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Original Article

Expert System for Diagnosis of Eye Defect and Recommendation

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Abstract – *While there are different ways to treat and correct defects of the eye, the software assisting system developed will only give appropriate recommendations for the correction of short and long-sightedness and offer guard on the use of 'tumbling E board' for carrying out acuity tests. Expert systems have proven to be vital in the movement to automation in various fields of endeavours. The time-saving advantage of using technological devices which can perform repetitive tasks faster than any human indirectly adds to a reduction in the price of production. This research work harnesses the power of recent development in the field of computer science in order to improve the current technique of eye defect diagnosis and recommendation.*

Keywords – *Expert, System, Eye, Defect, Recommendation, Diagnosis.*

I. BACKGROUND OF THE STUDY

The eye is one of the most sensitive organs of the human body. It is an optical medium of luminosity and vision, made up of a network of light receptive cells and neurons which transfer information directly to the brain. According to Wikipedia, the eye is a complex optical system made up of photoreceptive cells which react to light and allow vision ("The Human Eye", 2019). A problem with the eye affects the overall functioning of the body system and the overall wellbeing of an individual. As such, it is important to care for and protect it. Diagnosing and treating such an organ will require the highest level of precision, accuracy, and expertise. This research work seeks to explore recent advancements in the field of computer science as a platform for diagnosing eye-related problems and proffering appropriate lens types to correct these defects. Technology today has evolved from the ancient days of slow processing room-size computers to the present day powerful multi-processing hand-held devices capable of performing millions of operations in a unit of time. Spectacular technological innovations have emerged due to this paradigm shift and are affecting every area of human endeavour (Pan, 2016). The way we think, work, collaborate and communicate at individual levels, to innovations, inventions, manufacturing and processing activities done in industries have been transformed due to the presence of sophisticated devices and computer-powered equipment.

In the year 2015, world leaders put forth the 2030 Agenda of Sustainable Development Goals (SDGs), which is aimed at harnessing recent development in science and Information Communication Technology (ICT) to foster better, healthier, developed and inclusive societies (Durant, 2018). Computers are used to achieve greater job functions and work efficiency today, unlike in days of primitive technologies when manual machines were used. Working with technological equipment is time-saving and has proven to be cost-effective compared to the cost of acquiring, maintaining and operational expenses associated with the use of manual machinery. Interestingly in this digital area, disruptive technologies have come to replace most manual systems (Steven, 2015). According to Steve, such new technologies include Artificial Intelligence, 3D printing, renewable energy technologies, biotechnologies and others. Different areas have been revolutionized due to these emerging technologies, such as commerce and industry, politics and governance, medicine and health, agriculture, military and security, education and learning (Raja & Nagasubramani, 2018). ICT has, therefore, become the bedrock and backbone of modern innovations, cutting across diverse fields and bridging gaps to make life easier and better. Hülya (2015) said, "While certain countries regularly improve the life quality of individuals with the support of advanced technologies, other countries are way behind them in this improvement". The research by Keisci shows a direct link between the use of advanced technology and the economic growth of a Nation and how technology has helped improve every aspect of the lives of citizens. Medicine is one such area that has been technologically motivated in recent years. Laboratory experiments, testing and research in the medical field have been significantly improved by the availability and use of ICT tools.

Practical application of ICT also caught down on expensive procedures and reduced the cost of production due to labour and payment of manpower. Processing devices, when put to use, reduce the number of employees required to perform a certain job. The time-saving advantage of using technological devices which can be perform repeated tasks faster than any human indirectly adds to a reduction in the price of production. In hospitals, for example, the number of surgeons in a team required for surgery can be reduced by the use of smart technological devices (Neil, David, & Paul, 2015). Despite the present-day rapid changing technology, health challenges have continued to threaten human existence over decades, especially in developing and undeveloped countries of the world, where access to basic amenities is not readily available, the emergence of diseases is inevitable. Ikonne (2018) defines primary health care as "essential healthcare based on practical, scientifically sound and socially acceptable methods and technology made universally accessible to individuals and families in the community through their full participation and at a cost the community and country can afford to maintain at every stage of their development in the spirit of self-reliance and self-determination". In Healthcare centres around the world, the influence of technology is clearly seen in medical research, surgery, diagnosis, treatment and monitoring of patient response to treatment.

Information Communications Technology tools are employed in many of the developed nations for the process of diagnosis of various diseases. Automation provides a more reliable approach to the treatment of illnesses and even monitors the responses of patients to treatments. Ikonne argued that "Health technologies, especially those dealing with medical devices, are crucial for the services offered in prevention, diagnosis, and treatment of illness, disease, and disability". Health practitioners well trained to use computer-powered medical processes will improve healthcare delivery in developing countries. Computer software programs are known as "Expert Systems" can work with medical experts and doctors for efficient health care delivery in medical centres around the globe. An Expert is a specialist in a particular field who has acquired the knowledge, necessary training, skills and practical experiences and is able to proffer solutions to problems in the field of endeavour. Expert systems are built based on the same principle. According to Arkadiusz & Paweł (2017), "An expert system is a single or multiple sets of software which intends to support the use of knowledge and facilitate the decision-making process. Expert systems can assist or even replace human experts in a certain field. They can provide the user with advice, recommendations or diagnosis in the problems related to the study field." He further emphasized that the trend in surgery today is moving patients from operating rooms to offices as a result of the use of minimal procedures. High efficiency is achieved when small-size computers that occupy minimal spaces are used for the diagnosis and treatment of a patient in hospitals and health facilities.

Expert systems have proven to be vital in the movement to automation in various fields of endeavours. In medicine, an Expert system exists for the diagnosis and treatment of diseases such as heart disease, malaria and cancer (Sreekantha, Girish, & Fattepur, 2016). The researchers further argued that "Expert systems help the doctors in diagnosing of one or more diseases and suggests the appropriate therapy, it also diagnoses the absolute absence of any one of these diseases and further can find some symptoms or signs due to any exogenous cause (a differential diagnose), which notifies the doctor that the patient does not fill the minimum criteria for some of the diseases and in this case, suggests a new evaluation and send the patient to a specialist if needed". Computing technological devices fast, reasonably increasing the capacity of professionals in diverse fields. Employees can attend to more customers. Doctors can attend to more patients, entrepreneurs can attend to more clients, and the list is endless. Communication is enhanced beyond distant barriers, and this facilitates quick responses of experts to problems. The process of diagnosis in health care centres and hospitals is evolving. As complex algorithms are developed, powerful computer programs are written to assist doctors in diagnosis (Carley & Liang, 2018). Recent advances in technology can be used to solve problems and challenges in ophthalmology and the diagnosis of eye defects in health facilities.

II. STATEMENT OF THE PROBLEM

As with most manual systems, health procedures that are still done manually pose a number of challenges to health practitioners (Ronak & Rajvir, 2018), the need for accuracy and precision in the diagnosis of eye defects has various prone researches for better, more reliable and time-saving technics. The current system of traditional diagnosis has the following deficits: Inaccurate diagnosis due to human errors; patients are not able to really describe exactly how they feel, and doctors make wrong assumptions, mistaking similar symptoms of a disease that of another

- High cost of hiring opticians due to inadequate number of optical health practitioners in hospitals and health care centres
- Manual boards for acuity tests are prone to wear and tear
- In the present filing-cabinet system of storage, there is the inconsistency of patents record, and data may be lost due to improper management
- Long waiting time due to a large number of patients on queue requiring medical attention

This research work harnesses the power of recent development in the field of computer science in order to improve the current technique of eye defect diagnosis and recommendation. The result of this study, when incorporated into the current system, will ease the work of opticians in hospitals in the diagnosis of eye-related problems. It will also increase the credibility of test results and provide reliable solutions to the problems faced during the diagnosis. According to Arkadiusz & Paweł (2017), research has shown that computer-based approaches to healthcare delivery are more efficient than traditional methods. The problem of long waiting for appointment dates would be reduced, and patients will not have to go through the rigorous process of long queuing, as is the case in the current system. This is because, with an expert system, the time taken to diagnose an individual patient is significantly reduced. The high cost of Staff training will be also be reduced by the use of the software training functionality, thereby reducing expenses, especially for local eye centres. Hence, patients will benefit reduction in hospital bills.

The application developed will also increase the knowledge of health practitioners in the diagnosis process by offering expert guidance and training of hospital staff. Empowered by the application database, prescription errors due to inadequate training of medical personnel will be reduced to the barest minimum. Having a proper storage medium on a digital device is environmentally friendly. Over the years, one challenge of society that affects every sector is to create

III. LITERATURE REVIEW

As new facts are discovered, processes keep changing. Various investigations and research have been carried out by scientists to improve medical procedures. Experimental researchers in medicine are careful to take work with précises measurements taking into cognizes the effect of errors on patient wellbeing. According to errors when occur, magnify along with procedures in medicine, compounding their consequential effect on humans. Hence the need to carefully study what methods have been used for diagnosis by precedents researchers in order to figure out the most suitable and efficient method to proffers solution to the current problem.

The nature and behaviour of the expert system have been described to be 'mimicking' human experts in real-life scenarios' (Gregory, Nachamada, Djam, & Kimbi, 2011). Expert systems are built to be easy to understand and used, but non-experts, but their underlying architecture and abstract implementation may be complex, involving inference from a knowledge base (Robers and Edward). In this effort to develop user-friendly systems, it is important to use algorithms that will not reduce the validity of results or output of the system. Robert further buttressed that "despite all effort to produce an easy to use the problem-solving knowledge-based system, the quality decision of expert systems must not be compromised". This proves that developers of expert systems make all efforts to produce error-free and reliable systems. Research carried out by Gregory *et al. (2011).* shows that computer-based systems are efficient for carrying out diagnosis of disease in hospitals and health facilities. Gregory concluded that "there is no doubt whether fuzzy expert systems should be applied for medical purposes. The use of fuzzy logic for medical diagnosis provides an efficient way to assist inexperienced physicians in arriving at the final diagnosis of malaria more quickly and efficiently". The researcher suggested that where it is difficult to describe the values of variables involved in solving a particular problem due to the dynamic nature of the system, artificial intelligent methods such as expert systems are suitable. Such areas where knowledge-based systems find relevant applications include a sensitive field of medicine, engineering, business and commerce e.t.c

Recently there have been breakthroughs in advanced research on knowledge-based systems. This, in turn, has greatly improved the power of the systems and will reinvent the nature of the next-generation expert systems to support more complicated medical procedures. "Medical expert systems are developed to support medical professionals in making an appropriate prognostic and therapeutic decision". Therefore, as the trend moves towards technological systems, the future of medicine will to a great extent, be powered by the use of expert systems. It is evident that there is a shift in the way diagnoses are carried out today compared to the method of diagnosis in the past few years. Today, expert systems have affected clinical routines and decision processes in various ways. According to Hannes et al. (2014), "There are three different approaches to knowledge-based systems depending on the form of knowledge representation: rule-based, case-based, and model-based". A rule-based ES takes the form of an IF…. THEN… statements, a case based is one in which an inference engine tries to find the corresponding case from a database, while in models, biochemical or biophysical data are the basis of the knowledge system (Hannes et al., 2014).

Despite the advantages of expert systems for medical diagnosis, another challenge of computer science has been not only to determine what real-world problems are computable and how best to automate a process at a minimal and affordable cost. Computing technologies come at, and great cost than traditional methods used in hospitals, and this has a limit to an extent the implementation of computers for medical purposes. The use of acceptable, appropriate technologies within reach, especially in local hospitals, for diagnosis is an issue of great concern as Alma Ata () stated, "essential healthcare based on practical, scientifically sound and socially acceptable methods and technology made universally accessible to individuals and families in the community through full participation and at a cost the community and country can afford to maintain at every stage of their development in the spirit of self-reliance and self-determination".

A. Medical Diagnosis, Various procedures and Approaches

Medical diagnosis is the "process of classification based on a preexisting set of categories agreed upon by the medical profession to designate a specific condition" (Julet, 2009). Due to the complexity of healthcare, time constraints, and cognitive limitations, advances in the process of carrying out diagnosis have not been utilized even though such advances do exist, mostly in theory. The committee of the National Stroke Association (2015) described that "First, a patient experiences a health problem. The patient is likely the first person to consider his or her symptoms and may choose at this point to engage with the health care system. Once a patient seeks health care, there is the iterative process of information gathering, information integration and determining a working diagnosis. ” He further explained that diagnosis may involve a review of patient’s medical history, interviewing and series of physical tests. It also may extend to consulting other clinicians to understand a patient’s problem and reason out the possible cause.

Hombe and During (2014) pointed out that when a diagnosis is carried out at an appropriate time using systematic procedures that are well tested and proven by an expert in the medical field, there is a high chance that the patient will enjoy quick recovery and his or her medical condition will be corrected. To accurately determine the correct illness of a patient through the application of the systematic clinical procedure is termed “Clinician’s quintessential competency” (Hombe & During, 2014). According to the National Stroke Association (2015), “The process of diagnosis already established is patient-centred involving critical thinking and expertise in order to minimize diagnostic error.” Some illnesses are easy to diagnose, while others are maybe much more difficult, involving a series of tests and search for signs and symptoms in the external environment outside the health care setting. Such diseases may not have obvious symptoms, and if not recognized and treated at an early stage, the patient may suffer significant damage.

Diagnosing is an attempt to rehabilitate and re-install normal functioning of the vision system of a visually impaired person. According to the American Optometric Association (2010), “Vision rehabilitation is the process of treatment and education that helps individuals who are visually disabled attain maximum function, a sense of wellbeing, a personally satisfying level of independence and optimum quality of life, a function is maximized by evaluation, diagnosis and treatment including, but not limited to the prescription of optical, non-optical, electronic and/or other treatments”. The rehabilitation process involves the development of a strategic plan based on valid clinical therapy and reliable medical approaches.\

Presently in the medical field, a physical examination has been less effective due to the lack of training of medical personnel to accurately diagnose using the physical examination. Kassinier (2014) said, “there are concerns that physical examination sills have been underemphasized in current healthcare professional education and training”.

B. Diseases of the eye versus eye defects

Visual impairment was referred to as “functional limitation of the eye(s) or visual system and can manifest as reduced visual acuity or contrast sensitivity, visual field loss, photopia, diplopia, visual distortion, visual perceptual difficulties or any combination of the above”, (Fraser, Gordon, Eleanor, Paul, Gregory & Stelmack 2010). This dysfunction of the eye can occur due to heredity, genetic abnormalities or other acquired conditions. According to Fraser et al., visual impairment of eye defects can result in frustration due to a person’s inability to perform normal daily activities like reading normal-sized printed materials, driving, engaging in leisure activities and even recognising objects and faces of people. A problem associated with sight caused by certain illnesses or certain physical conditions of the eye, like abnormal distance of the eye lens or retina, affects the whole being and daily living of the patient. An American team of doctors led by Fraser studied the situation and mentioned that there are risk factors associated with visual impairment. These factors include age-related muscular degeneration, cataract, glaucoma and diabetic retinopathy. Most diseases of such kind, as mentioned, if not properly managed, may lead to an impairment of the eye or a patient visual system (Fraser et al., 2010).

The International Classification of Impairment, Disability and Handicaps (ICIDH) system of the World Health Organization (WHO) distinguished between three cases: -

- Eye disease: an illness or medical condition, irrespective of the origin or source that represents or could represent significant harm to the human eye
- Impairment of the eye: “is any loss or abnormality in an anatomical structure or a psychological function” of the visual system
- Disability: generally refers to “any restriction or lack (resulting from an impairment) of ability to perform an activity in the manner or within the range considered normal for a human being” (WHO)

This classification by WHO is based on the level of acuity and severity of the problem with blindness, defined as an extreme case of impairment that leads to disability. Another classification by the International Council of Ophthalmology classified eye problems as either “Painful” or “Painless”. Several eye defects like presbyopia, myopia and hyperopia fall under the painless category, while eye infections or eye diseases like viral conjunctivitis and bacterial conjunctivitis fall under the painful category. Painless category eye problems, also called refractive errors, are easily corrected using type lenses (Lightman & Cluskey, 2009).

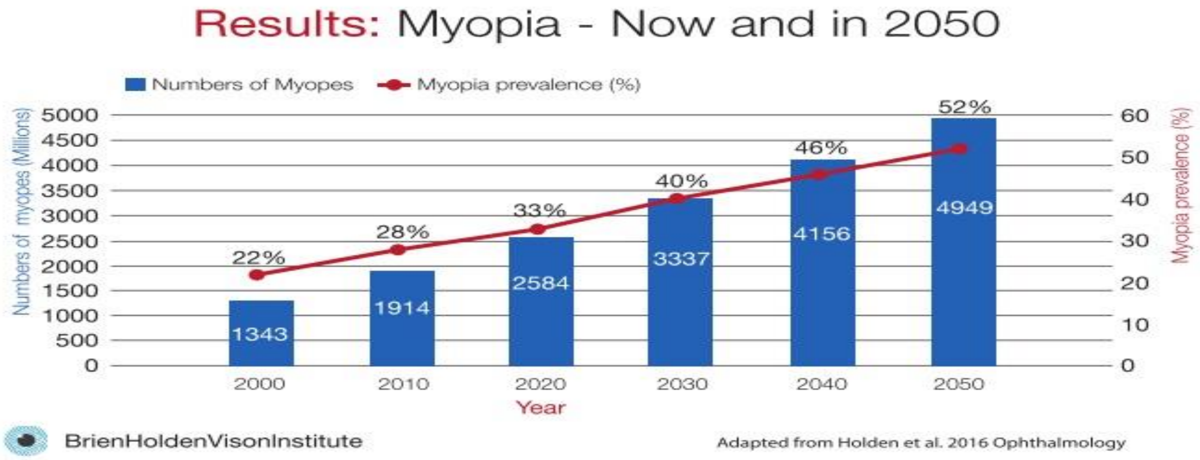
C. Myopia

Myopia, also referred to as “short-sightedness”, is a situation where an individual finds it difficult to see objects that are distantly placed. According to WHO:

• The definition of myopia is “a condition in which the spherical equivalent objective refractive error is ≤ –0.50 diopter (–0.50 D) in either eye”.

• The definition of high myopia is “a condition in which the spherical equivalent objective refractive error is ≤ –5.00 D in either eye” (WHO, 2017). A report of the World Health Organization Global meeting on Myopia shows that there has been a prevalent of refractive eye problems in countries like Africa, Central America and South America in recent years.

Fig. 1. Numbers of cases (blue) and prevalence (red) of myopia worldwide between 2000 and 2050



The defect is caused by factors such as optical and environmental influences, genetics and parental history and other diseases like diabetes. The diagnosis procedure of myopia involves a review of the patient's medical history, and all people with myopia should have access to medical care as a severe case of Myopia, if not adequately treated, can lead to complete loss of vision of the patient. The challenge in developing countries where many live below the poverty line is that access to health care and corrective measure for eye defects is not affordable for most people affected by the condition. Uncorrected distance refractive error was estimated in 2013 to affect 108 million people globally

D. Performing Acuity test and measuring vision level

To measure the degree of visual impairment and determine the proportion of its effect on a patient's sight, an acuity test is conducted. This test is traditionally carried out using a physical board with levels of symbolic inscription and index value to indicate the level of acuity corresponding to each level. The online medical dictionary refers to acuity as the "clearness of the visual perception of an image". This, according to Jack Holladay, is measured against the standard 20/20 vision level of humans (Jack, 2017). In his research, Jack mentioned that by performing an acuity test, a patient's acuity level could be measured to infer the amount of deflection from the norm. Various ways to measure vision level involve the use of the "Snellen" board or the popular "Tumbling-E" board used in many health centres. The best acuity ever recorded through this test is 20/10, about twice better than the standard vision level (Jack, 2017).

One method by Shiferaw (2016) measured acuity based on subjective refraction and used the formula: Standard Equivalence = Sphere * $\frac{1}{2}$ Cylinder to covert this value to its standard equivalence. This method also measures the refraction for each eye, combines the result and classifies under a high, medium or low degree of acuity. The method is complex, requiring experience and expertise beyond what is obtainable in most health centres, especially in developing countries. The advantage of the method is the reliability of the procedure, making for accuracy of result and dependability on the recommendation of the corrective measure to be administered to the patient. Perhaps an easier approach may be to employ the use of an expert system to guide optometrists in performing diagnoses. The Inference power of an expert system determines the accuracy of diagnosis, and the chances of an error-free prescription of spectacle are increased times more than when a human (which is prone to mistakes) expert independently suggest a method of rehabilitation.

E. Need for Regular Training of Medical Personnel

"The extent to which an Optometrist can provide treatment for the disease or condition underlying the visual impairment, depending on both the state's scope of practice laws and regulations and the individual Optometrist experience or certification" (Fraser et al., 2010). This statement by Fraser shows that there are rules that govern diagnosis in Opthtomogy and that diagnostic procedure, though systematically planned, is still influenced by the personal experience and skill of the medical personnel. Hence, the need to regularly train doctors and nurses, updating them with current development in the field of diagnosis cannot be over Emphasised. To assist medical practitioners and improve medical healthcare, there is a need for monitoring and better guidance. A better solution to this problem is to implement a self-tutoring system or a virtual guide that medical personnel can use to personally train at individual convenience without the necessary organization of formal settings. In his own word, Fraser said that "temporary or interim approaches to either raining or optical devices should be explored". Medical Technology is appropriate for diagnosis as it provides better guidance for the Optometrist (Ikonne, 2018).

In many health centres, the stochastic nature of diagnosis presents problems and errors in the current system are almost inevitable. Shiferaw (2016) mentioned that "there is a visible disconnection between eye care and refractive errors", and this is more prevalent in rural areas where the number of medical personnel and facilities used for tackling health problems is not inadequate supply.

There is, therefore, the need to equip health centres and train hospital staff to meet up the increasing demand for health care globally.

F. Medical Record Management

A medical record is a document that contains a complete account of the medical history of a patient managed in a filing system. It includes the complaints, examination, diagnostic tests and procedures, and treatment recommended for the particular disease of a patient. "In effect, medical record of a patient is the clinical representation of the patient that is built over a period of time by various clinicians with the consent, trust, privacy and confidence of the patient" (Teviu, Aikins, Abdulai, Sackey, Boni, Afari & Wurapa, 2012).

To adequately treat a particular illness, most medical procedures require to follow up to monitor the patient response to treatment. Discussing the period taken to treat the problem of short-sightedness Fraser (2010) mentioned that "determining the most appropriate magnification system for near may take several visits or even months". There will therefore be a need to manage patients records in order to monitor the rehabilitation process over some period of time. The patient's ability to use the recommended lens over a period of time and how effective the lens is in correcting the refractive error need to also be monitored. Files are opened in eye centres of hospitals when a patient visits a centre in need of the services of an Optometrist. Teviu et al. explained that medical records are not only kept for the patient but for the consumption of the medical personnel as well. Medical records acquired during follow-ups need to be kept consistent and updated from time to time. The problem with the physical cabinet and filing system is that records kept are prone to theft, misplacement and redundancy.

IV. METHODOLOGY

In this research work, the researcher carried out an intensive study of the existing system, its pros and cons, to understand what the problem is and how best to proffer a suitable solution. This section discusses the System analysis and result of the feasibility studies carried out, the System Requirement Specification (SRS) and System design and methods used to achieve successful implementation of the proposed system.

A. The existing system

When patients visit independent eye clinics or eye centres in hospitals, they are first referred to the receptionist, where each patient purchases the hospital card on which the result of the diagnosis is to be handwritten by the Optomologist. This process usually involves a queuing system and waiting for the appointment time. Sometimes, Optomologist is not available to see patients and patients are made to wait for days or weeks due to the limited number of eye professionals available in both private and public health centres of most developing countries.

At the point of diagnosis, the doctor asks the patient is made to sit upright 6 meters about from the auity, ensuring board. This physical board used in the existing system may be the popular Snellen board which contains the symbol of the letter 'E' followed by rows or letters decreasing in sizes or the tumbling "E" chart, which is made up of the letter 'E' rotated at various angles also decreasing in sizes sown the row, or any other from the numerous board and charts used for auity test. Below are some of the charts used in the current system for carrying out acuity tests.

B. Picture boards

Others include Bailey-Lovie letter chart, ETDRS, logMAR e.t.c The choice of a particular board is influenced by the need for precision in measuring a patients acuity level so that the Optometrist is confident that the result of the procedure can be used for future monitoring by other eye care medical practitioners without the need to re-conduct the test, (journal of vision research 2013, lan L. Bailey & Jan E. Lovie-Kitchin,). Sometimes, the different board has different spacing between rows and sizes of symbols depending on the distance of the patient from the test board. These physical boards have to be kept safe as they are prone to wear and tear. As with any other illness after the diagnosis procedure, the recommendation of the treatment measure or drug prescription is written by the doctor of the patient's card. In the case diagnosis of refractive eye errors, the acuity level is recorded as measured during the diagnosis and recommended corrective lens. This record has to be kept safe by the patient as it would be referred from time to time during follow up of the rehabilitation procedure. Sometimes there are reported cases of loss of record from the patient's files or due to misplacement of the card by the patient.

C. Research Design

The methods used for fact-finding and collection of information relevant for the purpose of this study include interview, observation and record inspection. The methods provided the researcher with firsthand information about the nature and problems posited by the existing system (Kothari, 2004) so that the new system design should provide solutions to the problems.

Interview: Personal interviews were conducted to understand the problems of the existing system from the user point of view. The result of thesis interviews showed that as the number of a patient requesting the services of the Optometric physician increase, the current manual diagnosis (especially the acuity test) becomes overwhelming, exhausting the optomologist, which may lead to inaccurate measuring and prescription of the wrong spectacle. This has limited the number of diagnoses carried out to a hand few of the total number of patients each week. Face to face interaction with patients also revealed that prolonged stay on queues due to the slow process of diagnosis has a negative effect on an aged patient suffering from presbyopia.

D. Observation

For more in-depth. Understand the problem, and the researcher visited various clinics and eye centres during working hours when diagnoses were conducted. It was observed that the period of waiting normally takes 6 hours of the day or at worst even days, at times when the doctor is on a visit to other hospitals.

The method of carrying patient files and hospital cards often presents its own problems for patients and hospital staff alike. Some old files were difficult to work on, and retrieval (sorting and searching) of these files from a physical filing cabinet extends the time taken to diagnose a patient. At the point of acuity testing, physical boards hugged on walls and mopped on a daily basis to be kept free of dust. The inscription on these boards so begins to fade and affects the result obtained during the test for acuity.

E. Record Viewing

During scrutinization of a patients record store in the manual system, it was observed that there was data redundancy which is one challenge of the manual system of storage. In some instances, multiple copies of the same paper record are kept sue not tally. Inaccessibility of voluminous records kept slows down the medical processes, thereby reducing the overall productivity of work in the hospitals and patients' history, which should be kept confidential, are easily accessed by unauthorized individuals. This reduces the trust that patients have in the ability of the system to keep their personal data safe.

F. Proposed system

The proposed system harnesses the power of AI, which is a disruptive technology, replacing traditional systems with more reliable, human-like reasoning systems. An Expert System is a sub of knowledge base artificial Intelligence. In this system, decision support for each case is validated by a knowledge base on established medical facts derived from a database connected to the application.

G. A knowledge base of the Exert System

In the heart of an expert, a system is a pool of factual knowledge (known fact belonging to the diagnosis domain agreed upon by experts) wired through sets of predefined rules based on which the system reasons and decides (Expert system Robert & Edward, .doc). By design, MySQL version 7 will serve as the storage system and language for manipulating the knowledge of this system.

Knowledge representation of the proposed system's DBMS is done in two forms: rule-based (also called production rule) and case-based – which makes the system a "hybrid knowledge-based expert system". By rule base, it means that the organization of knowledge or rules of the system will consist of an IF part and THEN part:

```
IF ….
        THEN ….
ELSE IF ….
        THEN …
ELSE
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By case-based, it is meant that the system will compare the cases of the patient with several other cases to find a closet match. Since a diagnosis of the disease involves a collection of signs and symptoms, that of a particular eye defect will tally to reasonably to predefined cases in the database of the application.

Inference engine

The Inference engine refers to the reasoning faculty of an expert system. It examines the knowledge base and makes reasonable guesses. There are basically two techniques:

- Forward Chaining Method: Here, the conclusion is not known, and so no hypothesis is put in place before the beginning of the process. The set of conditions or symptoms of the problem is collected and used to infer the possible cause of the problem.
- Backward chaining method: where the conclusion is made before the symptoms are gathered to prove that the hypothesis made is valid. (Expert system Robert & Edward, .doc).

This paradigm uses the forward chaining method for automating the diagnosis of refractive eye errors. The method involves chaining the IF… THENs and then using the matched cases to reasonably infer whether the case is myopia, hyperopia or presbyopia.

Another set of IF…THEN cases will be used to give a recommendation of the type of spectacle to be used by the patient over a period of time, during which the situation will monitor for improvement before a final recommendation is proffered.

V. METHODOLOGY

A. Software Development Model

Different models exist for building a software system, each with its pros and cons. A model defines a systematic framework for the process of developing the software from its inception to retirement. The iterative Waterfall model was used for the development of the proposed system. It breaks down the stages of development and defines the entry and existence of each stage as follows: Without a model, the development process will be carried out indiscriminately. The Iterative waterfall model allows for error detection and correction at each stage of development (Mall Rajib, Fundamentals of Software Engineering to browse). This model is justifiable since the software project will be broken down into sub-units called models, each targeted toward achieving a particular functionality to achieve which an Object-Oriented Design (OOD) approach will be used. It also provides feedback paths so that the software engineering can refer back to a previous level to correct a mistake at any time it is detected along the development cycle.

B. Object-Oriented Analysis and Design

In the development of this software, the waterfall model was used alongside Object-Oriented techniques to allow testing of independent models of the system so that errors are identified easily before the incorporation of the system as a whole (a bottom-up approach). In the Object-Oriented process, the software is broken down into simple independent functional units to allow for concurrency and cohesion between modules. The objects of the proposed system are the individual entities that make up the system, such as the patient object, acuity tester, database object e.t.c The individual models will be designed with interfaces for coupling these subunits to form a working software application.

Another advantage of using OOAD is that it makes system maintenance and troubleshooting easier as it facilitates communication between engineers (Mall Rajib, Fundamentals of Software Engineering to browse). This is necessary because the users of the proposed system may need to hire different engineers to perform system upgrades – OOD is is good practice for software scalability.

C. System Requirement Specification (SRS)

The result of the research design has been summarized into an SRS document which clearly shows the requirements of the proposed system. From the analysis, three (3) sets of requirements are expected of the proposed system functional, non-functional and hardware requirements.

a) Functional requirements

Based on the data-gathering technique and information analyzed in the research design, the proposed system is required to:

- Compute acuity level of the patient based on a set of input data keyed into it by an Optomologist
- Infer the refractive error and output recommendation for the corrective lens or spectacle to be used by the patient to correct the refractive error
- Store patients record and generate queries of patients registered for diagnosis
- Provide easy follow guide for beginner Optometrist on how best to diagnose refractive eye problems

b) Non-Functional Requirements

- Usability: the proposed system should be easy to navigate using menus, buttons and selections. Its training wizard offers step by step guide on how to use the system for the diagnosis at a beginner level.
- Maintainability: by the Object-Oriented Design of this system, future expansion should be easy to implement. More features can be added as separate modules and linked to the home page of the application
- Security and Safety: as a standalone system, it is fail-safe. Unauthorized access will be restricted through the use of username and password generated from the admin panel.

c) Hardware Requirement

The eye is a very sensitive organ and a delicate part of the human body system. Procedures of visual diagnosis must be done using appropriate technologies to avoid any complications in the rehabilitation process. For this reason, the following are the hardware recommendation for using this system:

1. Anti-glare computer screen to avoid the effect of light and ultra-violet rays which will affect the result of the acuity test
2. 32bit or 64 bit 1 GHz processor speed or faster
3. Minimum of 16 GB hard drive space
4. 1 GB of primary or Random Access Memory for 32-bit Operating system or 2 GB for 64 bits
5. Good resolution graphic card

D. System Design

System design is the first section of this document to start discussing how to actually transform the user requirements specified in the SRS section from problem domain to solution domain. It discusses what the software engineer has in mind as the real software solution in its actual form at the end of the implementation of this project. It visualizes the layout and software architecture for the user to verify whether or not the proposed system would fulfil the user preference. Changes were made early at this stage so as to ensure that the software fulfils the purpose of its development. This document also served as a guide for the implementation stage of this system development life cycle.

a) Front and backend

This research work proposed a user-friendly automated system that would assist Optomologist in performing eye diagnoses. It also ensures that the measurement and calculation of patient acuity are error-free. The User interface will contain menus and navigation buttons, checkboxes and other inputs for users to easily insert values to be used in the diagnosis process. At the backend, the admin panel controls the working of the system, providing login details and user access level to give particular use of a functional to certain groups of users. It is connected to a DBMS which is the knowledge base feeding the system with expert information, from which the results of diagnosis is inferred and conclusions about the disease and recommended treatment

b) Conceptual Design

The movement of data in the proposed system can be diagrammatically represented by the following Data Flow Diagram (DFD):

c) Detailed Design

For a better understanding of the functions of the proposed system, below is a detailed description of the major components that make up the system design. The graph shows the structure of the system with the various modules that would interact to achieve the system's functionality.

d) Input Design

One vital aspect of every good software design is the systematic plan of how to key in data from the user or external environment into the internal environment for processing. Here, the consideration made is that the user may not be a computer specialist, therefore to minimize the occurrence of an error, a fault-tolerant system design is proposed, which will provide clues for data entry and display error messages where a user incorrectly enters data for a given field.

E. Patient Full Name

For better user experience, data will be keyed into the system simply by clicking or selecting:

- Menus: present links for easy navigation within the application environment
- Option boxes: list of commands and possible values for a data field
- Radios check: Simple data entry buttons checked to a selected option

Every input will be converted into the appropriate data type and check whether it semantically conforms to the logic of the application design before it is processed. This is to avoid acceptance of input that has the potential of generating runtime errors that may lead to the crash of the program. *For example*, for every number entered, the input is checked whether it falls within a valid range.

a) Output Design

The output of this system may either be an error message indicating to the user that a particular entry for a field is incomplete or erroneous or a message to indicate the result of successful processing done by the system. The former has already been discussed in the input design section above. Where the diagnosis process has been successfully completed, the result is displayed on the computer screen for the consumption of the user (the medical personnel) or printed as hardcopy via a printing machine.

Every output of the acuity test with the patient profile, recommendation of type lens, drug prescription and other relevant information are sent to the database for storage.

b) Database Management System

As stated in the previous chapters of this document, knowledge-based ES is powered by an underlying wealth of established knowledge of a particular domain. This in implementation is referred to as a database.

An open-source relational database called MySQL version was used to design the knowledge base from where the inference engine of the application is fed with the required data. Tables were created for each model, the program conforming to a particular architecture, as can be seen from the table structures. As can be seen in the table designs in this section, each field of the table accepts data of a particular type. By data type, it means

Table 1.1 Structure of database design for patients table

FIELD NAME	DATA TYPE	SIZE	CONSTRAIN
Id	VARCHAR	10	Primary Key (Not Null), Autoincrement
Full_Name	VARCHAR	30	Not Null
Age	INTEGER	10	Not Null
Sex	BOOLEAN	1	
Date	DATE	10	Not Null
Address	VARCHAR	50	
Contact	VARCHAR	11	
Visible_signs	VARCHAR	50	
Symptoms	VARCHAR	50	
Acuity_level	DOUBLE	10	
Prescription	VARCHAR		
Date of the last Diagnosis	DATE		
Date of Next Appointment	DATE		

Table 1.2 Structure of database design for optometrist table

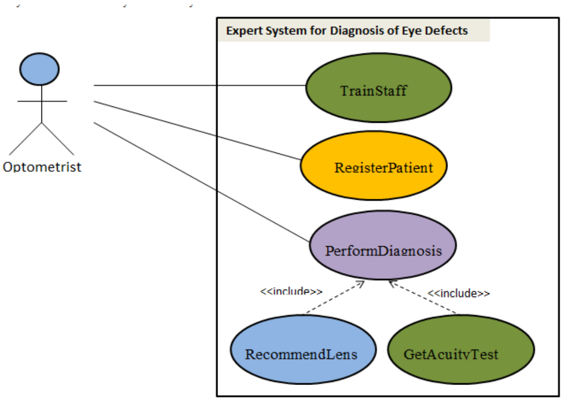
FIELD NAME	DATA TYPE	SIZE	CONSTRAIN
StaffId	VARCHAR	10	Primary Key (Not Null), Autoincrement
Full_Name	VARCHAR	30	Not Null
Access_Level	INTEGER	10	Not Null
Username	VARCHAR	30	Not Null
Password	VARCHAR	10	Not Null

Table 1.3 Structure of database design for eye defect table

FIELD NAME	DATA TYPE	SIZE	CONSTRAIN
DefectId	VARCHAR	10	Primary Key (Not Null), Autoincrement
Refractive_Error	VARCHAR	30	Not Null
Signs	VARCHAR	30	
Symptoms	VARCHAR	30	
Treatment	VARCHAR	50	

c) UML Design of the Proposed System

Unified Modeling Language (UML) is a powerful OOAD case tool for visualizing, specifying, constructing and documenting the artifacts of a software system. It provides various tools for documenting the structure of a software product. These models also serve as strong communication tools among software developers and engineers who will maintain, troubleshoot or upgrade the system when it is fully implemented and installed in the working environment.

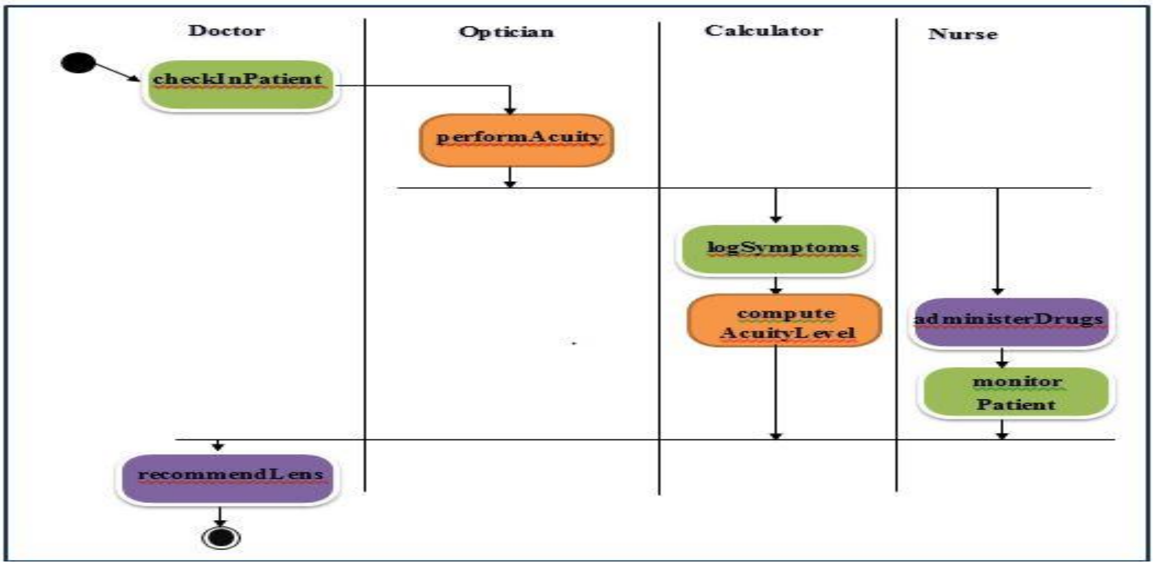


a) Use Case Diagram

This diagram presents various cases of use of the system. The functions that the diagnosis system will provide are modelled as cases within the system boundary will users of the system (in this case, the Optomologist) is represented by the stick outside the system boundary.

b) Class Diagram

From an Object-Oriented Design concept of the proposed system, models can be identified, which will be implemented as classes with various operations (functions) and attribute as depicted by the diagram below.



Activity diagram

VI. CONCLUSION

This research work follows a waterfall software engineering Model to design, develop, test and recommend a knowledge-based expert system that solves the problems of manual eye diagnosis in hospitals and health facilities. The result obtained in the research is a functional Expert System with easy to use interface. This system will help hasten the process of diagnosis and recommendation to patients. This automated system will solve the problems associated with manual diagnosis and will improve the medical process, reducing the number of patients suffering from eye defects.

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