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Design of a User Centered Web Based Expert System for Assisted VIA Result Confirmation in Nigeria

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ABSTRACT

The best way to prevent cervical cancer is through early detection of pre-cancerous lesions by regular screening to detect the presence of the Human Papilloma Virus (HPV), the cancer causing virus in the cervix of a woman. Although some diagnostic expert systems have been designed to detect the presence of pre-cancerous lesions in women, most are designed to work with Pap smear, a common method of screening for cervical cancer in more developed countries as against Visual Inspection with Acetic acid (VIA) that is more common in developing countries like Nigeria which is the major reason for this study.
The system called Cervipert was developed using Adobe Dreamweaver as the programming environment, HTML, JavaScript, CSS as the front end while PHP and MySQL were used for the backend and Apache was used as the server. The inference engine which is the brain of Cervipert was implemented in PHP. The system was built to detect the presence of HPV in the cervix, recommend advice and or treatment for patients based on clinical symptoms inputted by user after which VIA test input have been done on patients. It was developed using the Dokas approach, a standard approach for developing expert systems and the ISO 13407 recommendations for developing user centered systems. The system was developed based on medical expert information collected through interviews and review of several literatures found online. Black box testing was done on Cervipert to ensure the system was doing what it was meant to do and manual debugging was done on the codes to remove excess and redundant codes. The system was tested by health workers using 20 patients that have previously been screened manually and it was found to be 90 % accurate. The developed software can be used as a tool to support screening programs for cervical cancer by health institutions and Non-governmental Organizations (NGO) and thereby reducing the high prevalence of this disease.

Keywords: *Expert system, user centered system, cervical cancer screening*

1. INTRODUCTION

Since 1980, Expert Systems have been one of the most important AI technologies [1]. They 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. The major goal of any expert system developer is to build systems that can assist or in some cases function better than human expert in the area of performance, flexibility, reliability, cost-saving, adequate response time, intelligent database, increased availability, steady, unbiased and prompt response at all times.

The area of medical diagnosis greatly requires the use of expert systems as they help in supporting clinical decisions [2]. Over the years, maximizing the benefit that using expert systems has to offer in medical domain has resulted in human support and costs to decrease and has also led to increased diagnostic accuracy [3]. In addition, expert systems make expertise more accessible, relieve experts from routine tasks and provide a useful way for experts to develop, test ideas and theories.

Cervical cancer is a major health concern for all women. For centuries, the cause of cervical cancer was unknown. It wasn't until the 20th century that scientists understood that the disease was caused by exposure to

HPV Vaccines against some forms of the virus are now widely available, but for most of recorded history, the causes of cervical cancer were not really properly understood. Although some diagnostic expert systems have been designed to detect the presence of pre-cancerous lesions in women, most are designed to work with Pap smear, a common method of screening for cervical cancer in more developed countries as against Visual Inspection with Acetic acid (VIA) that is more common in developing countries like Nigeria.

In an article published in vanguard in 2013, it was ascertained that half of all women who die of cervical cancer live in just five countries – India, China, Brazil, Bangladesh and Nigeria, even as Africa has been identified as the most dangerous place to be a woman with cervical cancer. The Vice-Chancellor, University of Ibadan, Professor Isaac Adewole also remarked in that same article that "Twenty-six Nigerian women lose their lives due to cervical cancer every day and a further 14,000 women are diagnosed each year with this disease which can be easily prevented through early diagnosis and the use of vaccines that are being used around the world [4]. Presently, most developing countries face shortages of health workers who can accurately read and interpret diagnostic results of cervical cancer screening [5] which is the best, easiest and most cost effective way to prevent the disease hence the need for expert systems.

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The preventive measure that WHO recently approved for developing countries is screening for the cancer cells through the use of Visual Inspection with Acetic acid (VIA) hence most cervical cancer screening is normally done with VIA; however; certain issues still persist with this method leading to several cases of misdiagnosis. In order to avoid these anomalies, health workers usually confirm their results by carrying out another form of screening method known as Visual Inspection with Lugol's Iodine (VILI). Apart from time and other resources that are wasted, this usually leads to more confusion as conflicting results could be gotten from both tests hence the need for a system that can assist health workers in the confirmation of their findings from VIA screening to prevent misdiagnosis, conflicting results and to save valuable resources. There is a need for an improved system for diagnosis, such that is not time consuming and gives results that users can be confident with which is the main focus of this work. Moreover, in Nigeria, there are shortage of health workers [6] and for example in situations where only 5 health workers are to screen hundreds of women, fatigue is meant to set in, long queue of patients waiting to be screened amongst other negative factors.

2. LITERATURE REVIEW

Expert System, a core part of AI, is defined according to Edward Feigenbaum of Stanford University as "an intelligent computer program that uses knowledge and inference procedures to solve problems that are difficult enough to require significant human expertise for their solution". This definition is said to be one of the most widely accepted definition of Expert systems [7]. ES provide powerful and flexible means for obtaining solutions to a variety of problems that often cannot be dealt with by other, more traditional and orthodox methods. Thus, their use is proliferating into many sectors of our social and technological life, where their applications are proving to be critical in the process of decision support and problem solving. Some expert systems are designed to take the place of human experts, while others are designed just to assist them in decision making. Expert systems are widely used in domain specific areas in interpretation, prediction, diagnosis, design, planning, monitoring, debugging, repair, instruction and in control applications.

Today's world is one with increasing access to intelligent systems. In recent time, Artificial Intelligent methods have significantly been used in medical applications and research efforts have been concentrated on medical expert systems as complementary solution to conventional technique for finding solution to medical problems [8]. The emergence of information technology (IT) has opened unprecedented opportunities in health care delivery system as the demand for intelligent and knowledge-based systems has increased as modern medical practices become more knowledge-intensive.

2.1 Basic Concepts of an Expert System

Figure 1 below depicts a typical ES architecture. Human experts solve problems by using a combination of factual knowledge and reasoning ability. In an expert system, these two essentials are contained in two separate but related components: a knowledge base and an inference engine. The knowledge base provides specific facts and rules about the subject and the inference engine provides the reasoning ability that enables the expert system to form conclusions.

The knowledge engineering process is illustrated in the diagram below:

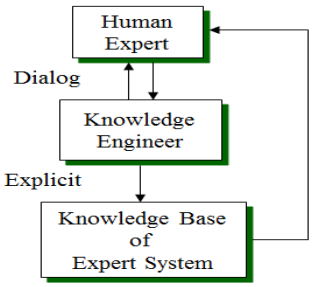

Figure 1: Knowledge engineering process [9]

Expert systems also provide additional tools in the form of user interface and explanation facilities. User interfaces, as with any application, enable people to form queries, provide information and interact with the system. Explanation facilities, a fascinating part of expert systems, enable the systems to explain or justify their conclusions, and they enable developers to check the operation of the system themselves and it should be noted that all expert systems are knowledge based systems but not all knowledge based systems are expert system.

The use of expert system in medical diagnosis dates back to the early 70's when MYCIN [10], an expert system for identifying bacteria causing diseases was developed at Stanford University. Since then, various expert systems like Internist, CADUCEUS etc. have been developed [11]. The goal of such an expert system is to aid the medical experts in making diagnosis of certain diseases or help the layman to diagnose the disease themselves. More recently, the potentiality of the Internet has drawn the interest of researchers because of its ease of use and wider availability [12] hence the necessity for improving current medical diagnostic process through the web.

3. REVIEW OF SOME EXISTING DIAGNOSTIC SYSTEMS

Ali & Mehdi [13] designed a fuzzy expert system for heart disease diagnosis. The system used the Mandani

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inference method and the system was designed in Matlab software. The system used 13 inputs and just one output.

The results obtained from designed system were compared with the data in the database and observed results of designed system was 94%. Datasets were used to diagnose the presence or absence of heart disease given the results of various medical tests carried out on a patient. The designed system was tested with an expert design and they concluded that results of the system were shown to be logical and more efficient. Experimental results showed that this system did quite better than non-expert urologist and about 94 % as a well as the expert did. Any system being designed should have a software development model for guidance and time saving purposes. Presently, heart disease is a major global problem as depicted in this work and because the main function of an expert system is to mimic expertise and distribute expert knowledge to non-experts, these benefits can greatly be enhanced with the emergence of the internet.

The rapid advances of the convergence of both technologies should be taken advantage of by most traditional expert system developers as web based expert systems are capable of offering much more than traditional stand-alone expert systems. Implementation and evaluation of expert systems is easier when they are web based as there is no need to install the system in advance. It is easy to collect feedback from online forms. By using Web site analysis software such as Open Web Analytics (OWA): an open source web analytics software, optimized amongst others, visitors can be easily traced and analysed. By collecting visitor's information, it is possible to profile the users, and determine the usefulness of the system. The use of Web design software makes the user interface design easier. HTML-based user interfaces allow the incorporation of rich media elements. Hyperlinks in HTML provide an extra facility in enhancing expert systems explanation and help functions as users can access the relevant Web site easily. This is normally not possible with stand-alone expert systems. Also, the World Wide Web (www) has been proven to be a useful knowledge source for knowledge acquisition in constructing the knowledge base of an expert system [14]. With a Web-based knowledge base, any knowledge updating and maintenance can be handled centrally, and no reinstallation needs to be carried out.

Useful links can be incorporated in the system which can help the user to understand and interpret the expert system's recommendations. E-mails, feedback forms and other Internet communication functions will allow users to question and comment on the system, thus making an expert system more interactive.

Tripty, Sarita, Wadhwani&Wadwani [15] designed a system to support the decision to perform biopsy in those patients who have suspicious findings on diagnostic mammography. The system functions as a database query of mammographic cases with known biopsy outcomes. The input to the system is a subset of the Breast Imaging-Reporting and Data System (BIRADS) which is a system that was developed by radiologists for reporting mammogram results using a common language. BIRADS was used to get mammographic findings and items from the patients' medical histories and the output is formed from the known outcome of biopsy.
Bayesian network was used to perform reasoning tasks. The researchers were just interested in a system that could minimize the probability of a radiologist mistakenly accepting an erroneous biopsy result. The system was evaluated using a round robin sampling scheme and they concluded that a case-based reasoning approach to computer aided diagnosis has the potential to improve the accuracy of breast cancer diagnosis. The system was designed to aid in the decision to perform a biopsy in patients who have suspicious mammographic findings. The decision to biopsy can be viewed generally as a two-stage process. Firstly, the mammographer views the mammogram and determines the presence or absence of image features such as calcifications and masses.

Secondly, the presence and description of these features and the patient's medical history are merged to form a diagnosis. The case-based reasoning system was an aid to the second step and was motivated by the large fraction of biopsies that are benign. Mammography is a sensitive procedure for detecting breast cancer, but the positive predictive value is low. Only 10 to 34% of women who undergo biopsy for mammographically suspicious impalpable lesions are actually found to have malignancy.

Between 0.5% and 2.0% of all mammographic examinations result in biopsy; several hundreds of thousands of biopsies are performed on benign lesions each year. The women undergoing biopsy for a benign finding are unnecessarily subjected to the discomfort, expense, potential complications, and change in cosmetic appearance, and anxiety that can accompany breast biopsy.

It was intended that the proposed system may significantly improve this performance through a simplified case-based reasoning approach that uses a large database of cases with known outcomes. Case Based Reasoning approach is one of the most recent problem solving techniques; it is the process of solving new problem by referring the solutions of similar past problems. In addition to this, it is a prominent kind of analogy making in every day human problems. In past, the Knowledge Based Reasoning technique was used as against case based reasoning to solve the problem, but solution which is obtained from the latter approach is not highly appreciable and also it has some limitations such as knowledge elicitation, inability to access high volumes of information, implementation difficulties and high maintenance cost as

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outlined by Mythili, Bivash, &Awanish [16]. There are different case based reasoning tools that can be used to handle these problems like Mycbr, Free CBR, Open CBR, Shell CBR and many others although each comes with its strengths and limitations. More so, critics of CBR argue that it is an approach that accepts anecdotal evidence as its main operating principle. Without statistically relevant data for backing and implicit generalization, there is no guarantee that the generalization is correct. However, all inductive reasoning where data is too scarce for statistical relevance is inherently based on anecdotal evidence. There is recent work that develops CBR within a statistical framework and formalizes case-based inference as a specific type of probabilistic inference; thus, it becomes possible to produce case-based predictions equipped with a certain level of confidence [17]

Djam&Kimbi [18] designed an expert system for hypertension management using fuzzy logic approach to deal with imprecise or noisy data which is usually common in medical data. They applied a forward chaining method in making inferences and the Root Sum Square (RSS) of drawing inferences was employed to infer the data from the rules developed. Centroid approach was used for defuzzification. Meddiag was implemented in the fuzzy logic tool box in Matlab 7.10.0. Diagnostic data for 30 patients with confirmed diagnosis of hypertension were evaluated.

The use of fuzzy logic approach gave them an exact diagnosis of 85% and they inferred from this result that fuzzy diagnosis resembles human decision making with its ability to work for approximate reasoning and ultimately find a precise solution. The issue with using fuzzy logic is that it is a form of many valued logic, it can only deal with reasoning that is approximate rather than exact, and hence it requires lots of human experts' interaction. Systems using fuzzy logic cannot really learn and adapt after solving a problem as some human experts can, it cannot also solve problems that no one has the solution to and they don't really make good candidates for systems that require extreme precision. Fuzzy logic systems are usually expensive to develop because they often require extensive testing. The better way to develop expert systems with fuzzy logic is to combine them with the use of neural networks. Fuzzy logic systems, although can reason with imprecise information, are good at explaining their decisions but they cannot automatically acquire the rules they use to make those decisions which is where neural networks come in.

Imianvan& Obi [19] proposed an expert system for prognostic diagnosis of pelvic inflammatory disease utilizing logical fuzzy classifier expert structure which was said to eliminate uncertainty and imprecision that is usually associated with the diagnosis of PID using fuzzy logic. Tools used in the design of the system include Visual Basic application language, Microsoft Access and Excel, Windows XP. This work demonstrated the application of soft computing in the domain of differential diagnosis of PID when given a set of symptoms only. Fuzzy logic is widely used for handling imprecise information; however, it is highly abstract and employs a lot of heuristic (trial and error) experiments which could lead to costly and prolonged expert systems. It also requires lots of human experts to discover rules about data relationship. The smartness of most fuzzy systems are dependent on the rules given by human experts which means that the performance of this system will be restricted by the capability of the human brains behind it. In other to overcome this limitation, instead of human experts putting specific fuzzy rules to deal with every situation, the machine should be able to produce its own rules through experience by adapting it with neural networks that can act as the eyes and the ears of this system and its rules will be able to change and fine tune itself with time. Cluster analysis which is a method of unsupervised learning was used to assign a set of observations into subsets (called clusters) so that observations in the same cluster are similar in some sense, although in the work the number of misclassified patterns was very low and in other for the rule based system to be optimized, some rules were deleted.

The consequence of this is that the analysis of the system will not be stable when cases are dropped: this will occur because selection of a case (or merger of clusters) depends on similarity of one case to the cluster. Dropping one case can drastically affect the course in which the analysis progresses and even when hierarchical clustering is used, nature of the analysis will mean that poor judgments will be very hard to rectify hence fuzzy classifier was used to address this issue in the research. Fuzzy classifier is any classifier that uses fuzzy sets or logic in the course of its training operation [20]. A classifier is an algorithm that assigns a class label to an object based on the object's description. The fact still remains that it is usually hard to develop a model from any fuzzy system as it requires more fine tuning and simulation before operational. The system was developed using Microsoft access which is proprietary software that can only be used relatively for small datasets and by a limited number of users. It is not scalable as with increased use, the limitations of a desktop database become apparent, it does not have multi user support.

Aru &Opara [21] developed an expert system that aims to provide patients with background knowledge for suitable diagnosis of some of the human diseases using VB.NET as the tool of design and concluded that the proposed system could help doctors and patients in providing decision support system, interaction training tool and expert advice. VB.NET was used according to them because of its flexibility, expandability and low cost. An initial evaluation of the expert system was done by doctors and patients. A number of doctors and patients tested the

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system and gave them a positive feedback and asked them to expand the expert system to cover more diseases. The scope of diseases covered by their expert system included the following common diseases: Malaria, Leukaemia and Hepatitis. Basically, an expert system should be designed to handle complex but specific problems. Putting too many information about different ailments that are not even closely related could lead to knowledge acquisition bottleneck, insufficient and ambiguous knowledge base.

Rajdeep [22] designed a rule based expert system that can be used to diagnose Cerebral palsy by taking user inputs and depending on the symptoms of the patient and diagnoses if the patient is suffering from cerebral palsy or not. The system was designed using Java Expert System Shell (JESS) and it made use of Rete algorithm to match the pattern facts with the rules. The system was evaluated by testing it against a few proved cases of cerebral palsy as test cases and it showed accurate results when the specific symptoms of test cases were given as user inputs. Jess is a popular, simple to use and powerful ES shell; it can easily be integrated with external java programs through its well defined Java Application Program Interface (API). Its inference engine is Rete based; forward and backward chaining is supported as well but it lacks a Graphical User Interface (GUI) [23] although, presently a group of AI researchers are working on a Jess GUI that will overcome all these deficiencies.

Another important advantage that the Jess GUI will also have over Jess is interoperability as knowledge base can be saved in XML format (in addition to the original JESS/CLIPS format) and these way web applications can access the knowledge base developed in Jess GUI although the present Jess GUI is being used a s teaching tool, it still has some limitations that currently being worked upon. Other researchers has also tried to develop a plug in called Jess tab [24] which integrates Jess with protege 2000, a popular ontology development and knowledge acquisition tool developed in Stanford University. There is also Java Don, an open source expert system shell based on the OBOA framework for developing intelligent systems but still at the research level but it comes with a XML scheme for interoperability and currently, efforts are being made to implement Resource Descriptive Framework (RDF) and Web Ontology Language.

Nidhi, Singh, Manoj&Priynka [25] proposed an integrated computerized decision support system for managing asthma in rural areas using a fuzzy based approach and concluded that the comparison of the output of the proposed system with clinical data records drew the good performance of the fuzzy based decision support system. Data were collected based on Interview with asthmatic patients and for evaluation of the result of the system, 40 patients were interviewed. In this work, no proper software design model was followed, no design patterns and framework. Design patterns are well known solutions for reoccurring problems, they allow for faster and easier developments instead of reinventing the wheel.

Frameworks allows for reusability and for great productivity which was missing in this work. The use of model driven development in designing expert systems should never be over emphasized as it creates room for more cost effective projects, leads to increased and information quality, leads to meaningful validation, empowers domain experts, encourages human computer interaction and it captures the domain knowledge better as highlighted by Johan in his online article published in 2009 [26]. The use of fuzzy logic could have also been integrated with neural network for more efficiency.

Margret, Clara, Jeevitha&Nandhini [27] designed a diabetic diagnostic expert system using rough set. The system developed was evaluated using a simple set of symptoms that is added to clinical data in determining diabetes and its severity. To test the system for its correctness and reliability with respect to the analysed requirements, black box testing was adopted. In black box testing, the tester inputs data and views the output from the test object. This testing involved thorough test case to the user who then verifies this for a given input, the generated output was said to be the same as the expected output in the test case. To demonstrate the efficiency of the system, a simple rule based system was developed. The system was said to have been of high advantage in areas such as accuracy and time consumption due to the use of rough set knowledge based representation. One of the disadvantage of rough set approach is its dependence on complete information systems i.e., A decision table to be processed must be complete and all its objects values must be known [28]. But in real -life applications, due to measurement errors, miscomprehension, access limitation and misoperation in register, etc., information systems with missing values often occur in knowledge acquisition. Information systems with missing data, or, in different words, the corresponding decision tables are incompletely specified and this for simplicity case should be called incomplete information systems. Black-box testing is a method of software testing that examines the functionality of an application (e.g. what the software does) without peering into its internal structures or workings. The issue with using black box testing method is that at times, results can be overestimated, without clear and concise specifications, test cases are usually hard to design and there may be unnecessary repetition of test inputs if the tester is not informed of the test cases the programmer has already tried besides black box testing seems like a general approach for all software, additional testing still need to be done to ascertain the quality and validation of the system.

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Tanaya & Sujit [29] presented the use of ANN in pancreatic disease diagnosis based on a set of symptoms.

The aim of this research was to show that neural networks can make an accurate individualized prognosis of a patient given his or her particular condition. This work provided a self-learning intelligent system that is capable of tackling uncertainties in the diagnosis process. The system was designed based on some symptoms which were taken from previous medical records and physicians. These symptoms were trained through neural network to detect which patient is suffering from pancreatic cancer or might be or may not suffer at all. The neural network used fuzzified symptoms.

Neural network from Matlab R2008a was used to evaluate the performance of the proposed networks. They used Levenberg-Marquardt back propagation algorithm to train the network. The system designed was an interactive system that informs which patient has a particular condition as regards pancreatic cancer. The prediction could help doctors plan for a better medication and provide the patient with early diagnosis. Experimental results indicated that the proposed method could analyse data more efficiently than other manual methods. Their methodology produced accuracy for pancreatic cancer but what is the probability that the accuracy that will be obtained when it is used for other diseases will be as high as the one obtained for this particular disease (pancreatic cancer)? This means that they still have to use that same approach to test on datasets of different diseases to be able to determine the validity of their method.

Adewale, Mayowa, Uchechi&Oke [30] designed an expert system that could diagnose and recommend treatment of malaria from symptoms and blood test results provided by user patients. The system was created based on medical expert information collected through structured interviews and through the use of extensive literature review. Waterfall software development process was adopted. It is a rule based system in which a scripting language was used for its inference engine purposes.

Knowledge was stored using a Relational Database Management System; the user interface was also designed to be friendly. The malaria diagnostic expert system was designed to allow for more efficient diagnosis of malaria and aid in reducing the workload of scarce medical practitioners. It was web based so as to allow more users have access to it. In this work, waterfall software development model was adopted for its simplicity and its easy implementation purposes but in reality, real life projects rarely follow the sequential flow and iterations in this model as it is usually difficult to get all users requirements just once especially in situations where users are IT illiterate. A small change in any previous stage can lead to big problems in subsequent stages as all stages are dependent on each other and going back a phase can be a costly issue and more so, it is usually difficult to integrate risk management when using the waterfall model except if all the requirements and specification details of the software was exhaustively done and detailed with proper testing to ascertain this fact.

Most diagnostic systems are only theoretically feasible especially in developing countries where access to the technology that will make these systems work are limited. Most are not web based hence can only be used by the limited few who can afford and have access to them; the web based ones are also not maximally accessed and used based on people's dependence on doctors that are limited in number, lack of internet facility, ignorance, poverty, illiteracy, trust issues, most potential users still prefer the emotional touch of a human expert, some expert systems can only be used by highly trained professionals due to low human computer interaction processes during the design phases, poor usability engineering processes, efficiency, effectiveness, quality and acceptability of most diagnostic expert systems needs to be established and all these need to be integrated at the early development of design stages so that the main goal for which all these systems are being designed for can be maximally utilized by users in developing countries.

In developed countries, most diagnostic systems currently designed favour early detection of cervical cancer cells through screening with Pap smear unlike developing countries where Visual inspection with acetic acid is the norm hence the need to design an expert system that can assist health workers in the confirmation of VIA screening results that will be web based to provide increased accessibility and availability which is being addressed in this study.

4. CERVICAL CANCER DIAGNOSTIC SYSTEMS REVIEW

Researchers in the area of diagnostic systems who understands the risks and negative impacts of cervical cancer disease and also know that this disease is preventable and curable at low cost and low risk when an accurate diagnosis is done in due time, since it is the neoplasm with the highest prevention potential are continuously working in this area with human experts in this field to design, model and implement various diagnostic systems that are able to emulate the decision making abilities of human experts in this area. Various expert systems have been designed to provide a diagnosis to cervical neoplasia (CN) precursor injuries through the integration of fuzzy logics and image interpretation techniques [31]. A novel method for automated diagnosis of cervical cancer by extracting cytoplasm and nuclei from cervical cytology images was developed by Lakshmi &Krishnaveni [32], Laurie [33] designed a system for the computer-assisted screening of

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conventionally prepared cervical smears called PAPNET using neural network technology, Pabitra, Sushmita&Sanker [34] described a way of designing a hybrid decision support system in soft computing paradigm for detecting the different stages of cervical cancer.

An automated pre-cancerous diagnostic system was designed by Nor Ashidi, Mohd& Nor Hayati [35] which had two parts; an automatic feature extraction and an intelligent diagnostic using a feature extraction algorithm called region-growing-based features extraction (RGBFE) and a new artificial neural network architecture called hierarchical hybrid multi-layered perception network. An expert system for the detection of cervical cancer cells using knowledge-based image analyzer to reduce deaths and morbidity from cervical cancer through detection of potentially cancerous cells, provision of prompt advice and opportunities for follow-up and treatments was proposed by Samuel, Leung & Felix [36]. Oguntoyinbo, Adeyemo&Akinkunmi [37] designed and implemented the prototype of a cancer diagnostic system which could diagnose breast, ovarian and cervical cancer using Bayesian formula. Domínguez, Aguilar, Posada, Palet& González [38] also developed an expert system that is able to provide a diagnosis to cervical neoplasia precursor injuries through the integration of fuzzy logics and image interpretation techniques in 2013. The research focused on atypical cases, specifically on atypical glandular cells. The system was validated using 21 already diagnosed cases with a positive correlation in which 100% effectiveness was obtained and they concluded that the system was able to reduce false positives and false negatives by providing a more accurate diagnosis for cervical neoplasia.

The best and easiest way of preventing this disease is through early detection and it is seen from literature that no work has been done yet in designing a system that is user centered and that can assist in screening against Cervical cancer using the Visual Inspection with Acetic acid method which is the norm in developing countries as a result of its screen and treat approach.

Most recently, the National Institute for Health and Clinical Excellence (NICE) approved the use of cervical cancer diagnostic screening systems to detect abnormal pre-cancerous cells on the cervix; these cells can be treated with a simple outpatient procedure and thus reduces the risk of cervical cancer developing in future. The new tests aim to improve the diagnostic accuracy of the selection of patients for biopsy or treatment according to UK cervical cancer expert Miss AdeolaOlaitan. Presently, there are several instruments which have been used to screen for abnormal cervical cells such as semi-automated or interactive system (PAPNET) and automated systems (AutoPap 300, Focal Point, and Thin Prep Imaging
System (TIS)) and all these instruments have been approved by United States Food and Drug Administration (USFDA) for screening systems [39].

Table 1: Information about cervical screening instruments [39]

Information	PAPNET	AutoPap 300	FocalPoint	TIS
Input data	Pap smear only	Pap smear only	Pap smear and ThinPrep	ThinPrep only
Characteristic	Semi-automatic system	Automatic system	Automatic system	Automatic system
USFDA approval	Secondary screening	Primary screening	Primary screening	Primary screening

Most diagnostic systems are only theoretically feasible especially in developing countries where access to the technology that will make these systems work are limited. In developed countries, most diagnostic systems currently designed favour early detection of cervical cancer cells through screening with Pap smear unlike developing countries where Visual inspection with acetic acid is the norm hence the need to design an expert system that can assist health workers in the confirmation of VIA screening results that will be web based to provide increased accessibility and availability which is being addressed in this study.

4.1 Methodology

The system was developed using the Dokas approach; a standard approach for developing web based expert systems.

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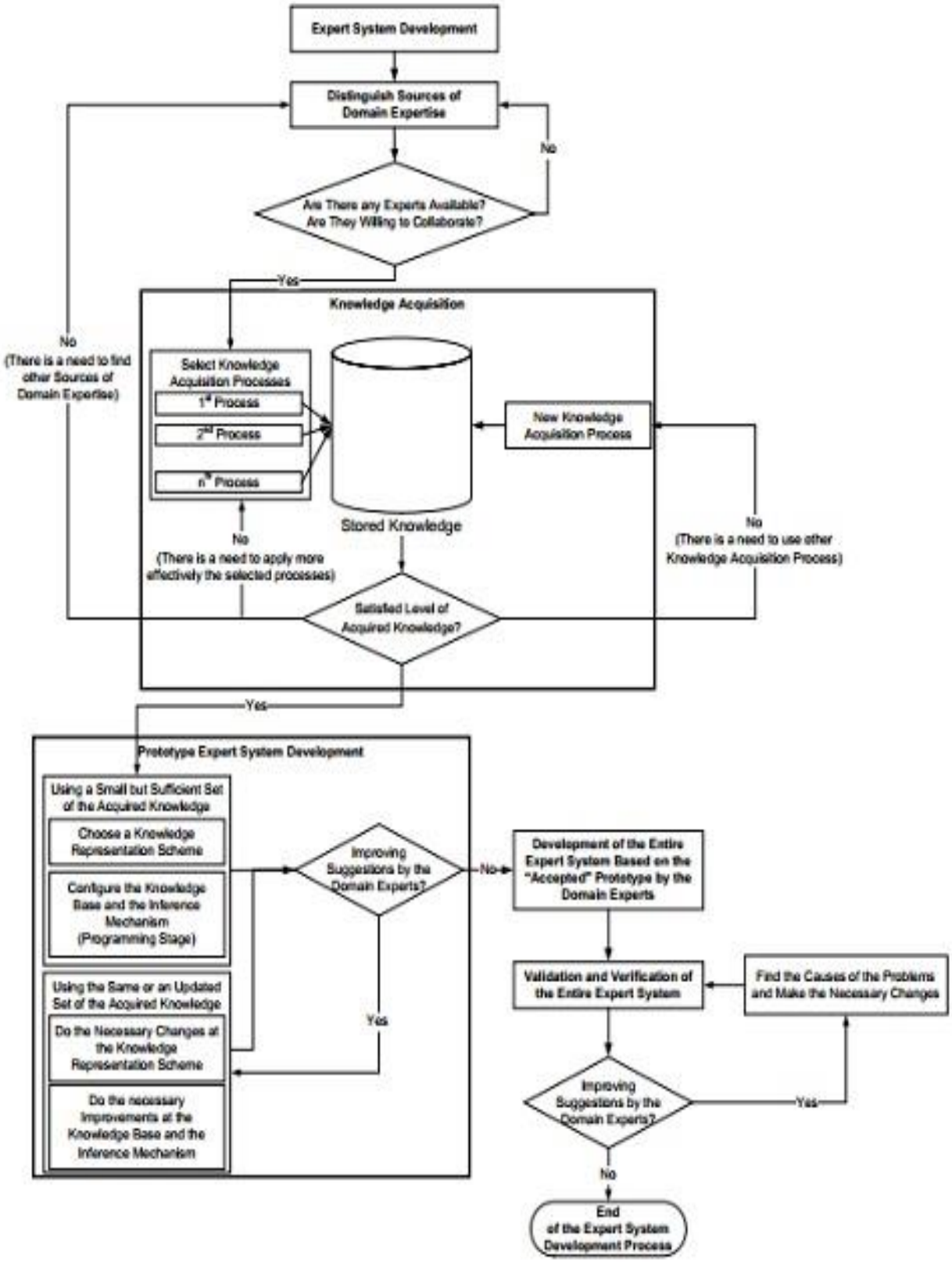

Figure 2: Expert system developing process [40]

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This process was adopted so as to help readers perceive the corresponding work flow process of the expert system development.

4.2 User Requirements

The need to know the user requirements is a very vital and integral part of information system design which is very essential to the success of most interactive systems [41]. As specified in International Standard Organization (ISO) 13407 standard [42], user centered design begins with a thorough understanding of the needs and requirement of users. It is a generic standard and can be applied to any system or product. According to this standard, it stipulated that there are four essential activities in a user-centered design which are:

- Requirement gathering: Understanding and specifying the context of use.
- Requirement Specification: Specifying user requirements.
- Design: Producing designs and prototypes.
- Evaluation: Carrying out user based assessment of the system.

The advantages of this approach range from increased usability enhanced information quality, reduction in support and training costs and improved user satisfaction.

The users need a system that can assist in the confirmation of cervical cancer screening with VIA results; offer more awareness on the diagnosis and treatment for cervical cancer, be more user friendly by being user centered. The users of this system are average health workers like nurses, medical students, etc. Internet access is also required since it is web based and it requires user login information for authentication. The inference engine of cervipert was implemented in Hypertext Preprocessor language (PHP) since it is open source, highly compatible, it has wide accessibility and besides this is just a simple simulation of the entire system hence the justification for using PHP to implement the knowledge base.

5. EXPERT SYSTEM ARCHITECTURE

The diagram below depicts the expert system architecture that has been adopted to be used in understanding all the basic components that will be featured in Cervipert.

5.1 Knowledge Acquisition

The knowledge acquisition methods that were used in this study include: interview schedules with medical professionals and also potential users of the system, extensive medical literature and journal reviews, working with registered NGOs involved in affordable and at times free cervical cancer screening with VIA.

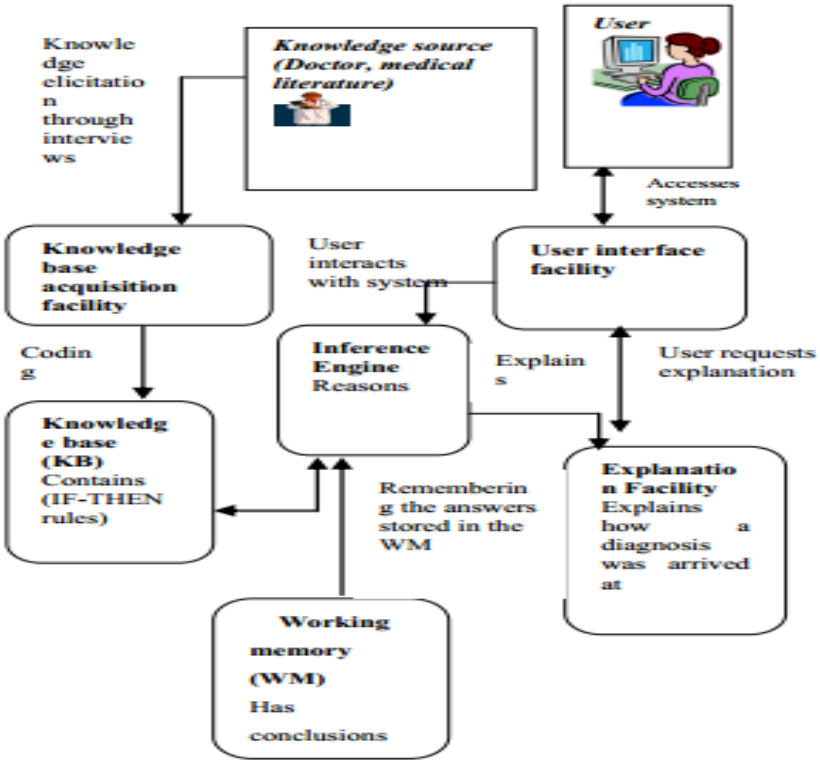

Figure 3: Structure of the expert system (Adapted from [43])

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6. RESULTS AND DISCUSSION OF FINDINGS

The knowledge base was implemented in PHP as it was realized based on the expert information on Screening to detect HPV in the cervix using VIA method that the number of IF……..THEN rules that need to be stored in the knowledge base are few hence could easily be accommodated using PHP, a general- purpose scripting language for web development.

6.1 System Implementation

The implementation phase of Cervipert covers the period from the acceptance of the tested design to its operation as supported by the appropriate user and operation manual.

Based on patient's information, Cervipert can detect whether a patient is either at risk, low or not at risk from having the HPV and based on this, advice is given to patients. Cervipert can also determine based on the information if the patient is eligible to be screened or not.

After the user might have done the screening on the patient, the system will ask the user to input observed results of VIA test as seen by the naked eye and based on this observations, the system will now confirm if patient is negative or positive to HPV.

6.2 System Testing/Analysis

Cervipert was designed with continuous user involvement throughout its developmental phase focusing more on acceptability, usability and quality of information that it possesses. Table 2 gives a detailed analysis of all important aspects of the system that was evaluated.

Table 2: System testing and analysis

Usability	By and large, Cervipert satisfies most of the usability criteria as it is fit for use, easy to learn and remember, easy to understand and navigate from one module to another and overall, it is satisfactory to use. Although using a multimedia interface to correctly match pre-defined text descriptions and images of symptoms should have been provided to users so they can choose text and images to describe VIA findings so they can actually be sure about their inputs into the system but this was not done as it could slow down access speed when users are trying to query the system. Online user feedback and evaluation of Cervipert was effective as it could actually increase user acceptability and bridge the gap between software developers and the actual system user making the system to be more user centered.
Security and access	A valid username and password is required by any user who really wants to have access to the system apart from the homepage that can be freely accessed to know more about Cervipert, get basic health tips and get contact information. Only the knowledge engineer has access and the sole responsibility to check, update and transfer knowledge into the knowledge base. Security was ensured by protecting the database from SQL injections.
Knowledge base	The knowledge base consisted of all the information that were collected from the human experts and structured using the IF……THEN constructs.
Reliability testing	This was done to ascertain the ability of the system to perform its required functions under stated conditions for a specified number of operations. This was done by actually using 20 number of patients results that has previously been screened for the virus using VIA, in putting it into the system to know whether the system will proffer the same result as gotten by the health workers that screened the patients in the first place and Cervipert was found to be 90% accurate
Black box testing	This was done to validate outputs in response to the inputs provided via the human interface based on previously understood requirements by the tester. Manual debugging of codes was also done to remove redundant codes thereby saving computational resources.
Integration testing	This was done by testing from one application to another to validate that the modules were working together. It was done to identify errors resulting from the interaction of the different interfaces.

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7. SUMMARY, CONCLUSION AND RECOMMENDATION FOR FUTURE RESEARCH

To ensure a successful user centered design for increased system usability, the needs and wants of the user must be satisfied at the completion of the developed system.

In other to achieve this, users should be more involved via simulations in order to prototype the user requirement which will of course evolve as the system develops and more formal evaluation takes place. In lieu of the above technique, a user centered diagnostic system have been developed that can assist health workers in the diagnosis of HPV which can lead to cancer if not detected and prevented early enough. Some of the benefits that Cervipert has to offer is that knowledge and expertise are made more accessible to its users, Cervipert is not prone to error in application of its knowledge, it is consistent, permanent and can easily be reproduced and more importantly, it gives second opinion thereby enhancing human service quality. The novelty of this study is the design and implementation of a User centered system that can be used by health workers to make more accurate decisions in the screening of HPV cancer causing cells using Visual Inspection with Acetic acid screening method.

It is expected that the research work will be a step towards adoption of electronic health, and contributing to sharing medical knowledge in Nigeria.

For any system developer to have an idea of how successful a developed system will eventually be, such systems need to be developed having users interest at heart and ensuring such systems are user centered by taking into all users requirements at each phase of the system development. User acceptance is also a pivotal factor in determining this assertion. User acceptance will help software developers uncover if a particular system that is being designed will have a high success rate or not as numerous literatures have justified the fact that lack of user acceptance of technologies has always been an obstacle to the success of recent technologies due to many factors hence further research can be done in evaluating users willingness to accept and use such systems before actually developing it to ensure high success rate. Cervipert is just a prototype of how a real expert system should behave and proffer human capacity based solutions in screening against HPV, the cervical cancer causing virus using Visual Inspection with Acetic acid method. In reality, Artificial Intelligence language such as Prolog, Lisp, Python, Haskell amongst others can be used in the implementation of the knowledge base. The knowledge base can also be made available on the web through Ontology representation so that other researchers who are interested in knowledge representation can assist in updating the knowledge base regularly online so as for it to become more robust. In cases where datasets of patients exists in screening using VIA, machine learning algorithms such as fuzzy logic, neural network, and decision trees amongst others can also be employed although each has its strengths and limitations hence comparative analysis of pattern classification algorithms on appropriate datasets should be performed before choosing the most appropriate one.

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