DEVELOPING AN ADAPTIVE LEARNING EXPERT SYSTEM FOR DIAGNOSIS AND TREATMENT OF ALZHEIMER'S DISEASE

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Abstract
Alzheimer's is a disease of the brain that causes problems with memory, thinking and behaviour. It is not a normal part of aging. Alzheimer's gets worse over time. Although symptoms can vary widely, the first problem many people notice is forgetfulness severe enough to affect their ability to function at home or at work, or to enjoy hobbies. The disease may cause a person to become confused, get lost in familiar places, misplace things or have trouble with language. However, among people in the developing countries like Nigeria, permanent diseases are growing to be causes of death. These problems are becoming worse due to the scarcity of specialists, practitioners and health facilities. In an effort to address such problem, this study attempts to design and develop a prototype adaptive learning expert system that can provide advice for physicians and patients to facilitate the diagnosis and treatment of Alzheimer's disease patients. To this end, tacit knowledge is acquired from domain experts using interviewing technique and explicit knowledge is captured from medical documents through document analysis technique to find the solution of the problem. Then, the acquired knowledge is modelled using decision tree structure that represents concepts and procedures involved in diagnosis and treatment of Alzheimer's disease and production rules are used to represent the domain knowledge and knowledge-based system is developed using SWI Prolog editor tool version 7.7.19. The system is tested and evaluated to ensure that whether the performance of the system is accurate and the system is usable by physicians and patients. The accuracy of the adaptive learning expert system is 79.5%. Thus, the prototype system achieves a good performance and meets the objectives of the study.

Keywords: Adaptive learning, Alzheimer's disease, confusion matrix, decision tree, expert system, prototype system

Introduction
Dementia describes a variety of brain disorders which progressively lead to brain damage and cause a gradual deterioration of the individual's functional capacity and social relations. In 2015, dementia resulted in about 1.9 million deaths. Alzheimer's disease is the most common form of dementia, representing about 60% to 80% of cases (OECD, 2017).

Alzheimer's disease (AD) is an irreversible, progressive brain disease that affects as many as 5.5 million Americans (Hebert *et al.*, 2013). In developed countries, AD is one of the most financially costly diseases (Bonin-Guillaume *et al.*, 2005). Nigeria, Libya, Tunisia, Morocco, Mali, Algeria, Gambia, Egypt, Burkina Faso, Sierra Leone, Namibia, Sudan, Togo and Angola are Africa Countries with high rate of Alzheimer's and Dementia. In the world rankings, Nigeria is ranked number eleven among the countries with high rate of Alzheimer's and Dementia (WHO, 2020). AD slowly destroys brain function, leading to cognitive decline (e.g., memory loss, language difficulty, poor executive function), behavioural and psychiatric disorders (for instance, depression, delusions, agitation), and declines in functional status (for instance, ability to engage in activities of daily living (ADLs) and self-care) (Burns & Iliffe, 2009).

The disease is named after German psychiatrist and pathologist Alois Alzheimer, who first described it in 1906 (Berchtold & Cotman, 1998). Dr. Alois Alzheimer first documented the disease when he identified changes in the brain tissue of a woman who had memory loss, language problems, and unpredictable behavior. Her brain tissue included abnormal clumps (amyloid plaques) and tangled bundles of fibers (neurofibrillary tangles). Brain plaques and tangles, in addition to the loss of connections between neurons, are the main pathological features of AD (ADERC, 2011). However, other pathologic features occur commonly in the brain of older Americans diagnosed with AD and these are thought to also contribute to the burden of dementia in the United States (NIA, 2010).

Expert System is one of the most common applications of artificial intelligence. It is a computer program that simulates the decision and actions of a person or an association that has specialist facts and experience in a particular field. Normally, such a system contains a knowledge base containing accumulated experience and a set of rules for applying the knowledge base to each particular situation. The major features of expert system are user interface, data representation, inference, explanations etc. Advantages of expert system are increased reliability, reduced errors, reduced cost, multiple expertise, intelligent database, reduced danger etc. Disadvantages of expert system are absence of common sense and no change with changing environment (Kadhim *et al*., 2011).

The Adaptive learning is system that has the ability to adapt with dynamic knowledge by generalizing rules and discover new rules through learning the newly arrived knowledge from domain experts adaptively without any help from the knowledge engineer (Agizew, 2019). In order to develop such medical expert systems, adaptive learning mechanisms used the input sign or symptoms of the disease, the current available knowledge base, and the valid diagnosis result to produce an updated knowledge base. Before applying the adaptive learning techniques for the expert system, deciding how and when to apply those different types of learning mechanisms is very important. These mechanisms may refine rule statistics, rule hypotheses, or add new rules.

Statement of the Research Problem

AD/ADRD is a major public health issue and will increasingly affect the health and well-being of the population. As at 9th of November, 2020, Nigeria total deaths due to Alzheimer's and Dementia is thirteen thousand and sixty one (WHO, 2020). There is currently no cure or disease modifying treatment, but better policies can improve the lives of people with dementia by helping them and their families adjust to living with the condition and ensuring that they have access to high quality health and social care (OECD, 2017). Alzheimer's and Dementia is one of Nigeria top 50 causes of death. Unless the diseases can be effectively treated or prevented, the number of peoples with AD/ADRD will increase significantly in the next two decades (WHO, 2020).

Dementia is very prevalent among the elderly but is often overlooked even by skilled clinicians. Improving our ability to recognize dementia is a key first step toward improving this widespread situation.

Developing expert systems would play essential and critical role in providing aid for giving diagnosis, capturing guidelines and knowledge and experience of well-educated and experienced physician and make it available for those health workers which also help the country in providing a quality health care service for the people who are living in remote and rural areas.

Therefore, this study aims to develop adaptive learning expert system that can improve the compressiveness of advice provided by the system in line with accurate diagnosis and management of Alzheimer disease using both discovery and generalization mechanism.

Research Questions

This study explores and finds solutions for the following research questions:

(a) What suitable domain knowledge available for the diagnosis and treatment of Alzheimer's disease?

(b) What are the suitable ways to develop adaptive learning expert system for diagnosis and treatment of Alzheimer's disease?

Aim and Objectives of the Study

The aim of this study is to develop adaptive learning expert system that can provide advice for physicians in order to aid the diagnosis and treatment of Alzheimer's disease.

The objectives of the study are to:

(i) Model and represent the knowledge in a suitable way for knowledge based expert system implementation.
(ii) Design the prototype expert system with adaptive learning ability.
(iii) Evaluate the expert system performance

Literature Review

There are different studies on knowledge based system which have been done in the medical domain. Tarekegn (2016) developed a localized knowledge based system for TB disease diagnosis using Ethiopian national language. The system is tested and evaluated to ensure that whether the performance of the system is accurate and the system is usable by physicians and patients. The average performance of the localized knowledge based system has registered 81.5%. Agizew (2019) developed adaptive expert system for diagnosis and management of viral hepatitis using disease symptoms. The proposed system has the ability to adapt with dynamic knowledge by generalizing rules and discover new rules through learning the newly arrived knowledge from domain experts adaptively without any help from the knowledge engineer. Chopra *et al*. (2020) studied pathophysiology and pharmacotherapy of Alzheimer's disease. Mubangizi *et al*. (2020) presented cross-sectional, population-based study of Alzheimer's disease using Multivariable logistic regression. Zhang *et al*. (2021) presented an overview of current epidemiological advances related to Alzheimer's disease. This epidemiological studies identified potential modifiable risk and protective factors for Alzheimer's disease prevention.

However, in reviewing the above literatures and as to the researcher's knowledge no attempt has been done to design an adaptive learning expert system for diagnosis and treatment of Alzheimer's disease. Moreover, most of knowledge based system didn't propose a treatment method for clinical activity and previous literatures didn't demonstrate user acceptance testing of the system which is done by users to ensure that whether the proposed system satisfies the requirements of its end-users. Thus, in this study an attempt is made to design an adaptive learning expert system (ALES) that can discover new rules through learning the newly arrived knowledge from domain experts adaptively without any help from the knowledge engineer.

Methodology of the Study

Data Collection Method

The data source for this study was University College Hospital (UCH), Ibadan, Nigeria. It is worth noting that only one geriatric care centre exists in all of Nigeria is at the University College Hospital, Ibadan. There are many different kinds of complex human disease diagnosed in the hospital. For this study, the researcher selected Alzheimer's disease (AD) which is one of the most complex and deadliest diseases in the world. During data collection, explicit and tacit knowledge are acquired from both documented sources and non-documented sources respectively. Non-documented sources of knowledge are acquired from internists and medical doctors who work in the geriatric care centre of UCH by using interviews and discussions. Similarly, documented sources of knowledge such as medical books, training manuals and journal medical articles are acquired by using document analysis technique. In addition to tacit and explicit knowledge, documented Alzheimer's patient history is collected from patient records for evaluation purpose.

Sampling Techniques

Purposive sampling technique is used to select domain experts for knowledge acquisition and to collect previous AD patient cases archived in University College Hospital. The selection criteria of domain experts for the study is based on the profession or expertise, educational qualification level, year of experience and their immediate position in the AD disease diagnosis. Six experts have been consulted in the courses of study and one BSc nurse is involved in the registration of the patient cases from the card collection. Purposive sampling is one of the most common sampling techniques in qualitative research in which participants are decided preselected criteria relevant to a particular research question (Mack *et al.*, 2011). Expert sampling is a type of purposive sampling technique that is used when the research needs to gather knowledge from individuals that have particular expertise. It is also called judgmental sampling that occurs when the researcher interviews a panel of individuals known to be an expert in a given domain. Expertise can be any special knowledge, not necessarily formal training, depending on the topic of study (Garson, 2012).

Knowledge Modelling and Representation

In this study, after the knowledge is extracted from documentary and non-documentary sources, it is modelled using decision tree structure. Decision trees models by constructing a tree based on training instances with leaves having class labels is used. These are easy to interpret and can be represented as if-then rules. The knowledge acquired from different sources has to be represented using the knowledge representation methods. After the acquired knowledge is modelled, it is represented by using knowledge representation methods. Production rules are the most popular form of knowledge representation methods for knowledge based system development. Knowledge is represented in the form of condition/action pairs: IF this condition occurs, THEN some action (or conclusion) will (or should) occur (Kayode *et al.*, 2013). Production rules are also easy for a human expert to read, understand and maintain. Production rules contain simple syntax which is flexible and easy to understand and are reasonably efficient in diagnosing of human diseases. The reasons for using productions rules in this study are because of its ease of modifications and applicability when there is a need to recommend a course of action based on observable events (Pearson Education, 2012).

Implementation Tool

Prolog programming language is used to develop the adaptive learning expert system. The reason for selecting this programming language is the features and abilities of the language that incorporate it. Prolog is a declarative language and has the capacity to describe the real world. Because of its declarative semantics, built-in search, and pattern matching, Prolog provides an important tool for programs that process natural language. We can write natural language grammars directly in Prolog.

Knowledge Acquisition

Knowledge acquisition is the process of collecting, extracting, structuring and organizing knowledge, and recording it in a convenient form for representation from different sources like human experts, books, medical documents, journals and the Internet, so it can be used in knowledge-based system development (Ashenafi, 2013). This is usually done through visual, aural, reading and mining from large documents in which a knowledge engineer receives through different techniques. The acquisition of knowledge is a major and critical phase in the development of knowledge based systems and is still the most difficult and error-prone task that knowledge engineer does while building a knowledge-based system.

Explicit knowledge acquisition

There are several sources of explicit knowledge including literatures, books and guidelines. The knowledge captured here should be used as a reference and to confirm the tacit knowledge captured from the human expert and should never replace an experienced domain expert. The following are some sources for explicit knowledge acquisition (Rhem and Associate, 2011): Literatures, Reports, guidelines, Published books and journal articles.

Tacit knowledge acquisition

Since printed materials can sometimes become outdated and not sequentially arranged, printed materials should never be considered as sufficient sources of information for the development of knowledge-based systems. The experience that guides the reasoning of a domain expert cannot all be found in printed sources such as books. The range of problems which a textbook examines and solves is always smaller than the range of problems that a human expert is master of (Rhem and Associate, 2011). So, acquiring domain knowledge from the human expert is needed for development of knowledge based system. The most important part of knowledge acquisition is knowledge elicitation which consists of a set of techniques and methods that attempt to elicit the knowledge of a domain expert, typically through some form of direct interaction with the expert (Nigel and Paul, 2014).

Knowledge acquisition process

Knowledge elicitation was performed through Knowledge Acquisition. In order to acquire required knowledge for this study both secondary and primary sources of knowledge are used. Secondary source of knowledge involves gathering knowledge from existing documentations. Secondary sources of knowledge is gathered from the Internet sources, Alzheimer's disease diagnosis guide line, Alzheimer's disease prevention, Alzheimer's disease treatment guide line, manuals, and published Articles. The primary sources of knowledge include AD experts who work at University College Hospital, Ibadan, Nigeria. During the preliminary investigations, seven experts from UCH have been contacted to understand the dimension of AD disease. During this time, the researcher is trying to conduct informal kinds of interviews with these experts.

However, for extensive discussion with experts, the researcher selects five experts. The experts were purposively selected for the interview by their knowledge of AD and years of experience they worked on AD. These experts are consulted throughout the research work to evaluate the correctness of the acquired knowledge and to verify the cases acquired from the previous patient history. To collect the knowledge from a given specific domain there are different techniques available such as interview, protocol analysis, document reviews, questionnaires and card analysis (Audrey, 2012) which can be used to acquire both tacit and explicit knowledge. Basically the researcher used structured interview to acquire knowledge of domain experts and organizational document analysis to acquire knowledge from relevant documents. This is because of a structured interview is a systematic, goal oriented process; It forces organized communication between the knowledge engineer and the expert.

Knowledge Modeling

Conceptual modeling is considered to be an important stage in knowledge based system development process. According to Pamela (2009) conceptual modeling is the activity of formally describing aspects of the domain knowledge for the purposes of understanding and communication. The knowledge engineer has to determine what aspects of the real world to include and exclude from the model. The way that this is done depends on the needs of the potential users, the domain to be modeled and the objectives to be achieved. There are many techniques used for knowledge modeling such as decision tree, semantic network, UML, and hierarchy of frames. For knowledge-based systems, decision trees have the advantage of being comprehensible by domain experts and of being directly convertible into production rules i.e. decision tree has the ability to represent the problem in natural and simple if-then description (Hussein *et al.*, 2002).

Moreover, when used to handle a given case, a decision tree not only provides the solution for that case, but also states the reasons behind its choice. Thus decision tree is used in this study to model the elicited domain knowledge.

The details of the conceptual model that domain experts use during diagnosis and treatment of Alzheimer's disease using decision tree are depicted in Figure 1 below:

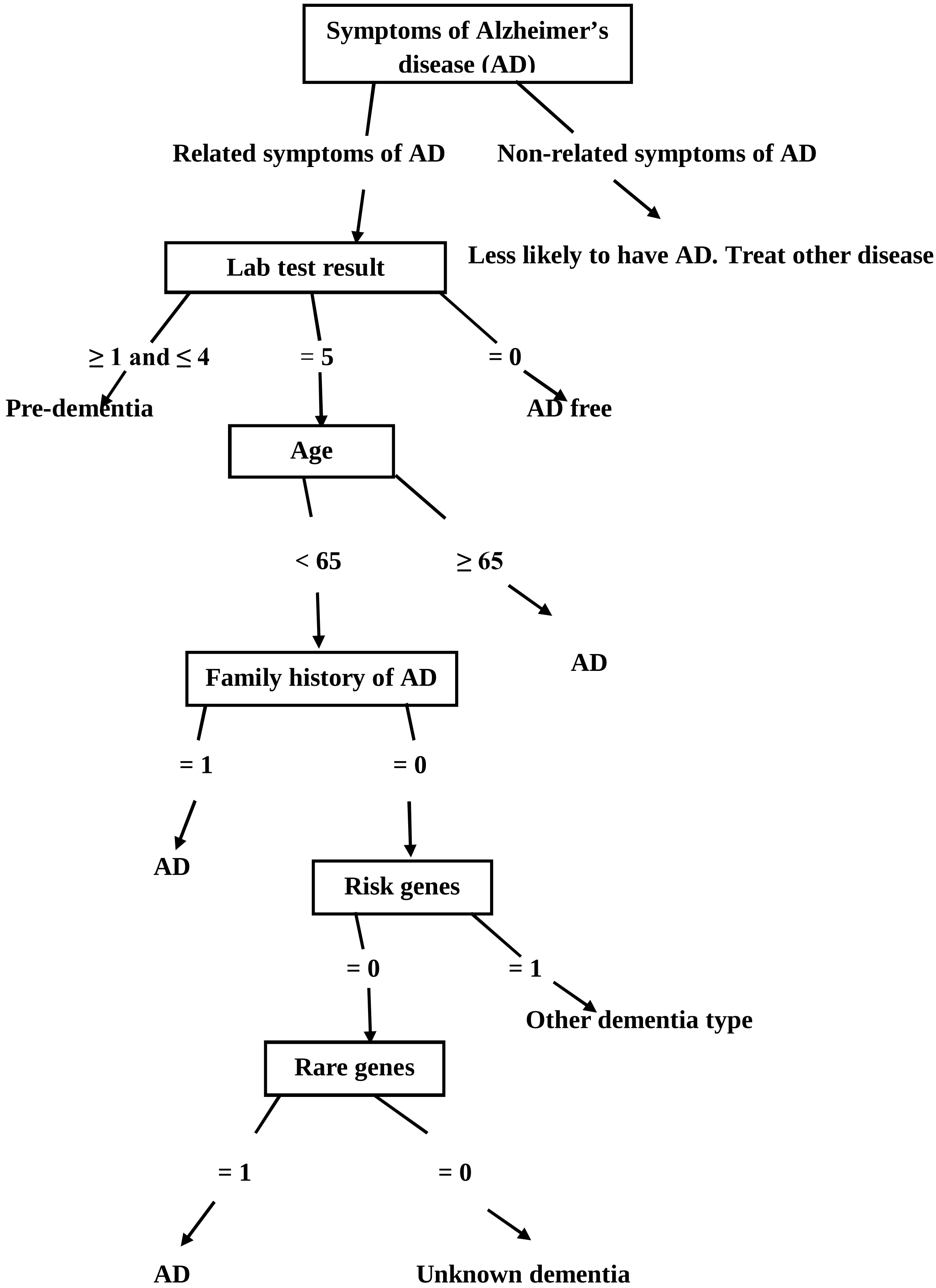

Figure 1: Decision tree for diagnosis and treatment of Alzheimer's disease (AD)

In the diagnosis process, any person who presents with symptoms or signs suggestive of AD, in particular memory lapses is an AD suspect and should have mood and mental status, blood and urine laboratory and brain imaging study examinations. Starting these examinations quickly helps the patient to start the treatment as early as possible for better outcome. For diagnostic purposes, all persons suspected of having AD at any site should undergo five laboratory tests. The results of the tests must be known by either the patient or the caregiver. The decision tree based on conceptual model depicted in Figure 1 shows the levels of decisions that domain experts use during diagnosis. It is modelled by classifying the laboratory test results as all positive (5), mixed (some positive and some negative) (≥1 and ≤4) or all negative (0).

Knowledge Representation

After the raw data is acquired from the domain experts, it must be modelled and converted into intermediate representations. Knowledge representation is the process of encoding domain knowledge in to machine understandable representation. There are several commonly used techniques for knowledge representation in the development of knowledge-based systems. These are logic, production rules, semantic nets, frames and cases. In this study production rules are used to represent the domain knowledge and a rule-based knowledge representation and reasoning is followed. They are one of the most commonly used technique for the development of knowledge-based systems. Knowledge is represented in the form of condition-action pairs: IF this condition (or antecedent-condition or premise) occurs, THEN some action (or conclusion or consequence) will occur. For instance, the rules for the knowledge based system are constructed based on the AD diagnosis knowledge modelled using decision trees above. The following are fragments of sample rules of the knowledge base.

If patient has AD symptoms
Then the patient is AD suspect AND must check

- *(i) Mood and mental status tests*
- *(ii) Blood and urine laboratory tests*
- *(iii) Brain imaging study test*

If all tests results score = 5
Then the Patient has AD
If all tests results score= ≥ 1 and ≤ 4
Then the Patient has pre-dementia.
If all tests results score= 0
Then the Patient is less likely to have AD, check for other disease.

Implementation

An adaptive learning expert system is implemented based on the decision tree model and the knowledge represented in a form of rule-based representation. The SWI Prolog implementation tool is used to develop the prototype, which has different components. It involves user interface, knowledge base, and inference engine and explanation facility. Figure 2 shows the architecture of the system which is constructed.

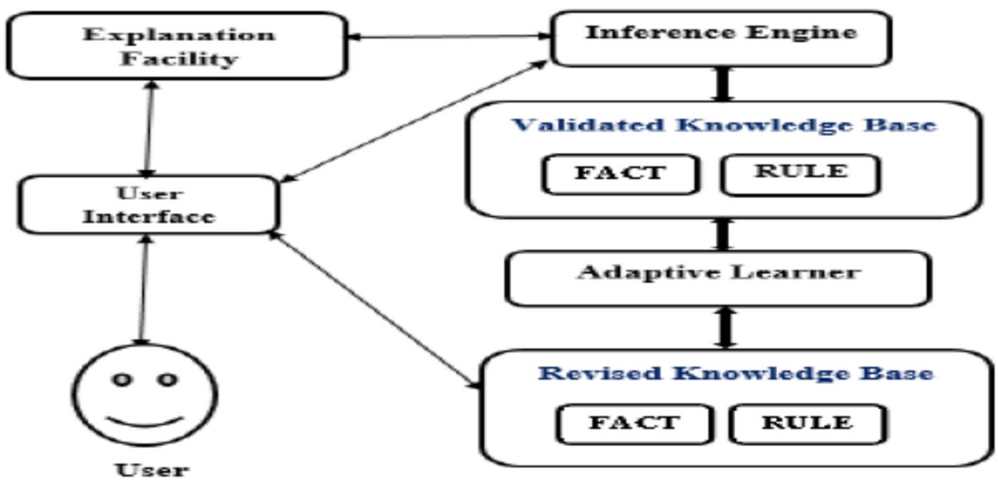

Figure 2: Prototype Adaptive Learning Expert System Architecture

As shown in Figure 2, the developed prototype system functions by asking questions to the new patient who came for diagnosis and treatment of Alzheimer's disease. First it checks the appearance of the basic symptoms of Alzheimer's disease in the patient and sends the patient for (i) mood and mental status test (ii) blood and urine laboratory test and (iii) brain imaging study test to decide whether the patient has Alzheimer's disease. If the patient has tested positive, then it further diagnoses the patient to identify which type of dementia the patient has. To decide whether the patient has Alzheimer's disease or other dementia, it considers the risk factors of Alzheimer's disease such as age, family history of Alzheimer's disease, risk genes, rare deterministic genes and serious head injury. Besides, if the previous diagnosed test result of a certain patient shows the patient has Alzeimer's disease and when the patient wants to diagnose again, the test result shows the patient has Alzheimer's disease. The system automatically remembers the patient"s history from the facts base and decides the patient has Alzheimer's disease, i.e. the prototype system learns from experience and updates its knowledge accordingly. Lastly, it recommends treatments for patients.

Starting the Adaptive-Learning Prototype System

The end-user of the system can start the diagnosis by inserting the word "start" then full stop "." and press "enter" using the SWI-Prolog Editor window. The welcome window will be displayed in order to help the end-users to interact easily with the system. This is shown in Figure 3 as follows:

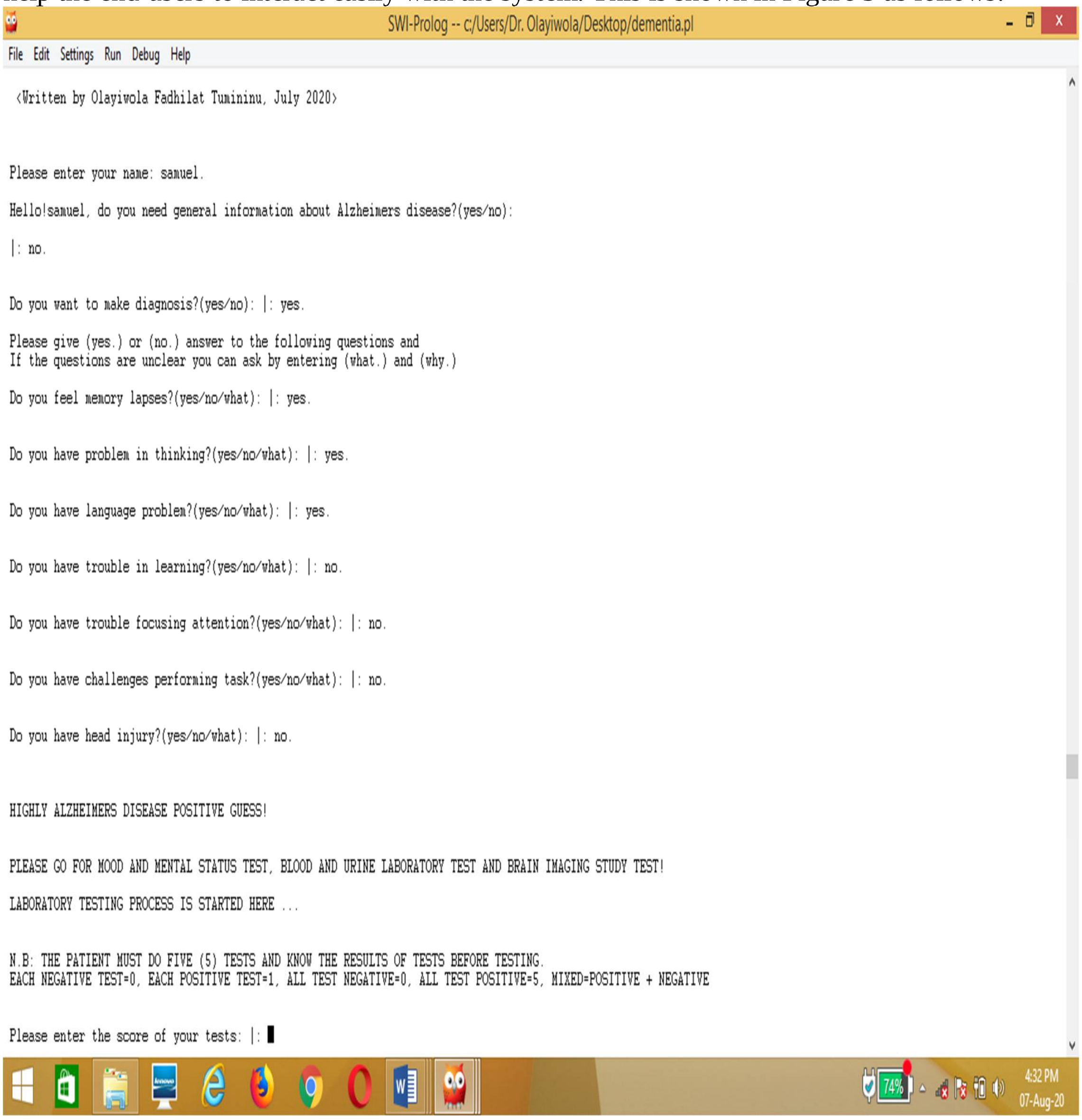

Figure 3: Sample dialogue that uses three basic symptoms to guess high dementia positive

After the welcome window is displayed, the system requests the end-user to insert the name of the patient before proceeding to the diagnosis process. Then it gives general information about Alzheimer's disease if the end-user needs to know about Alzheimer's disease. Next the system can diagnose the patient by asking the most common signs and symptoms of Alzheimer's disease so as to enable the system to predict whether the patient has Alzheimer's disease or not. When the system guesses as high Alzheimer's disease positive using symptoms, it depends on the appearance of at least the above first three main symptoms, that is feeling of memory lapses, having problem in thinking and having language problem must be answered as 'yes' by the end-user. After this the system suggests the patient to score the tests results to assure. This is the most important and useful suggestion by the system in order to conclude whether the patient has Alzheimer's disease or not.

Testing and Evaluation

Evaluation is an important issue for every knowledge based systems. It is a technique used to demonstrate the performance of the system and its acceptance by the end users. The purpose of the evaluation process is to get the end user's views on the significance or usefulness of the system. The evaluation and testing issue of the system answers the question "To what extent the adaptive learning expert system give acceptable and accurate diagnosis and treatment service to Alzheimer's disease patients?" To answer this question, system performance testing and user acceptance testing methods are used.

User acceptance testing

User acceptance testing is the process of ensuring that whether the system satisfies the requirements of its end users. This allows users of the system to test the prototype system by actually using it and evaluating the benefits received from its use. A questionnaire is prepared to evaluate the user acceptance of a system, and the evaluators fill the questionnaire after they have used the system. The questionnaire prepared is used to measure the system performance based on the standard of user acceptance validation. The researcher adopted the questions from Audrey (2012), Solomon (2013), Ashenafi (2013) and Tarekegn (2016). Table 1 represents the questions that users used to evaluate the system.

Table 1: Questions for user acceptance testing

Questions Number	Questions
Question 1	The system is simple to use during interaction?
Question 2	The results and descriptions provided by the system are easily understandable
Question 3	The system operates in a very good speed and efficiency
Question 4	The system is helpful and free physicians from boring routine tasks
Question 5	Coverage of AD knowledge is sufficient
Question 6	The commands are easy to learn and understand for new users
Question 7	The system has an ability to remember the patients history
Question 8	The advice provided by the system is accurate and useful

The evaluators fill in the questionnaire as strongly agree, agree, neutral, disagree and strongly disagree for each of the questions. The author assigned values for each word or phrase as strongly agree = 5, agree = 4, neutral = 3, disagree=2 and strongly disagree = 1. A total of six domain experts are participated in the system evaluation. Table 2 shows the evaluation results.

Table 2: Results of Evaluation

Question	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree	Average
1	2	3	0	1	0	4.00
2	2	2	1	1	0	3.83
3	3	2	1	0	0	4.33
4	3	2	1	0	0	4.33
5	2	1	3	0	0	3.83
6	1	3	2	0	0	3.83
7	2	2	0	2	0	3.67
8	3	2	0	1	0	4.16
Total Average						**4.00**

It is found in Table 2 that most respondents agree that a user can use and interact with system easily. The simplicity of the system showed 83.33 % scored as agreement, 16.67% as disagreement. Similarly, 83.33 % of the respondents agreed with the speed of the system as it is fast but 16.67 % of them remained neutral.

For evaluation criteria 4, it was found that most users agree that the system can be very helpful and could reduce some of the workload for medical assistants especially during peak times (50% of them selected strongly agree, 33.33 % agree and 16.67 % remained neutral). This will decrease the long queues in clinics because other physicians can still use the system without assistance. For evaluation criteria 5, it was found that most of the respondents agreed that the system has incorporated sufficient knowledge of the domain which scores about 50 % and 50% of them argued that the system didn't incorporated sufficient knowledge of the domain.

For evaluation criteria 7, which has to do with the ability of the system to remember the patients' history, the users have also given their opinion. Based the collected results 33.3% of the respondents are strongly agreed on the ability of the system to remember the patients' history, 33.33% of them grouped as agree and the remaining 33.33% as disagree. The total sums of the users that agreed on the ability of the system to remember the patients' history are 66.66%. This indicates that the majority of the users agreed on the ability of the system to remember the patients' history. However, the remaining 33.33% of the evaluators didn't agree.

Generally, it was found that most evaluators have positive feedback about the ALES, especially about the knowledge that system contains and ability to remember the patients' history. The average performance of the prototype system according to the evaluation results filled by the domain experts is 4.00 out of 5 or 80% which shows the users are satisfied with the adaptive learning expert system (ALES).

System Performance Testing

This testing method is applied to evaluate the performance of the adaptive learning expert system (ALES) using the parameters precision, recall and F-measure. These three parameters are used in order to measure the accuracy of the prototype system. In this study, twenty-two patients' test cases are circulated to the evaluators. In the process of testing the performance of the ALES, the domain experts classify correctly and incorrectly diagnosed patients cases by comparing the judgments reached by the ALES with that of the domain experts 'judgments reached on the same patients' test cases.

Performance of this system is usually evaluated using the data in the matrix. Table 3 shows the confusion matrix for a three class classifier.

Table 3: Confusion matrix of the ALES

		ALES Suggestion		
	Class names	Predementia	Alzheimer's	Other dementia type
Experts Decision	Predementia	**6**	**2**	**0**
	Alzheimer's	**3**	**5**	**0**
	Other dementia type	**0**	**0**	**6**

A confusion matrix is a visualization tool typically used to present the results attained by the learner. Each column of the matrix represents the instances in a predicted class, while each row represents the instances in an actual class. One benefit of a confusion matrix is that it is easy to see if the system is confusing two classes.

In Table 3, of the 8 actual predementia patients, the system predicted that 2 were alzheimer's patient. In this case, $TP = 6$, $FP = 2$, $FN = 3$, $TN = 5$ and $P = \frac{TP}{(TP+FP)} = \frac{6}{6+2} = \frac{6}{8} = 0.75$ (1)

$$R = \frac{TP}{(TP+FN)} = \frac{6}{6+3} = \frac{6}{9} = 0.67 \quad (2)$$

$$F = \frac{2\times P\times R}{(P+R)} = \frac{2\times 0.75\times 0.67}{(0.75+0.67)} = \frac{1.005}{1.42} = 0.71 \quad (3)$$

and of the 8 actual alzheimer's patients, it predicted that three were predementia. In this case, $TP = 5$, $FP = 3$, $FN = 2$, $TN = 6$ and

$$P = \frac{TP}{(TP+FP)} = \frac{5}{5+3} = \frac{5}{8} = 0.63 \quad (4)$$

$$R = \frac{TP}{(TP+FN)} = \frac{5}{5+2} = \frac{5}{7} = 0.71 \quad (5)$$

$$F = \frac{2\times P\times R}{(P+R)} = \frac{2\times 0.63\times 0.71}{(0.63+0.71)} = \frac{0.89}{1.34} = 0.67 \quad (6)$$

Also, of the 6 actual other dementia type patients, the system predicted that 6 were other dementia type. In this case, $TP = 6$, $FP = 0$, $FN = 0$, $TN = 0$ and $P = \frac{TP}{(TP+FP)} = \frac{6}{6+0} = \frac{6}{6} = 1.0$ (7)

$$R = \frac{TP}{(TP+FN)} = \frac{6}{6+0} = \frac{6}{6} = 1.0 \quad (8)$$

$$F = \frac{2\times P\times R}{(P+R)} = \frac{2\times 1\times 1}{(1+1)} = \frac{2}{2} = 1.0 \quad (9)$$

$$Average\ weight\ of\ \Pr ecision = \frac{0.75+0.63+1.0}{3} = 0.79 \quad (10)$$

$$Average\ weight\ of\ \mathrm{Re}call = \frac{0.67+0.71+1.0}{3} = 0.79 \quad (11)$$

$$Average\ weight\ of\ F - Measure = \frac{0.71+0.67+1.0}{3} = 0.79 \quad (12)$$

We can see from the matrix that the adaptive system can make the distinction among predementia, alzheimer's and other dementia pretty well.

From Table 3, we can see that the result of the testing has revealed 79% accuracy in diagnosing dementia cases. The detailed generated result for this performance measure is shown in Table 4 which includes the precision (P), recall(R) and F-measure.

Table 4: Accuracy of the ALES

	Precision	Recall	F-Measure	Class names
	$\frac{6}{8} = 0.75$	$\frac{6}{9} = 0.67$	**0.71**	**Predementia**
	$\frac{5}{8} = 0.63$	$\frac{5}{7} = 0.71$	**0.67**	**Alzheimer's**
	$\frac{6}{6} = 1.00$	$\frac{6}{6} = 1.00$	**1.00**	**Other dementia type**
Average Weight	**0.79**	**0.79**	**0.79**	

As shown in Table 4, the precision for other dementia type scores the highest rate (100%) followed by predementia (75%) and alzheimers' (63%). The recall for other dementia type is 100% which is the highest score. The weighted average precision is 79% which shows the ALES has an accuracy of 79% in diagnosing dementia patient cases, that is, of the 22 dementia cases, 79% of the cases are diagnosed correctly. Similarly, the weighted average recall is 79% which shows the ability of the KBS system to select instances from a set of cases.

Results and Discussion

In this study both system performance testing and user acceptance testing have been done for the adaptive learning expert system. As indicated in section 9.2, the accuracy of the system is calculated as 79%. In addition to accuracy, user acceptance evaluation of the system has been calculated as 80%. The average performance of the adaptive learning expert system is 79.5 % which is an encouraging result.

Conclusion

Alzheimer's is a permanent disease and therefore it will not be treated for once and last. Due to this reason, patients need self-diagnosis and consistent treatment. But, in most developing country, there are no sufficient numbers of physicians. This condition leads to disproportional numbers of physicians and patients. Because of this problem, Alzheimer's disease patients are not getting enough diagnosis and treatment.

Knowledge based system is basically an interactive computer programme that can help a great deal in disease diagnosis and treatment. Hence, in this study an effort has been made to design and develop a prototype of an adaptive learning expert system that can provide advice for physicians and patients to facilitate the diagnosis and treatment of patients living with Alzheimer's disease.
The system is evaluated using different evaluation methods and achieved 79.5 % of an average performance. The research contributed to knowledge by constructing the prototype adaptive learning expert system for diagnosis and treatment of Alzheimer's disease using SWI-Prolog editor.

Recommendation

However, in order to make the system applicable in the domain area for diagnosis and treatment of Alzheimer's disease additional study is needed like updating the rules in the knowledge base of the system automatically, incorporating a well-designed user interface.

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