18	3
Hyperthyroidism	54	9
Hypothyroidism	120	20
Polycystic Ovary Syndrome (PCOS)	258	43
Thyroiditis	90	15

3.4 Proposed System Architectural Design

The system consists of several components as shown in Fig. 1, the expert system comprises of six main components; and they are as follows:

Knowledge Engineer: A skilled person who design and develop, validate and maintain the expert system using the application programing interface (API).

Domain Expert: An expert (medical practitioner) in the medical domain with many years of experience.

Application Programing Interface: The application programing interface (API) serves as an intermediary between the system and the users (backend). It creates connectivity, allows the transmission of data and also provides a standard way of communication between the application and connected devices.

Inference Engine: The inference engine handles input from the users and compares it with that of the knowledge base in order to get a matching rule for conclusion and result.

Knowledge Base: The knowledge base is the database created where all information obtained from the case notes of patients and from medical practitioner were collected and stored. It also stores set of rules used for the diagnosis in the expert system.

User interface: A simple graphical medium of access and interaction between the users and the expert system (front-end).

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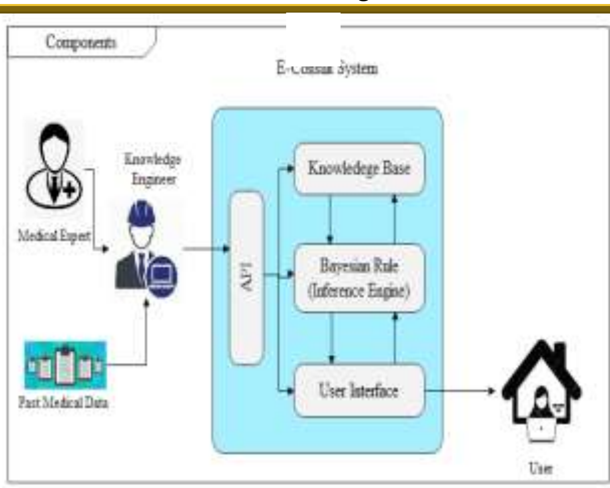

Fig.1. *Proposed expert system architecture.*

3.5 Implementation of the Expert System

The implementation of the expert system was carried out in two stages namely: Model building and the application development.

Model Building: In the model building stage, this study employed Waikato Environment for Knowledge Analysis software (WEKA) to develop the model used for the classification and prediction of hormone imbalance. The model consists of 144 instances, 42 predictor variables and 1 target variable (hormone imbalance). During the training phase of the model, 80% of the data were used and the remaining 20% were used for testing. The model from the model was converted to Comma-Separated Values (CSV) data file to fit in to rows and columns format. It was later uploaded in to the database for further development of the expert system application.

Application Development: At this stage, all the components that form the expert system were put together. The front end (user's interface) was designed using hypertext markup language (HTML), Cascading Style Sheet (CSS), Bootstrap, JavaScript (JS). This makes the system simple and user friendly. It was also designed in such a way that may not seek for assistance or guide to use the system. The backend was developed using Hypertext preprocessor (PHP) and My Structural Query Language (MySQL). Bayesian Network was constructed using the Bayes net editor (WEKA) containing probability and rules of hormone imbalances were saved in XML format. Every rule of the expert system characterizes a hormone imbalance by relating probability outcome of a disease. This enables the system to sort the likely disease, which would be displayed to a user.

4. RESULTS AND DISCUSSION

4.1 Performance Evaluation Metrics of Classifiers

The classifying algorithms used in the modeling process includes: Bayesian Networks (BayesNet), Decision Tree (J48), Logistic Model Trees (LMT) and Sequential Minimal Optimization (SMO). Each of the four models used were implemented using Waikato Environment for Knowledge Analysis (WEKA). The evaluation gives the full idea of how good the model is in predicting the outcome of a given classification. In other words, modeling requires results of the prediction accuracy and errors of a model by comparing the predicted result to the actual result in order to know the performance of models. Based upon the accuracy measure, the most successful claccifier models in descending order are BayesNet (98.33%), J48 (96.67%), LMT (95.83%) and SMO (95%). Also, the Mean Absolute Error (MAE) and the Root Mean Squared Error (RMSE) were also checked during the modelling process. Detailed performances of the classifier models used for the prediction of hormone imbalances are shown in Table 3.

Table 3: A comparative analysis of the classification methods for diagnosis

Classifiers	MAE	RMSE	Correctly Classified Instances % (Value)	Incorrectly Classified Instances % (Value)
BN	0.003	0.057	98.33 (118)	1.67 (2)
J48	0.006	0.081	96.67 (116)	3.33 (4)
LMT	0.010	0.087	95.83 (115)	4.17 (5)
SMO	0.014	0.099	95 (114)	5 (6)

Although the overall accuracy is the most important criteria in this study, other metrics such as Precision and Recall were also considered. The precision (positive predicted value) refers to the percentage of the relevant results which are given in based on the scores. BayesNets scored 0.98, decision tree has a value 0.97. Logistic Model Tree and Sequential Minimal Optimization algorithm both have score value of 0.96 and 0.94 respectively. Recall (sensitivity) refers to the percentage of total relevant results correctly classified by the algorithms. The scores are given as: 0.98 for BN, 0.97 for J48, 0.96 for LMT and 0.95 for SMO as given in Table 4. The values range is from 0 to 1. Higher precision in a model means that the algorithm returns more relevant results than irrelevant ones, and high recall means that the algorithm returns most of the relevant results (whether or not irrelevant ones are also returned).

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Table 4: Performance evaluation result of the model

Metrics	Classifiers			
	BN	J48	LMT	SMO
Precision	0.98	0.97	0.96	0.94
Recall	0.98	0.97	0.96	0.94

4.2 Developed Expert system

The expert system developed in this study is a web-based interactive diagnosis system, it can only be accesible when the user is connected to a network with an internet connection. The system allows the user to register before gaining access to carry out further actions. Users are provided with a simple interface and can only be granted access to the use the application after registration. The system collects personal relevant details of a user and store them in the database. It performs diagnosis through interaction between the system and the user. It is made up of several modules and essential elements such as images, texts and buttons.

The main interface of the system is given in Fig. 2, registration interface in Fig. 3, signs and symptoms selection in Fig. 4 and the user's result in Fig. 5. The provided interface is the medium of interaction between the user and the system (Fig. 2). A user is first expected to register by providing the necessary information requested before gaining access to consultation page (Fig. 3). The user proceeds and login using the username and password used for the registration. After entering information, e.g. date of birth of a patient; the system automatically calculate the age of the patient, fetch from the knowledge base and present to the user the possible symptoms that may be seen (Fig. 4). The user then select the symptoms observed from the provided checkboxes listed on the user interface and click to the next step until all symptoms observed are selected. Finally, the system processes the information provided and return to the user the predicted disease (Fig. 5).

Fig. 2. *Main user's interface of the expert system.*

Fig. 3. *User's registration interface.*

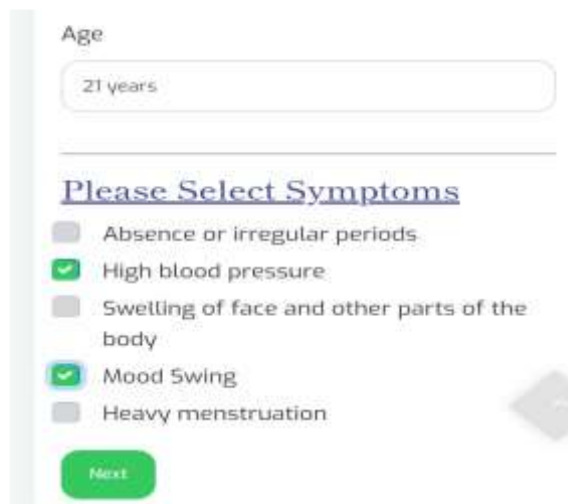

Fig. 4. *Signs and symptoms selection interface.*

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Fig. 5. *A user's result from the expert system.*

4.3 Usability Test Result

The expert system was evaluated in two phases; evaluation by the domain expert and through usability testing.

Evaluation by domain expert: This phase of evaluation was done by the domain experts. A number of doctors tested the system by following the diagnosis procedure and comparing the predicted diagnosis to the actual data.

Evaluation through usability testing: In this phase of evaluation, 31 users tested the system and were given questionnaire containing 12 questions formed from the 5 aspects of usability testing by Jacob Nielson method (efficiency, few errors, learnability, memorability and satisfaction). Questions asked can be seen in the appendix section. Users responded to the questions based on their experiences while testing the application. In the table VI, the usability points were rated as; 1 (poor), 2 (fair), 3 (Good), 4 (very good) and 5 (excellent). The satisfaction points of the users were analyzed by finding the average of points of answers from the respondents for each question. Depending on the user's experience during the test, each question in the questionnaire was assessed on 5 points scale (see Table 5). The attributes have the following points using the five guidelines of usability testing:

Attribute "The ease to recognize the interface of the system" has usability point 4.8.This indicates the learnability value.

Attributes "Ease for patient to register successfully", "Ease for patient to see and select symptoms" and "Ease for patient to obtain final diagnosis" have 4.16, 4.19 and 4.10 respectively showing the efficiency value.Attributes "Ease of finding login form" and "Ease of access to information and recalling menus" have the memorability value of 4.31 and 3.89.

Attribute "Ease of reading letters and understanding symbols" has a value of 3.90 indicating that there was minimal error.

Attribute "Overall experience using the application" has a value of 4.29. The value shows a very good overall system rating.

Table 5: Usability test summary

S/N	Attributes	Usability Points
1	The ease to recognize the interface of the system	4.48
2	Ease of finding login form	4.31
3	Ease for patient to register successfully	4.16
4	The ease for patient to see and select symptoms	4.19
5	Ease of reading letters and understanding symbols	3.90
6	The ease for patient to obtain final diagnosis	4.10
7	Ease of access to information and recalling menus	3.89
8	Experience while navigating on the application	3.94
9	Overall experience using the application	4.29
10	Recommending application to others	4.14

5. CONCLUSION

In the case of hormone imbalance, a number of patients may have different symptoms and also have one or two common symptoms for same hormonal disease. This is so because scenarios have a degree of ambiguity associated to the signs and symptoms. The study has afforded a technique to determine a way of diagnosing and predicting hormone imbalance. Expert system developed in this study is web-based and also an interactive system that can serve as a supporting tool for clinician in the diagnosis of hormone imbalance of women. The system allows reasoning under uncertainty through its ability to apply Bayesian inference rules to produce reliable diagnosis. The study was conducted in a single university hospital and focused on a hormone imbalance affecting only women of child bearing age. This can be enhanced by collecting both men and women data, adding more hormone imbalance and ages before puberty to generalize the system.

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