EBOLA VIRUS DISEASE DIAGNOSIS WITH EXPERT SYSTEM

A THESIS SUBMITTED TO THE GRADUATE SCHOOL OF APPLIED SCIENCES OF NEAR EAST UNIVERSITY

By

NICK KABONGO NSENGA

In Partial Fulfillment of the Requirements for the Degree of Master of Science in Computer Engineering

NICOSIA, 2020

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Nick Kabongo NSENGA: EBOLA VIRUS DISEASE DIAGNOSIS WITH EXPERT SYSTEM

Approval of Director of Graduate School of Applied Sciences

Prof. Dr. Nadire ÇAVUŞ

We certify this thesis is satisfactory for the award of the degree of Masters of Sciences in Computer Engineering

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I hereby declare that all information's in this document have been obtained and presented in accordance with academic rules and ethical conduct. I also declare that, as required by these rules and conduct, I have fully cited and referenced all materials and results that are not original to this work.

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To my Parents…

ABSTRACT

One of the most important things in the procedure leading to detection of a disease is to know how to discover the specific problem which disturbs the patient. When there is a new virus epidemic such as Ebola, Corona virus, zika virus, etc. virologists use to struggle in order to find a quick solution to the problem due to similarities between symptoms of new virus and existing diseases. This study supply a development of an expert system for the diagnosis of Ebola Virus Disease (EVD) and comes to clear the confusion that exists while detecting Ebola virus. Expert system is basically a part of artificial intelligence that helps with making decisions; it is mostly used in medical domain for taking decisions regarding the detection and diagnosis of diseases with respect to the known symptoms. To reach the level of taking decision using expert system, a VP-Expert program needs to be implemented based on the queries, rules and facts. Furthermore, this study follows the systematic review method which involves review of several past studies conducted on the similar topic.

The developed system has been tested by 35 specialists in the area, the results were compared with the expert's diagnosis and advice in the area, it was found that the accuracy rate of the developed system is 94 %.

The efficiency of the developed system can be used for the diagnosis of Ebola virus disease were the percentage of death is fatal, hence the system will improve and help the specialists in the medical domain to diagnose the virus faster, easier and with good accuracy diagnoses with no time consuming.

Keywords: Artificial intelligence (AI); diagnosis; Ebola virus disease (EVD); expert system (ES); VP-Expert.

ÖZET

Prosedürde bir hastalığın saptanmasına yol açan en önemli şeylerden biri, hastayı rahatsız eden spesifik sorunun nasıl keşfedileceğini bilmektir. Ebola, Corona virüsü, zika virüsü vb. Gibi yeni bir virüs salgını olduğunda virologlar, yeni virüs belirtileri ve mevcut hastalıkların arasındaki bazı benzerlikler nedeniyle soruna hızlı bir çözüm bulmak için mücadele ederler. Bu çalışma, Ebola virüsü hastalığının (EVD) tanısı için uzman bir sistemin geliştirilmesi ile ilgilidir ve Ebola virüsünü tespit ederken var olan karışıklığı giderir. Uzman sistem temel olarak karar verme ile ilgilenen yapay zekanın bir parçasıdır; çoğunlukla tıbbi alanda bilinen semptomlara göre hastalıkların karar vermesinde kullanılır. Uzman sistemi kullanarak karar verme düzeyine ulaşmak için, sorgulara, kurallara ve olgulara dayanarak bir VP-Uzman programının uygulanması gerekmektedir. Ayrıca bu çalışma, benzer bir konuda yapılmış geçmiş çalışmaların incelenmesini içeren sistematik inceleme yöntemini takip etmektedir.

Geliştirilen sistem bölgedeki 35 uzman tarafından test edilmiş, sonuçlar uzmanın bölgedeki teşhis ve tavsiyesiyle karşılaştırılmış, geliştirilen sistemin doğruluk oranının% 94 olduğu bulunmuştur.

Geliştirilen sistemin etkinliği, ölüm yüzdesi ölümcül olduğu için Ebola virüsü hastalığının teşhisi için kullanılabilir, bu nedenle sistem, tıp alanındaki uzmanların virüsü daha hızlı, daha kolay ve iyi doğrulukla teşhis etmesine yardımcı olur zaman alıcı değil.

Anahtar Kelimeler: Yapay zeka; Teşhis; Ebola virüsü hastalığı; uzman system; VP-Uzman

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LIST OF ABBREVIATIONS

AI	Artificial Intelligence
ANN	Artificial Neural Network
BDBV	Bundibugyo Ebola Virus
BL	Boolean Logic
CDC	Centers for Disease Control and Prevention
CNN	Convolutional Neural Network
DL	Deep Learning
EBOV	Zaire Ebola Virus
EF	Explanation Facility
ES	Expert system
EV	Ebola Virus
EVD	Ebola Virus Disease
EVDDExS	Ebola Virus Disease Diagnosis Expert System
FL	Fuzzy Logics
HF	Hemorrhagic Fever
IE	Inference Engine
KA	Knowledge Acquisition
KB	Knowledge Base
KBS	Knowledge Base System
LIPS	Linear Program Solver
PAHO	Pan American Health Organization
PROLOG	Programing Language in Logic
RESTV	Reston Ebola Varus
RNN	Recurrent Neural Network
RT-PCR	Real Time PCR
SUDV	Sudan Ebola Virus
TAFV	Taï Forest Ebola Virus
UI	User Interface
WHO	World Health Organization

CHAPTER 1
INTRODUCTION

1.1. Background

The name Ebola takes its origin from the Ebola River located at 111 Km from the village called Yambuku in Congo DR formerly Zaire; this virus Ebola has firstly been discovered at Yambuku (Congo DR) and simultaneously in the village Nzara (Sudan) in the year 1976 (Kadanali and Karagoz, 2015; Tseng and Chan, 2014; Jana et al., 2016; Umair et al., 2016; WHO report, 1978). Umair et al., 2016 specified that the virus family Filoviridae includes three types of viruses which are Marburg, Cueva and Ebola. Filoviridae is the virus that causes hemorrhagic fever to humans and nonhumans primates (Umair et al., 2016). Furthermore, Ebola virus (EV) consists of five genera which are Bundibugyo EV (BDBV), Sudan EV (SUDV), Taï Forest EV (TAFV), Zaire EV (EBOV) and Reston EV (RESTV); among all these five types of EV the first four causes disease to humans and the latter to nonhuman primates. It has to be notified that the five given names of EV are related to their place of origin where it was found for the very first time (Kadanali and Karagoz, 2015; Burd, 2015; Tseng and Chan, 2014).

Artificial Intelligence (AI) is part of computer science and computer engineering that proceed to the creation of intelligent computers. The term artificial intelligence was first used by John McCarthy who is consider as the father of artificial intelligence, John McCarthy defines Artificial Intelligence as a science of engineering that develop smart computers, in particular intelligent computer's programs. There's higher demand in the AI field and particularly Expert Systems (ESs) domains whether in health, science, engineering, business, or any area in humans' life. Expert Systems (ESs) is a subfield of AI that have an impact in various domains of humans' life. Expert System or decision support system are computer programs that are built to integrate and manipulate knowledge acquired from human experiences. Furthermore, ESs is a decision making (Crina Samarghitean1 and Mauno Vihinen, 2008, Abu-Nasser et al., 2017).

1.2. Objectives

The aims of this study are (i) to have a better understanding of EVD from the clinical manifestations point of view, differentiate EVD from others infectious diseases by studying EVD symptoms; (ii) to develop a system based on the symptoms for the basic diagnosis of EVD; (iii) to select the concept of expert system VP-Expert shell to develop the system proposed. The 3 objectives are so important since they help to take a right decisions based on the knowledge acquired from experts in medical area. Considering the 2014 epidemic of EVD in the West Africa, it is important to develop informatics system that deal with this epidemic virus irrespective of region or location that patients may be found (Oluwagbemi et al., 2016).

1.3. Importance

It should be noted that according to the clinical point of view, it is not easy to detect EVD at its early stage due to the confusion that exists between its symptoms and that of other infectious diseases (PAHO/WHO, 2014). The development of the informatics systems is needed to avoid the said confusion thereby bring a clear solution to that confusion; that's why this study is of valuable importance. Additionally, the importance lies on the rapidity in the diagnostic of the disease regardless the region or location.

1.4. Limitations

The following are limitations of this study:

- The System is not a multi-disease diagnosis even though the system will provide some suggestion related to others HF and virus.
- The system will suggest drugs to common symptoms that doesn't require medical expert assistance.
- The system will provide only advice and not the details about treatment.
- The result will be based on the symptoms present in the system if the patient has other symptoms the system will not detect them.
- The system is not a multilingual system.

1.5. Description

This study covers six chapters where the chapter one talks about introduction to Artificial Intelligence and Ebola Virus Disease (EVD). EVD includes the overview, clinical manifestation and epidemiology. AI includes Artificial Neural Network (ANN), Deep Learning (DL), Fuzzy Logic (FL), Expert System (ES) and the application of expert system in different areas of human life such as engineering, computer science, agriculture and medicine. Chapter two is the Literature Review of the related work in different zone of artificial intelligence and expert system, Chapter three speaks about Expert System and VP-Expert shell. Chapter four the implementation of the Ebola virus disease diagnosis with expert system. in this chapter all the methods require in the development of the system are describe. The chapter five speaks about the system testing and the outcomes. And the chapter six gives the conclusion of the work as well as future studies that must be done.

1.6. Ebola Virus Disease (EVD)

1.6.1. Overview

The first epidemic of EVD occurs in 1976 in Yambuku a small village in the north of Congo DR formerly named Zaïre. The name Ebola originate from Ebola River near Yambuku village. During the same period the virus appears in South Sudan in the village called Nzara (Kadanali el at., 2015; Tseng el at., 2014; Jana et al., 2016; Umair et al., 2016). EVD belongs to the family of Filoviridae virus, the Filoviridae is the virus that provokes HF in humans and nonhumans primates. (Umair et al., 2016). EVD is a dangerous and even catastrophic disease. Detecting Ebola virus in the early stage is challenging due to the symptoms that are not specific. In order to detect it properly one must know the history behind EVD epidemiology (PAHO/WHO, 2014).

There is no specific treatment that concerns curing of EVD, there is only supportive care so far. EVD has a mortality index that range from 25 to 90 percent and may spread from human to human, this is called straightforward transmission. The indirect transmission can occur through the contact with the objects that belong to the patient this mode of transmission is very rare, by eating infected animals or bush meat found dead in the forest.

The straightforward transmission can be made by the direct contact with the body fluids like blood, saliva, sweat, breast milk, urines, vomiting and semen of the person suffering from EVD. (PAHO/WHO, 2014; Kadanali et al., 2015; Tseng et al., 2014). Ebola Virus can also be transmitted during the sexual intercourse from one person to another and from mother to baby during the breastfeeding. (G.F. Deen et al., 2017). Furthermore, EVD can live for more than 83 weeks in human body specimen such has blood, sweat, urines, saliva, breast milk, semen and vaginal discharge of survivors, that's why it's important to provide condoms to the survivors to prevent sexual transmission in the period of 6 months until the test comes out negative (Keita et al., 2016; Alexander K et al., 1999).

1.6.2. Epidemiology

Virologists define EVD as negative single strand ribonucleic acid virus (RNA) that contains nucleocapsid and infectious envelope. Up to now there is more than 25 outbreaks since the first apparition of EVD in 1976. The West African epidemic during the year 2014 to 2016 appears to have the highest spread number in history of Ebola with 24.754 suspect cases and 10.236 deaths in Guinea, Mali, Liberia, Sierra Leone, Nigeria, and Senegal. During the same period some countries out of Africa were affected by the EVD in Europe Italy, Spain and United Kingdom and in America the United States of America. EV is a collection of five subcategories which are Bundibugyo Ebola virus (BDBV) discover for the first time in Uganda in 2007, the name Bundibugyo refer to the name of a village in the western part of Uganda where it appears for the first time, 149 laboratory cases confirmed, 37 deaths in 2007. The Sudan Ebola virus (SUDV) is one of the oldest Ebola Virus it occurs for the first time in Nzara a small village in Sudan during the year 1976, 284 laboratory cases confirmed 151 deaths. The Taï Forest Ebola virus (TAFV) discovered in 1994 in Ivory Coast, 1 laboratory case confirmed 0 dead. The first discovered was “EBOV” in Congo DR 1976, 318 laboratory cases confirmed 280 deaths during the first epidemic in 1976. The EBOV is the most and current one among all the types of EV. These four types of EV are deadly, and cause disease in human. The Reston Ebola virus (RESTV) known under the name of Philippine EV; the RESTV causes sickness in nonhuman primates and pigs. The mortality rate of EV ranges from 60 to 90 percent for EBOV, 40 to 60 percent for SUDV, and 25 percent for Bundibugyo Ebola filovirus. Bundibugyo Ebola

filovirus appeared just once since the first appearance of the EVD (Kadanali et al., 2015; Burd, 2015; Tseng et al., 2014; Bushra Rashid et al., 2016; Broadhurst et al., 2016; WHO report, 1978; Denis Malvy et al., 2019).

1.6.3. Clinical Manifestation

The Ebola Virus Disease symptoms can be classified into 3 groups the early febrile stage, the gastrointestinal stage and the late stage known as the Recovery stage. The first symptoms of EVD appear in the interval of 2 to 21 days, this is also known as the incubation period and the minimum period is 4 to 10 days. EVD always start with symptoms like profound tiredness, anxiety, higher fever, these symptoms are usually followed by headache, myalgia, chills, anorexia and hiccups this stage is also known as the early febrile. The manifestation of these symptoms in the patient body take 0 to 3 days. The Early febrile stage is followed by the gastrointestinal stage, the symptoms of this stage appear from 3 to 10 days, and it is usually marked by the following symptoms vomiting, nausea, diarrhea and abdominal pain. This stage can cause lots of damages in case of loss of fluid in one day the patient can lose 5 to 10 litters. Sometimes the gastrointestinal provokes respiratory and vascular problems. In case of respiratory it causes chest pain, breathing. Coughing as well as nasal drainage; for vascular it causes hypotension, edema and conjunctival injection. Some patient can start recovering from this stage, but other can have Ebola Virus Disease Hemorrhagic manifestation. Petechial and ecchymosis can be notice in the late stage of the disease (PAHO/WHO, 2014; Malvy et al., 2019; Tseng et al., 2014; Kadanali et al., 2015). The neurological sign are not frequent in most of the cases it depends from one patient to another, but the neurological sign can cause convulsion, confusion, and delirium. The patients that had fatal disease in the past when they contact EVD, they die mostly from day 6 to 11 due to the hypovolemic shock, coma and sometimes the failure of the multiple organs (Malvy et al., 2019; Tseng et al., 2014; Daniel S. Chertow et al., 2014).

1.7. Artificial Intelligence (AI)

Artificial Intelligence (AI) also known as the intelligent computer, AI is part of computer science and computer engineering that proceed with the creation of intelligent computers. The term artificial intelligence was first use by John McCarthy who is consider as the father of artificial intelligence, John McCarthy defines Artificial Intelligence as a science of engineering that develop smart computers, in particular intelligent computer programs. The fulfilment of Artificial intelligence was done by studying the humans' behavior. The study was conducted on how humans learn things, how human's brain thinks over the specific problem, how they make decisions, and how they work to bring solutions to problems. Based on the results of this study an idea of developing systems and software's that are enough intelligent to compete with humans' intelligence were initiate. (Gouda Naveen et al., 2019). AI is a group of another different field like ANN, FL, ES, etc.

1.8. Artificial neural network (ANN)

There is four main components in humans' brain which are axon, nucleus, soma and dendrites. They are as shown in the figure 1.1 below.

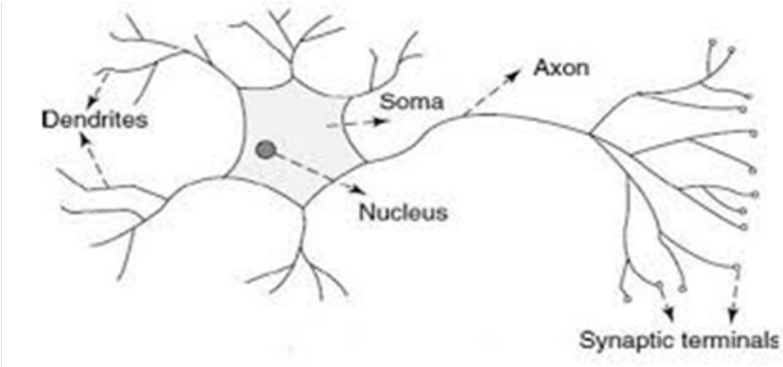

Figure 1.1: A Nucleon (Dey, 2016)

The electrical signal in humans' brain is also known as the dendrites. The process that helps to reach the electrical signal in humans' brain is called the soma. The axon and soma are the process that helps to get the output and they help the transmission of output to the neuron. The most important thing that the neuron needs so that it can function properly is

known as the nucleus. Finally, the combination of this entire system is called the neural network or artificial neural network (Dey, 2016).

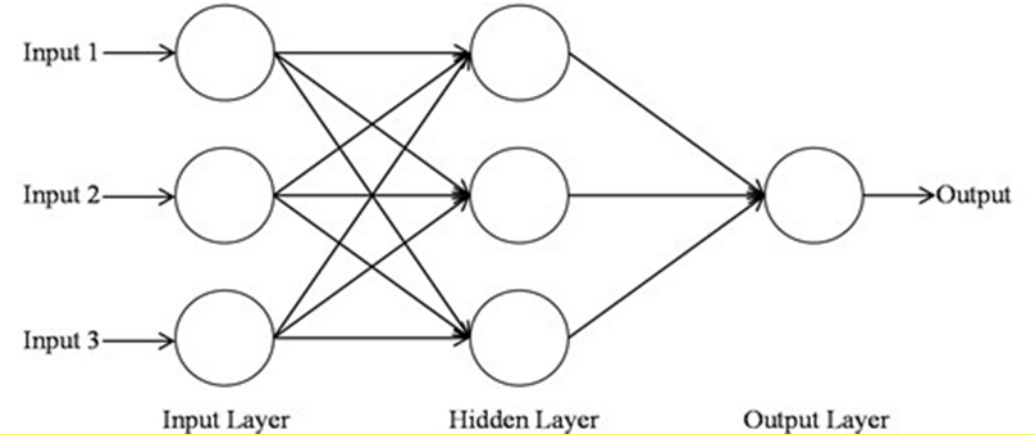

Figure 1.2: The Artificial Neural Network structure (Dey, 2016)

The above figure demonstrates how ANN works. It mainly works on the three layers' structure. The collection of the input is done by the input layer, it has the same functionality as the dendrites in the humans' brain. The action of processing the input is done by the hidden layer if it has to be compared to the humans' brain, it has the same purpose as soma and axon. The calculation of the output is done by the output layer, the same as terminals dendrites in humans' brain. The Artificial Neural Network is classified into three groups which are reinforcement, unsupervised and supervised neural network.

1.8.1. Supervised

For this method, both inputs and outputs are available, the calculation of the output will be calculated based on the available inputs and outputs. The result will be compared with the available output if there is an error the parameter will be changed and the process must be repeated (Attran et al., 2018; June-Goo Lee et al., 2017; H. Greenspan et al., 2016).

1.8.2. Unsupervised

On the unsupervised Neural Networks, there is not available output and input. The Neural Network has the aim of classifying the dataset according to their similarities. That the

Unsupervised neural network must verify the relationship between the input and classify them together (Attran et al., 2018; June-Goo et al., 2017; Greenspan et al., 2016).

1.8.3. Reinforcement

In this technique the network acts like the communication between humans and the place they live in. the response that the environment gives to the network must be checked in order to provide a decision based on the environment. If the response is positive the connection must be made with the specific output otherwise the connection is weak (Dey, 2016).

1.9. Deep Learning (DL)

The Artificial Neural Network have some limitations when it has to deal with present issues; this problem is the results of the overfitting and vanishing gradient, when it comes to train the deep structure and mostly the lack of enough dataset that the system must train. Due to the problem of overfitting and vanishing gradient in ANN, Deep Learning was introduced to overcome these problems. Deep Learning is considered to be the solution to the limitations of Artificial Neural Network. The subfield of Machine Learning that consist of gathering several hidden layers of data that already exist in an artificial neural network is known as deep learning or deep structure learning. Deep learning moreover is the concrete upgrade of artificial neural network (Attran et al., 2018; June-Goo Lee et al., 2017; H. Greenspan et al., 2016).

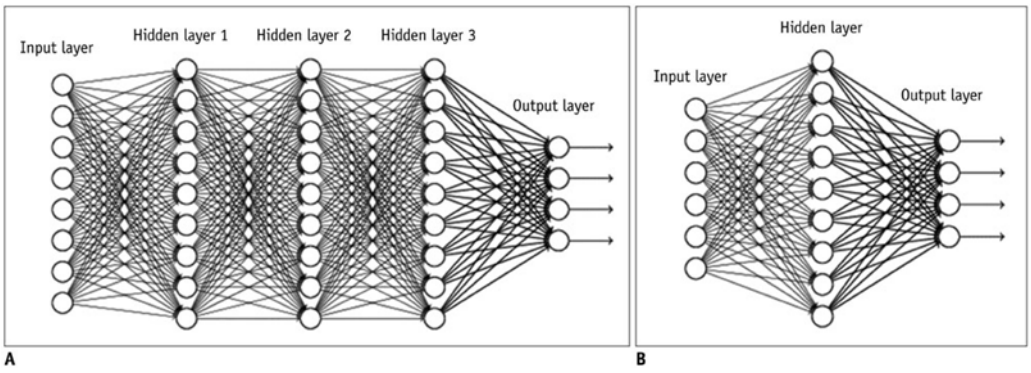

Figure 1.3: Differentiation of Deep Learning and Artificial Neural Network.

In the Figure 1.3 above, the structure A is a deep learning structure that contains a single input layer, three layers that are hidden and a single output layer. The structure B is the artificial neural network which contains a single input layer, one layer that is hidden and a single output; this determines the limitations of artificial neural network compared to the deep learning (June-Goo Lee et al., 2017). CNN and RNN are known as types of deep learning. The rapid development, the growth of computer vision and the improvement in deduction of normal number of parameters in deep neural network by avoiding loss of many qualities of any model is the merit of CNN. CNN is mostly used in detection of image and classification of image. (June-Goo Lee et al., 2017; Greenspan el at., 2016). Recurrent Neural Network is extremely used in the process of text recognition and speech recognition (June-Goo Lee et al., 2017).

1.10. Fuzzy Logic (FL)

The term Fuzzy Logic (FL) was first introduced by the professor of the University of California, the professor Lofti Zadeh, he introduced this term FL for the first time in history in 1960s at Bartley (Dahiya, 2017; Prasad et al., 2017). Fuzzy Logic has shown successful results in different areas. For instance, in medical field it is used for diagnosis of disease; in geology it is utilized for image analysis and detection; it is also used in the control of vehicles, agriculture, engineering, astronomy, chemistry and finally in the analysis of the pattern recognition (Prasad et al., 2017). By definition, fuzzy logic is the characteristic that is used in the representation of the unstable nature of humans' knowledge (Dahiya 2017; Prasad et al., 2017; Ibrahim, 2016). The humans' reasoning of the fuzzy logic makes it to be the improvement of the traditional BL. FL is quite the same with the traditional Boolean logic where the result is whether 0 or 1, that is true and false. However, the main difference resides in the fact that fuzzy logic is focused on the humans' thinking. In the traditional Boolean Logic, the result is whether 0 or 1; this implies that the results are true or false; despite that, fuzzy logic's result is not always 0 or 1, that means there is alternatives or some numbers between 0 and 1. In fuzzy logic not everything is black and white like in traditional Boolean Logic where there are not intermediate colors. In FL there are some colors in between black and white (Dahiya, 2017). FL is one of the AI field that is mostly used in the analysis of data, recognition of pattern, operational

research, linear and non-linear control. The similar use of fuzzy logic is expert system (Dahiya, 2017).

The transformation of inputs or crisps into the fuzzy grammatical content is done by the fuzzification interface, this is the important step of the system because it transforms the crisp into mathematical value. The crisps are then transferred into the inference engine and then fuzzy rule based is applied in order to generate fuzzy outputs. “IF-THEN” is the rule-based form of the fuzzy and this incorporate the grammatical value. The last step of the fuzzy logic is the defuzzification interface and the job of this step is to produce the output. The figure 1.4 below shows the structure of Fuzzy Logic System.

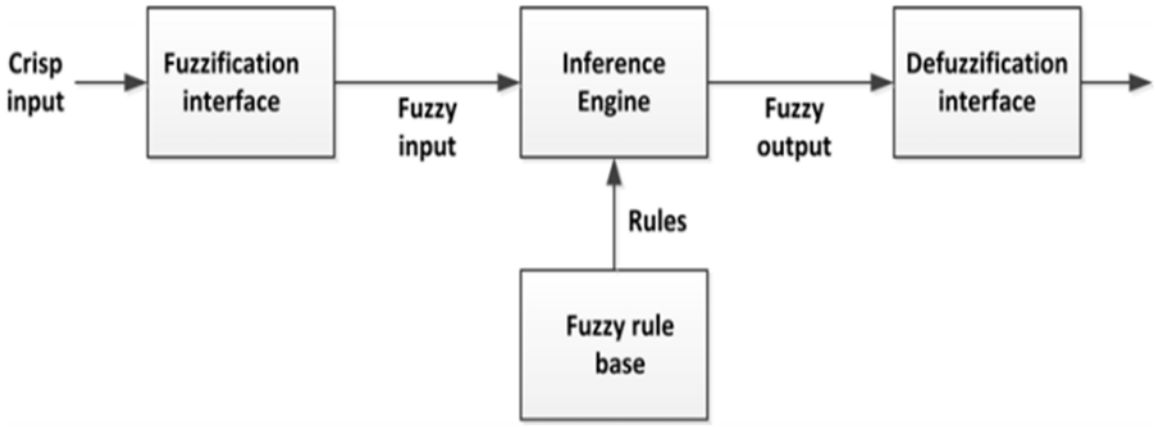

Figure 1.4: Structure of Fuzzy Logic System

One of the benefits of the fuzzy logic is when it applied to the design of nonlinear control system. This application is so difficult to design and stabilize when using old practices. That’s why fuzzy is of importance since it makes the application practical (Ibrahim, 2016; Ojha et al., 2019).

1.11. Expert System (ES)

Expert system or decision support system, is basically a part of AI that proceed with making decisions. The analytical knowledge that includes humans’ expertise in the form of computer program to a particular domain is an expert system. The aim is to construct an expert system that plays an important role when it comes to the representation of the

knowledge of an expert in form computer program. The representation of the expert knowledge must be clear and understandable for those who don't have experience in the domain. In addition, ES is the representation of stimulated decision regarding humans' reasoning that incorporates expert knowledge and involvement to a specific area in form of computer program. ES used knowledge and the set of rules from an experience expert, the expert knowledge is also called knowledge base. The set of KB, IE, KA, EF and UI in an ES is known as the Rule-based. Backward and forward chaining are used when it comes to the practices of knowledge representation. Expert system has higher capability experience in term of its application, by applying the heuristics, the backward reasoning, the forward reasoning, the explanation capability and the uncertainty.

1.11.1. Application of Expert System

Expert system has an impact in various domains of life, several systems have been developed with expert system in different fields like chemistry, business, geology, agriculture, engineering, computer science, etc.

1. Agriculture

In agriculture expert system have shown good results by managing the harvest, the control of insect and the raising consideration of given productions. The famous expert systems that have been developed in agriculture are COMAX, CROPPRO and PLANT. (John Durkin, 1990).

2. Engineering

Expert system has shown several interests in various fields of engineering. Expert system applications in engineering can help engineer in various way and it can also replace the operation of human in the control of system. PEACE, DELTA and the Smidth Cement Kiln Controller are some of the expert system applications that have been developed in engineering (Durkin, 1990).

3. Computer science

Computer science application with expert system deals with the design and the diagnosis of the computer system. The detection of a specific fault in a system is not an easy task and also the configuration of the computer that meet the user demands are not easy and sometimes it time consuming. YES, DART and XCON are the famous expert system applications developed in computer science (Durkin, 199.

4. Medicine

Expert system played an important role in the medical environments whether in diagnosis of diseases or treatments. In medicine domain expert system rule-based have shown good results since the 1970s. System such as AAPHelp, INTERNIST I, MYCIN, CASNET etc. have been developed using different approaches of expert system (Nath and Prasenjit, 2015).

In the mid of the year 1970s Ted Shortliffe and colleagues developed the MYCIN system at the Stanford University. (Alder et al., 2014; Nath et al., 2015). This system is the most popular and well-known expert system in the medical domain. The primary goal of developing this system was to help doctors with lack experience in the antimicrobial medication and prescription of drugs in case of blood infection, particularly in the selection of person with meningitis, this system was then improved to handle other infectious diseases. The representation of the knowledge in the MYCIN was the combination of the IF-THEN rules, the system was developed based on the rule-based expert system. The backward chaining technique was used due to the ability of this method to handle medical diagnosis (Nath et al., 2015; Durkin et al., 1990).

AAPHelp was implemented in 1972 at Leeds University, also known as de Dombal's system, the Naïve Bayesian technique was used to develop this system. The objective of AAPHelp is to bring support in detection of abdominal pain, the system is based on the examination and the demand for surgery (Nath, et al., 2015).

In the year 1974 INTERNIST-1 was developed at Pittsburgh University this system used rule-based expert system. The aim is to bring support in the detection of internal medicine (Nath et al., 2015; Alder et al., 2014). This system detects diseases based on patient opinions and predict the level of the disease. (Nath, et al., 2015). This system included more than five hundred diseases (Alder et al., 2014).

CHAPTER 2
LITERATURE REVIEW

2.1. General

This chapter describes the previous research done based on related topics. In the same way, this chapter will be based on the review of previous works concerning application of artificial intelligence techniques and expert system in healthcare, the different informatics systems that have been developed using expert system and other domain of artificial intelligence.

2.2. Literature Review of Artificial Intelligence Techniques in Healthcare

James P. et al. (2020); proposed a new evolution of deep learning classification for classifying and improving ultrasound of video in echocardiography. The most useful medical ultrasound is the echocardiography. However, many efforts have been put together in the improvement of echocardiography due to the time consuming and to provide more access to the sonographer to be able to scan many patients every day. The collection of data was done based on the selection of random echocardiogram and videos, data was collected from the Imperial College Healthcare NHS and confidence database echocardiogram. The data were in the form of DICOM. James et al, Apply the Convolution Neural Networks (CNNs) due to the powerful of this method in classification of image. The old method of CNNs structures was used for classification of data in the first place. After the introduction of new techniques. These techniques are similar to the recognition of humans' action. The classification was divided into 4 steps

- The Classical CNN. The five distinct structures of CNN are used in this step and every step is considered to be the state in the design for image recognition in the network. The calculation of accuracy of this study is done using the modal prediction for multiple video frame.

- The Classical CNN, this is covered in the distributed time layer. Here the video goes through a Classical CNN, the classification is produced frame after frame

and the collection of output from a single frame is done by the CNN's. After collecting the output from each frame, the outcomes of the classification are fed again into another level of the neural network in form of sequence.

- The Three – dimensional (3D) CNN. Here the determination of the 3D CNN and its ability to not only be able to constitute a clean scan ('convolve') of the frame video in the two dimensions but this is done in the 3D as well.

- The "Two stream" CNNs. The constitution of this network is based on two modes of streaming data, one is the spatial and the other one is temporal stream. The video frames are combined into the distributed classical CNN network or 3D. The achievement of these techniques is done in the sequential way and this step is also known as the spatial stream. But in the temporal stream data are moving between frames. Decision of the two stream CNNs is made with the integration of both streaming signals.

The result found by James et al. demonstrate the improvement between the old CNNs and the novel CNNs. From the conventional methods the error comes all the way from 8.1% to 3.9% and the difference in the accuracy can be considered in the fact that the movement of the specific structure like heart valves in the cardiac cycle is produced due to the ability of the networks.

Zahra Hoodbhoy et al. (2019); conducted a survey based on the question Does the artificial intelligence play an important role in the healthcare based on the setting resource? The survey was conducted by a group of researchers in Pakistan at Aga Khan University Karachi. The survey aim was to get from the local professional in the field the better understanding and importance of Artificial Intelligence in the healthcare sector, to know if the artificial intelligence technologies are current used to fix health and to find the limitations of AI in healthcare sector. The age of the participants was mostly 34 years. The age of participants starts from 16 to 72 years old most of them with 10 years of working experience. The working experience were considered from 3 months to 45 years. Hoodbhoy et al. get 368 responses from the conducted survey and 63% of them works in the healthcare industry, 13% of engineers, 15% of business experts and others 10% data

analysts, researchers etc. 68% of them have an idea about AI in the health industry, but 21% of them have never had the opportunity to use and experiment AI in healthcare. During the survey most participants have ideas about Artificial Intelligence for diagnosis based and decision making. Similar answer for future and current use of AI technologies and 80% of them are confident that AI can address the healthcare issue and make it affordable and accessible. In case of the fact that computer can replace humans in their jobs 8.2% of them think that it's not possible compare to 81% that think that AI will boost humans' intelligence.

Xu Q et al. (2020); proposed a systematic review and identification model that currently used machine Learning and Data Mining to diminish the rate of nephropathy, retinopathy and neuropathy which are the types of diabetes. The method used by Q et al. based on the collection of old publications review that predict the model used in the management of diabetes and the difficulties. The review targets the English literature PubMed and Google Scholar these two databases are the most used and contains thousands of publications in healthcare industry. Q et al. selected these two engines in order to collect information based on the medical and computer sciences respectively. 3.769 data were collected from these databases all the duplicate were removed. Prediction algorithms were construct and applied to the data collected cross-sectional. Q et al. conclude that more study is needed.

Wu J and Qian T (2019); proposal is based on the previous and recent related work done in case of detection, segmentation and classification with deep learning algorithms in the CT scan of pulmonary nodules. The most and deadly cancer with higher ratio of death is the lung cancer also known as lung carcinoma. The lung cancer has the higher proportion of death due to the fact that there is no symptom in the early febrile the patients have symptoms in the next phase of the disease which is the advanced stage. Due to this problem therefore detecting the lung cancer in the early stage is very important the CT scan is the most and commonly method used to detect the pulmonary nodules, the problem with the CT scan is that scanning images required more time for the radiologist it's consider to be time consuming. It's very important to have computer aid system for the diagnosis and the advanced computer aid-based detection system in order to overcome the CT scan limitations. Wu J et al. proposed the use of Convolutional Neural Network method

in deep learning due to the result of this method. This technique has shown remarkable result in computer vision applications and when it comes to the image classification. Detection, segmentation and classification are the most important steps in the application of pulmonary nodule. Prediction and location of nodule is made in the detection step, prediction of voxels is done in segmentation step, nodules types are classified in classification step. The detection of the cancer can be completed using two steps, one is to generate the candidate nodule and the other one is the reduction of false positive. The generate candidate is the basic stage but the reduction is the advanced stage in the detection. In conclusion Wu J et al. believe that deep learning methodologies have a great implication in the detection of pulmonary nodule.

2.3. Literature Review of Expert System in Healthcare

Oluwagbemi et al. (2016); proposed the development of an Ebola fuzzy informatics system. The aim is to help medical industry and individuals that are in the region where Ebola Virus Disease occurred. The main purpose of the system is to diagnosis and make available useful information to the healthcare personnel and to provide advice to the individuals. Oluwagbemi et al. proposed three objectives that help to achieve the development of the system. (i) The collection of facts trough survey to determine the transmission of the disease from the public's perception. (ii) Based on the symptoms construct an Ebola fuzzy system that will help healthcare and patients. (iii) Apply the knowledge in the development of the informatic software. Oluwagbemi et al. conducted two tests, the first test was an online survey this test was conducted in the period of 2 to 9 months and around 100 people participated. During the first test 31% of them were not aware of the fact that there is not cure concerning treatment of EVD, 28% thought that there is cure. 43% of them said that Ebola Virus Disease can be transmitted through air and through water, 33 % disagree to that fact that EVD can be transmitted through air and water and 24% didn't have any idea. 23% thought that insect can transmit the virus into humans', 30% ignored the fact that insect can transmit the disease into humans. During the test Oluwagbemi et al. concluded that the majority number of participants were ignorant. 45 peoples participated into the second test, this test was based on the usage of the Ebola fuzzy informatics systems. 60% of the attendee were happy with the system 16% were not

happy, the remaining 24% were optimist with the system. In term of the importance of the Ebola fuzzy informatics systems 69% agreed that the system helped compare to the 20% that don't think the system helped and 11% of indifferent participants. The user interface point of view 67% find out the system is easy to manipulate and 13% didn't agree to the fact that the system is easy to manipulate and the indifferent participants were 20%.

Samy S Abu Naser and Mariam W Alawar (2016); proposed an expert system that is able to detect the feeding problems in children and infant by doing the diagnosis. The aim is to bring more clarifications in the feeding problems and to get a better method that will help to avoid the dysfunctionalities concerning the feeding of children and infants from 3 years old. Compared to the old method or impartial method of detecting feeding problems Naser et al. finds out that the suggested system is beneficial compared to the previous ones. The design and the implementation of this expert system is very useful; well it comes to bring more details and gives the capacities to parents to deal with the feeding of infant. The language called CLIPS was used in the implementation and the design of the expert system.

Mahmoud J. et al. (2016); proposed the knowledge based expert system that will help patients to diagnose themselves from problems related to teeth and gums and to be able to receive the treatment recommendation. The SL5 object language for Knowledge Based System (KBS) was used for the design and implementation of the system. The methodology used by the KBS is to make the system able in the diagnosis of teeth and gums. The system must be able to ask patients questions based on the symptoms. This will bring a clear understanding to the patients regarding the disease diagnosis and the pain they are going through. As result in the development of the KBS system, J et al. concluded that the system is much faster than the conventional techniques that were used in the detection of teeth and gums disease, the user interface of the system is simple and easy to manipulate without further complication.

Samy Salim Abu Naser and Ali Osama Mahdi (2016); the foot has complicated structure from the composition and the contents. With more nerves, ligaments, muscles of different types 26 bones, and 33 joints all of these constitute the foot. Most of the minor pain cases are not complicated and can be treated and taking care at home, but when it comes to the

major cases medical care is needed and appropriate treatment as well. Naser et al. developed an expert system for foot disease diagnosis and treatment. The results found by Naser et al. were tested with success by the medical student although the system presents some limitations, the system was designed and implemented in the detection of only eighteen-foot diseases.

Nkuma-Udah et al. (2018); proposed an expert system that will help developing countries in the detection of malaria and some other diseases related to malaria, and gives the description of the treatments based on the diseases detected. At the end the system will be able to give more details to clinicians. The system must perform two major tasks first the identification of malaria and related diseases second to give and describe the method and the treatment required.

Cuteso Matumueni et al. (2019); proposed an expert system model that is based on the knowledge of professional in health care and physicians. Xper Typh is an expert system that helps to detect typhoid fever. The usage of this expert system will bring support to the healthcare in the rural zones where it is almost impossible to detect diseases easily. The qualitative method was used by Matumueni et al. in the detection and diagnosis of typhoid fever since this method helps the validation. This study was done through the following steps

- Problem identification, this stage is concerning with the identification of problem and the development of the system based on decision, the system must be able to work in any environment and detect typhoid fever.
- Knowledge Acquisition, collection of information' from experts, internet, books in order to develop the system in a systematic way.
- The representation of knowledge, information collected from experts, books and internet are represented in form of rules in this stage.
- Verification and Validation, rules that was designed in the system are checked in this stage, the rules were constructed based on symptoms of the disease.

Matumueni et al. conducted the test with 65 participants all the participants were patients of typhoid fever. 30% of patients were diagnosed positive and 41% of patients were diagnosed negative.

CHAPTER 3
VP-EXPERT AND EXPERT SYSTEM

3.1. Characteristics of Expert System

Expert system computer program can have tremendous tasks it can advise and consult, analyze and classify, learn and teach, facilitate the communication and exchange of information between a computer and the user in the form that they are required.

Knowledge is the heart and the important thing in every ES. The dependency, quality and power of an ES depends on knowledge that it contains. Construction of ES computer program can be done from scratch or by using software tool and shell. The construction and maintenance of applications of knowledge based are done in expert system shell. Expert system shell also provides an environment where expert system can develop a computer program step-by-step, it offers a friendly user interface with a graphical interface, when it comes to the knowledge engineering. This helps expert in the specific domain to be involved in a direct way with the architecture and encoding of knowledge. Expert System can have different characteristics as follow:

- The higher quality performance of an expert system which helps to afford a better solution to the challenge programs in a domain compared to the expertise of humans' knowledge.
- The application of the heuristics approaches in an expert system offers a better management of expert system reasoning and diminish the research effort in the specific field.
- The explanation capability makes ES unique; the uniqueness of an ES is the merit of its capacity to give explanation. It gives expert system the abilities to have a review of its own reasoning and make a decision based on those explanations.
- The application of symbolic reasoning helps the expert system to clarify complex problems. The facts, concepts and rules are the types of symbolic representation of knowledge in an expert system.

- Expert system has the ability to bring an advice to a particular problem, brings the modification to the problem, can update the knowledge that already exist in it, and expert system can expand when it faces the uncertain and irrelevant data.

3.2. Expert System Architecture

ES is a composition of different elements, the knowledge based and the reasoning engine are the main element of any ES. ES is a set component which are KB, IE, KA, EF and UI.

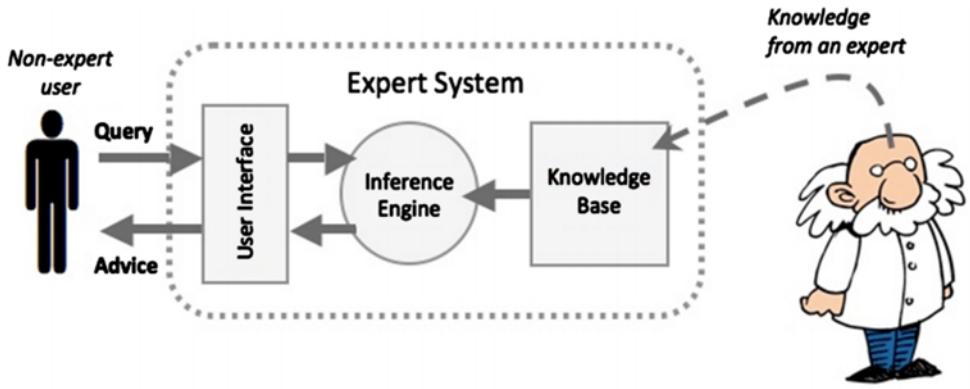

Figure 3.1: ES structure

3.2.1. Knowledge Based (KB)

The knowledge based in expert system derived from human expert and encoded in the expert system knowledge based with the application of different knowledge representation methods. Factual and heuristic knowledge are the foundations of KB in ES. Factual knowledge is commonly gained from textbooks, journals, papers etc. This knowledge is commonly shared. The knowledge that required more experiments, judgements and less accuracies is known as heuristic knowledge. The point of divergence between factual and heuristic knowledge is that heuristic is more personal compared to factual it is difficult to debate the heuristic knowledge. Furthermore, heuristic is considered to be the best method compared to the factual due to the fact that it is a suitable exercise of knowledge and provides best decision when it comes to knowledge and good reasoning. The knowledge can be created by the set of rules or the rule production. The rule in expert system is

produced with the “IF” part and “THEN” part. IF part is sometimes called the condition part and THEN part is called the action part. The reasonable combination and the set of lists of conditions are created by IF part. Knowledge that is represented by productions rules can only be satisfied if and only if the rules are relevant to the improvement of the reasoning in the conditional part. The conclusion part is also known as the action part, this is considered to be the action tacking of the problem to be solved (Tripathi et al., 2011)

3.2.2. Inference Engine (IE)

This is a tool in ES that interpret and analyses process in which the rules must be produced. Furthermore, inference engine has the purpose to examine the status of knowledge based, after the examination of knowledge based it handles the knowledge-based content and then make the decision and determine in which order they must be created. The two main techniques used by the inference engine is the forward chaining and backward chaining technique. (Tripathi et al., 2011).

1) Forward chaining

This technique is used by inference engine to search for rules in expert system, rules are searched in the condition part if satisfied the condition returned the value true. When the forward chaining finds the exact rules, it gives the conclusion by adding new data. Forward chaining start with checking the results from the available rules it compared the input with all rules available, if satisfied it gives the conclusion. This technique is used by expert system when it has to give answers to questions. It is also called data l-driven. It commences with new data. It has the features like the bottom-up reasoning that is the process start from the bottom, rules are first checked and then the goal or conclusion. It is a better technique for the dilemma that begins with collection of data, due to fact that the forward chaining must check all the rules available in a system, this technique is consider to be the slow process (Ashwini Rupnawar et al., 2016)

2) Backward chaining

The process where the data are checked from the goal is known as the backward chaining. The backward chaining process begins with facts and after the application of rules so that it can determine all the available conclusions. The backward chaining is applied when the outcome of the process is known compare to the forward chaining where the goal is unknown. The backward chaining is the goal driven, it begins with the conclusion or the goal. It has the features like top-down reasoning, that is the process start from the top, goals are first checked and then the rules, it is better technique for hypothesis dilemma, it doesn't require to check all the available rules therefore the backward chaining process is faster (Rupnawar et al., 2016).

3.2.3. Explanation Facility (EF)

Apart from providing conclusions and results it is necessary for the expert system and the human expert to give an explanation of "how" it reaches to the specific results and of "why" to the given conclusion. It is very useful and important for expert system to give the explanation and justification of results that it must give to the user, this is due to the fact that expert system can handles task that required more justification. The given explanation can make and help the user of the system to be restful while manipulating the system. (Tripathi et al., 2011).

3.2.4. User Interface (UI)

The interaction or the communication between a system and user is known as the user interface. UI can be defined as the way human communicate or interact with the computer. The purpose of UI in ES is to transform the rules in the way that the client must be able to understand. The facilities like menus, graphical interface is provided by user interface (Tripathi et al., 2011).

3.2.5. Knowledge Engineering

Knowledge engineer is a computer scientist who knows how to use artificial intelligence methods to plan and implement a computer program that include artificial intelligence. His job is to make an observation, to learn from a human expert or a group of experts. He must be able to understand what the expert knows and have the ability to know the human expert reasoning when it comes to their knowledge. He has the responsibility to translate the human expert knowledge in the computer language program, the design of an interference engine, the reasoning format and to use the human expert knowledge in the reasonable way.

3.3. VP-Expert shell

The VP-Expert shell is one of the environments where the expert system rules are implemented and run. There are various software that run expert system like logic programming language commonly known as PROLOG, linear program solver LIPS, etc. VP-Expert shell use rule-based. It contains user interface, inference engine and all essential elements that helps in the design and development of an expert system. It is a monolingual software rules can be constructed using basic English and can only support the representation of the knowledge in the form of rule-based.

3.3.1. Reason for Using VP-Expert

The reason of using VP-Expert in development and design of Ebola Virus Diagnosis Expert System is due to the fact that VP-Expert provides a collection of powerful tools such as:

- The creation of automatic knowledge from the table or the database that include text, worksheet file provided by the Induce command.
- The system provides the usage of backward chaining included in the inference engine.
- The facility of using easy English in the construction of rules.
- The questions are generated automatically.

3.3.2. Knowledge Base in VP-Expert

In VP-Expert the representation of knowledge based can be constructed with the following steps the Actions block, Rules and the Query statements.

1) Action Block

Execution of statement in action block is done based on the order in which they appear, it controls the statement and actions in the shell. The order in which the inference engine must find the goal is produced in this section. The action block contains two major keywords FIND and DISPLAY. FIND keyword has the aim of expressing the goal, DISPLAY keyword is used as a guideline to user it tells the user what they have to do and more details of these two key words are given in the section below.

Find basic syntax is "FIND variable"; inference engine is activated when the keyword FIND is invoked. When FIND keyword is called the inference engine checks all the rules in the knowledge base this process can continue till the value of the particular variable is found. It has to be notice that we can have multiple FIND statements in the action block but this method is not currently used.

To display text in VP-Expert shell the keyword DISPLAY is needed. Text must be in the inverted comma. The message in quotation mark are displayed on the screen, to help the user of the system to read the message. The double quotation must have some characters, so that the characters can appear on the screen putting empty quotation nothing will be displayed on the screen.

2) Query Statement

Variables that don't look like important in the KB rules are mentioned as questions to the client. If the IE encounters these variables, it will convert them in form of questions to the client and ask the client to provide values of those variables. This is produced with ASK and CHOICES statements.

All the possible answers to client questions must be well defined and presented in the menu this can be formed with CHOICES statement the syntax of the CHOICES statement is CHOICES variable: values list;
ASK statement can be used to give explanation about the variable prompt. The syntax ASK statement is ASK variable: “Prompt”

3) Rule Statement

The rule production of any expert system must include the domain knowledge, this must be expressed in the form of IF-THEN rule. When it comes to Backward Chaining the rules are not running as placed into the list but they are referred whenever they are needed. The basic form of the rule can be explained as follow:
RULE index
IF descent
THEN resulting
A specific name must be given to each rule, the rule name must contain at least 40 characters and the name must be added after the RULE failing to add the rule name will produce the syntax error.

3.3.3. VP-Expert Main Menu

The different options that VP-Expert provide in the main menu can be accessed by the use of the arrow keys, by pressing any function key provided by the VP-Expert and sometimes by the use of the letter or character of the specific option name. The VP-Expert provides some line in the submenu this helps to give highlight of choice to the user. The below information gives an idea of the important options in the main menu:

If we want to go back from one step the use of Escape key in particular is needed, the consultation can be terminated by using the combination of the Ctrl-c.

Table 3.1: The list of command editor of VP-Expert

Command	Purpose
Edit	The aim of this option is to create and modify the knowledge base
Consult	The current knowledge base is executed by this command
Filename	The selections of knowledge in the directory are done using this command
Path	This helps to change the directory from where we can select knowledge
Quit	Exit VP-Expert

1) Editor command Menu

The lists of the editor commands are displayed in the bottom of the screen and can be used by using the function keys. It is important to note that choices can switch from the list whenever the key Alt and Ctrl are pressed down.

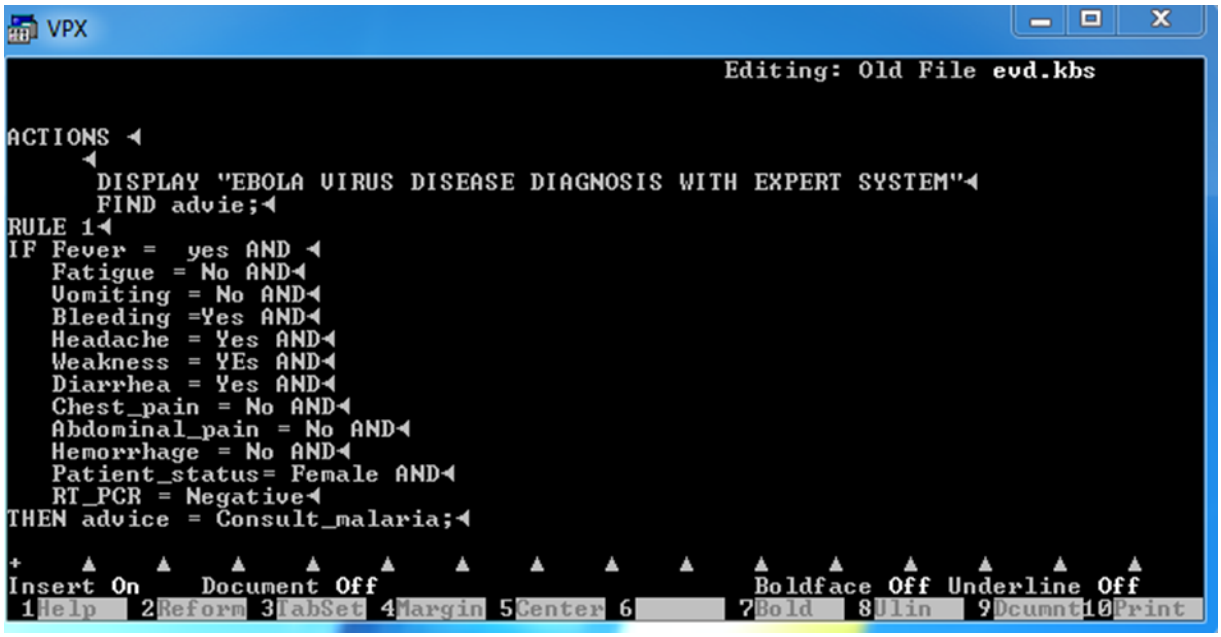

Figure 3.2: Editor Command menu editing mode

2) Editor commands

The most used commands in VP-Expert editor are listed in the table below

Table 3.2: The list of Command Editor of VP-Expert

ALT+F6	Exit and Save file
ALT+F8	Exit without saving file
Control + Enter	New line insertion
Delete	Erase the attribute at cursor location
Backspace	Erase the left attribute from cursor location
Control + T	Erase from cursor to the end of word
Control + Y	Remove the line
PageUp	One screen up
PageDown	One screen down
Home	Jump to the commencement of a line
End	Jump to the end of the line
Alt + F5	Save the current file without exiting

CHAPTER 4
EBOLA VIRUS DIAGNOSIS EXPERT SYSTEM

4.1. Ebola Virus Disease Ebola

Detecting Ebola virus in the early stage is very challenging due to the fact that the symptoms of EVD are not specific it's better to get the history and epidemiology of EVD and the patient (PAHO/WHO, 2014).

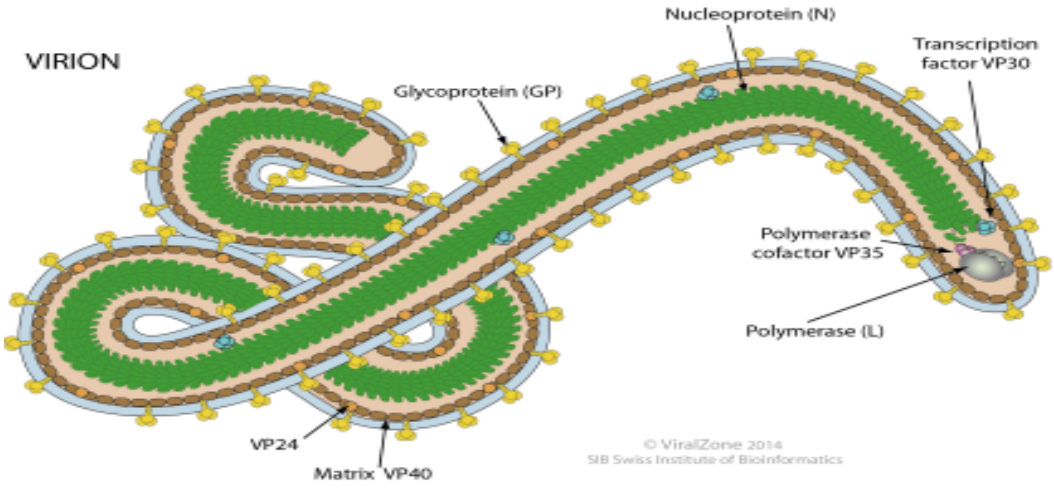

Figure 4. 1: Ebola Virus

4.1.1. Diagnosis

Identifying Ebola Virus Disease, from the early stage is very difficult due to the similarities with others infectious diseases like Malaria, Typhoid fever, Leptospirosis, Shigellosis and some hemorrhagic fevers like Yellow fever, Hantavirus hemorrhagic fever, and dengue hemorrhagic fever. EV is categorized as one of the dangerous HF. It is important to have the Laboratory Biosafety Level 4-equivalent for utilization and isolation of patient. (Tseng et al., 2014; Kadanali et al., 2015; PAHO/WHO, 2014; Malvy et al., 2019). Ebola virus is recognized to be a major agent of bioterrorism according to the Centers for Disease Control and Prevention (CDC). It is more complicated to inactivate Ebola virus, they are not stable and cause RNA envelope (Burd, 2015). During the 2014-2016 West African

epidemic the Real Time RT-PCR were the main test conducted to detect the virus, but for many years the unique technique that was used for detection was isolation in cell culture (Malvy et al., 2019). The confirmation of EVD case must be proved based on two tests, the RT-PCR and IgM/IgG. RT-PCR helps to detect the particular nucleic acids and IgM/IgG consists of serologic measurement (PAHO/WHO, 2014; Malvy et al., 2019; Tseng et al., 2014; Kadanali et al., 2015).

Table 4.1: List of EVD Diagnosis Test

Test	Days
RT-PCR	Day 3-16
IgM assay of antibody	Day 5-1 month
IgG the neutralisation of antibody assay	Two needed samples separated by 14 days, the collection of first sample must be done after day 7

4.1.2. Treatment

The only thing that virologists used to struggle with is to find the best treatment for any virus, especially the new once, up to now there's no better medication or treatment for most of viruses and Ebola Virus Disease is one of them, since the first epidemic in 1976 there's no treatment for EVD. Symptomatic and supportive care are the two main methods that are currently used in treatment of Ebola Virus Disease, these two methods can be imply by entertaining the blood pressure, status of the oxygen, preservation of fluid, balance of the electrolytes and finally find the treatment to other infections (Malvy et al., 2019; Tseng et al., 2014; Kadanali et al., 2015).

4.1.3. Prevention

Due to the lack of standard treatment and the higher frequency of death in EVD it's advice that the suspected case and the confirmed case of Ebola Virus must be isolated to avoid

contamination with other people. The personnel in charge of following up with the patient must be well protected with the recommended protection equipment the personnel must have the gloves, cover the face, have eyes protection, boots and cover the head (Malvy et al., 2019; Tseng et al., 2014; Kadanali et al., 2015).

4.2. Methodology

In the past few years many works have been conducted in the management of diseases diagnosis and many informatics applications have been developed in the field. The design and development process of all the techniques used in this study are explained. So, in the present study, VP-Expert shell software is used in the design of the system for diagnosis of patients suffering from EVD. The main techniques used in the construction of the system are the acquisition of knowledge and the Representation of Knowledge.

4.2.1. Knowledge Acquisition

Acquisition of knowledge that helps the implementation and the design of Ebola Virus Disease Diagnosis with Expert System (EVDDExS) was produced based on the collection of data through expert in the medical field and mostly the one who deals with Ebola Virus, data were also collected through papers and materials that are related to EVD. Based on the above research and some modifications the implementation and design of the system will be concluded.

4.2.2. Knowledge Representation

The rule-based is used for implementation and representation of knowledge. The rule-based is represented in the knowledge representation in form of IF…THEN where the IF is the condition part and the THEN is the action part its job is to provide the solutions. The rule-based can be constructed based on the knowledge gain from the experts' in the field. Three phases are needed for the representation of knowledge the first one is the Block diagram, the second one is Flowchart diagram and the third one is the table of decision.

Figure 4.1 below Provides the description of diagnosis. Based on the information provided in the Diagnosis block diagram, the queries were constructed. The diagnosis consists of collecting information of patient. The first functionality of the system is to collect the status of the patient and this consist of patient gender. The second functionality of the system is detection of symptoms from patient. The Last functionality is the test according to the result of the test the decision will be made if the RT-PCR results are positive this means the patient has the virus and if negative the patient is free from the virus.

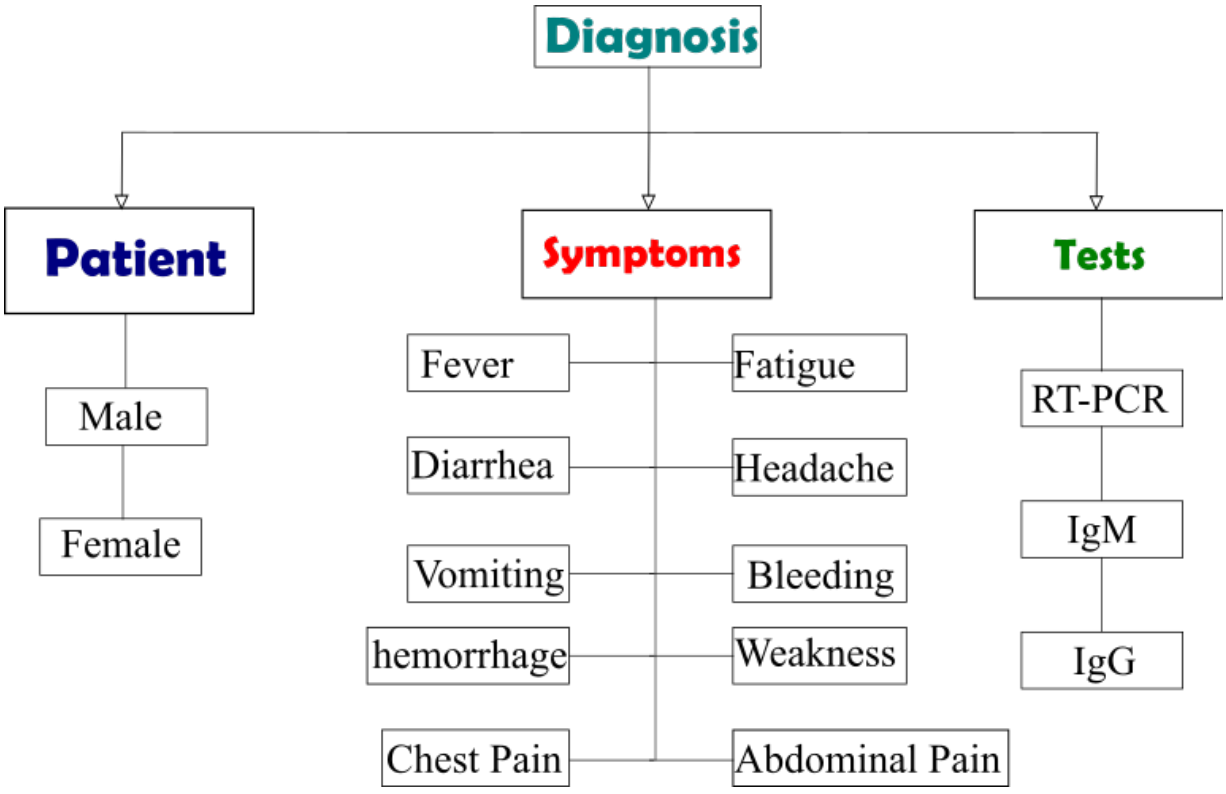

Figure 4.2: Block Diagram of Diagnosis

Figure 4.2 below describes the visualization of the diagnosis process, first human body fluid specimen is collected and sent to the BSL4 laboratory for the EV nucleic acid detection using RT-PCR test. If the test is positive the second RT-PCR assay is required, if the second test is positive EVD case is confirmed and if the second test is negative the second sample is requested. In case the first RT-PCR test is negative the geolocation of the

patient is taken into consideration if the patient is in the area of higher risk of exposure, the second test must be conducted in the period of 3 days after symptom onset and if the patient is in the area of no risk of exposure then there is no case of EVD the patient should go through other hemorrhagic fevers test.

Figure 4.3: Flowchart Diagram of EVD Detection

Table 4.2: The Decision Table of Symptoms

Symptoms	EVD Negative	EVD Positive
Fever	Negative	Positive
Headache	Negative	Positive
Bleeding	Negative	Positive
Vomiting	Negative	Positive
Diarrhea	Negative	Positive
Weakness	Negative	Positive
Fatigue	Negative	Positive
Abdominal pain	Negative	Positive
Chest pain	Negative	Positive
hemorrhage	Negative	Positive

4.2.3. Coding

The VP-Expert shell is used in implementation and design of Ebola Virus Disease Diagnosis with Expert System (EVDDExS). The backward chaining in the inference engine is used by the VP-Expert shell. The inference engine, user interface and some other tools are made available by the shell. The VP-Expert shell is also known as the rule-based expert system shell. The manipulation of the shell is much easier for the expert system developers. The VP-Expert shell provides the inference engine where the knowledge base is analyzed in order to be able to give response to user queries, an editor code where the knowledge base rules are edited and modified. Interaction between the client and the machine is available, client give the feedback to the questions or queries in order to get a suggestion at the end, based on the responses given. 11 attributes questions are asked as inputs in order to represent the production rule of this expert system.

1. What is your gender?
2. Do you have Fever?
3. Do you have sign of fatigue?
4. Do you have chest pain?
5. Do you have abdominal pain?
6. Do you have diarrhea?
7. Do you vomit?
8. Do you have any sign of weakness?
9. Are you bleeding?
10. Do you have hemorrhage?
11. How is your RT-PCR test?

For a better explanation of expert system rule the sample of this expert system is described below:

According to Rule 2

IF patient has fever Yes AND

Patient have sign of fatigue Yes AND

Patient is vomiting Yes AND

Patient is bleeding No AND

Patient have headache No AND

Patient have sign of weakness = No AND

Patient have Diarrhea Yes AND

Patient have pain in the Chest Yes AND

Patient have pain in the abdominal Yes AND

Patient experiencing any hemorrhagic sign Yes AND

Patient status Male AND

Real Time (RT-PCR) test is Positive THEN

advice = You have Ebola Virus

RULE 2
IF Fever = Yes AND
Fatigue = Yes AND
Vomiting = Yes AND
Bleeding = No AND
Headache = No AND
Weakness = No AND
Diarrhea = Yes AND
Chest_pain = Yes AND
Abdominal_pain = Yes AND
Hemorrhage = Yes AND
Patient_status= Male AND
RT_PCR = Positive
advice = You have Ebola Virus

Figure 4.4: A sample Ebola Virus Disease Diagnosis expert system rule

CHAPTER 5
RESULTS, TESTING AND VALIDATION

4.1. Design Presentation

VP-Expert platform is used in the design and the development of the EVDDExS, VP-Expert shell runs under DOS operating system. The test of rules, paths and all the relationship attributes has been modified with the necessary test. The evaluation of the Ebola Virus Disease Diagnosis Expert System (EVDDExS) has been conducted with the help of 35 specialists in medical field, since this system were first design to help medical core without experience in detection and diagnosis of EVD and then patients can use this system to check about their health status by just answering the questions regarding the symptoms. The test of the EVDDExS was conducted in Lubumbashi Congo DR, in the last step of the development all the suggestions and recommendations have been taken into consideration.

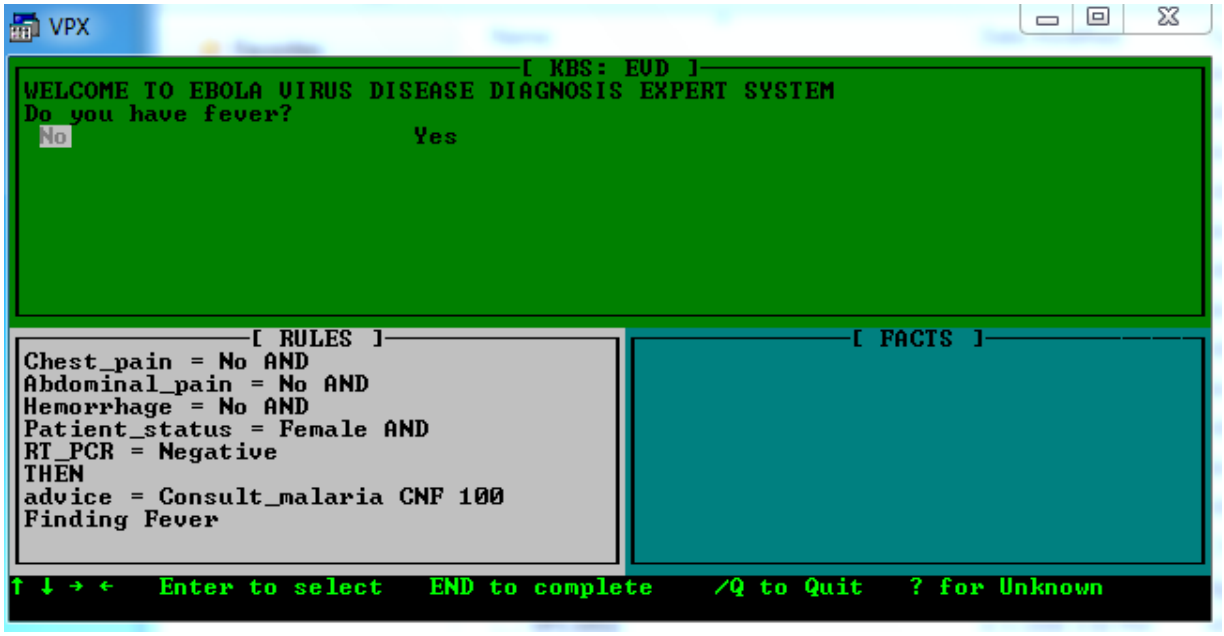

Figure 5.1: The system design before the consultation

4.2. Result and Discussion

The performance of the knowledge and the important evaluation through the facts and rules are achieved by the EVDDExS user interface, to determine the result that should be given to the user base on the questions answered.

Figure 5.2: The System Consulting the KB

The figure above shows how expert system loads the knowledge base file from database. VP-Expert shell software provides three windows to the user, who is interacting with the system. The windows provided by the VP-Expert shell are the rules window, the facts window and the queries window. These windows are available to the user, the user will be responding to the queries asked by the system. Each time the user gives a response to a query, the rules are cheeked in the rule window until the value that the user gives ties with one of the values in variables that are in the knowledge base. If the value has been found then the fact will be produced based on the queries and the results found in the knowledge base. The results will be shown in the facts window and this must be available when the user attends all the system queries.

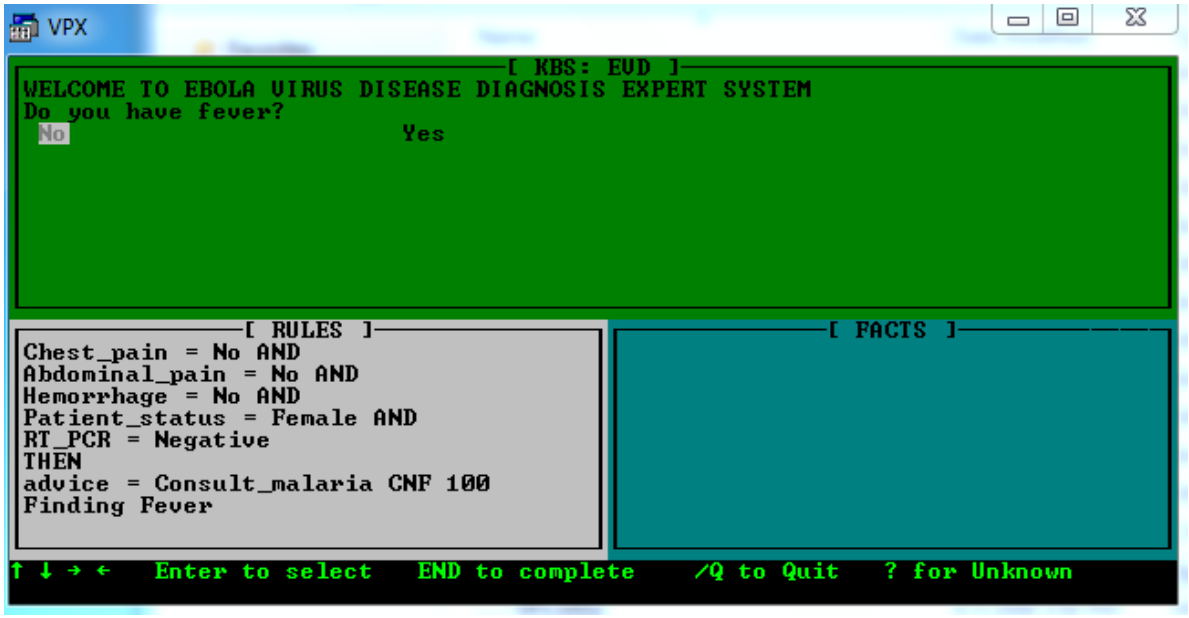

Figure 5.3: User start the interaction with the system

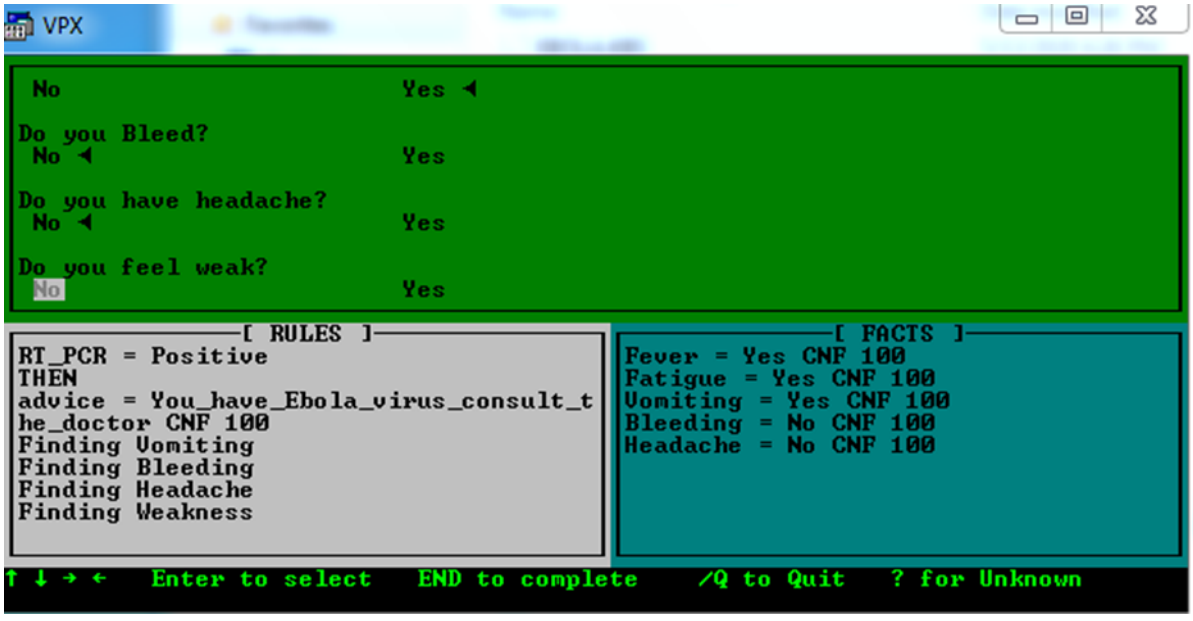

Figure 5.4: User answering questions

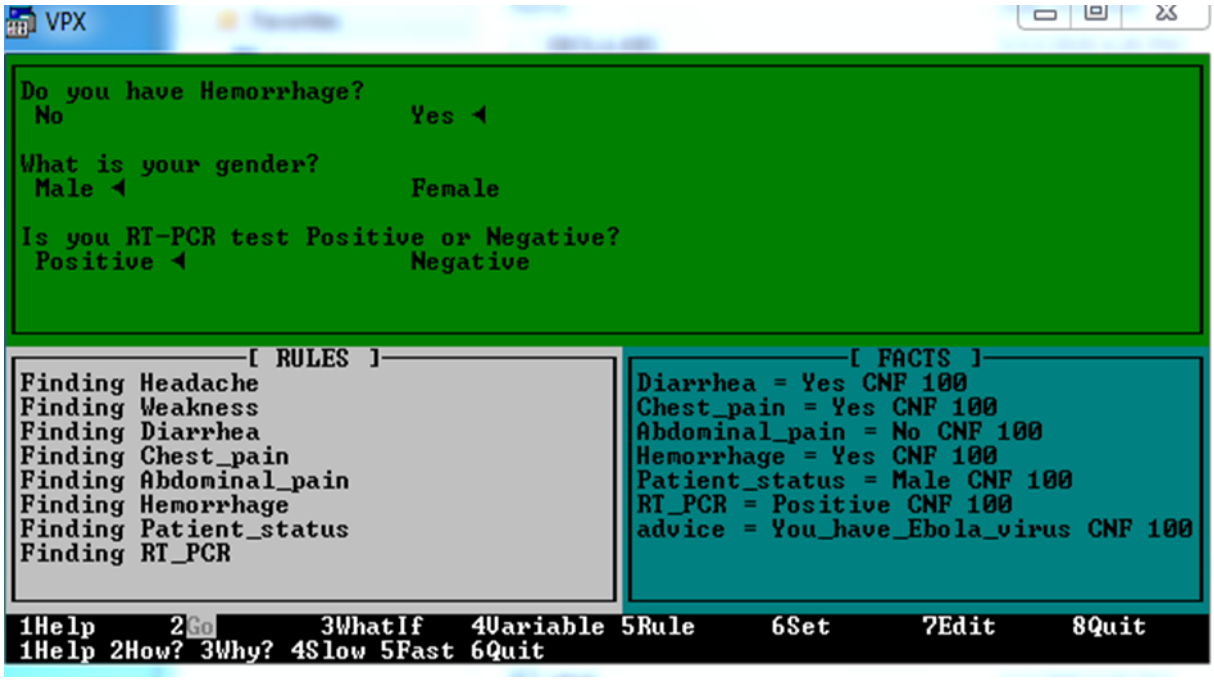

Figure 5.5: Result of Diagnosis

The performance and the validation of the EVDDExS have been accepted by experts in the field. The above figures show all the process in which the user must go through in order to find the result. Experts in the domain confirmed that this system can be used in diagnosis of EVD and it will be helpful in the field due to the major confusion when it comes to the detection of EVD. EVDDExS is easy to use and manage. Due to the higher rate of death that EVD can cause and the rapid transmission of the virus, this system will decrease the pressure on medical personnel if they can detect it with minimum time, it will help also the medical personnel with no experience. Figure 5.5 above shows how the result will be displayed after the user attends all the queries and this shows how much this system is important in the medical care.

The death rate of EVD is higher and this virus is very fatal, the early diagnosis and accuracy diagnose of EVD are crucial to avoid loss of life, EVDDExS is implemented with the objective to prevail the loss of life. If medical personnel can manually and daily diagnose 200 patients with Ebola Virus Disease, the capacity of diagnose 500 patients daily can be achieved with EVDDExS. With the use of EVDDExS the diagnosis of Ebola Virus Disease becomes much faster and easier with good accuracy. The objective of an

expert system is to give decision faster with precision like a human expert, therefore the aim of EVDDExS matches with the objective of expert system to give precise and faster decision like a human expert.

CHAPTER 6
CONCLUSIONS

6.1. Conclusion

Decision support system plays an important role in many branches of artificial intelligence. It has the ability and capacity to make decision and to give advice. ES have shown good results in many domains of human life with many applications developed in different fields like medicine, agriculture, computer science, engineering etc.
In medicine ES has been used in diagnosis, detection and treatment of diseases. In agriculture ES has been used in order to help farmers to make decision and to provide the ability to manage the soil, seed, harvest, control of insect and to make consideration in raising productions. In engineering the application of ES helps engineers in various environments and it can also replace operation of human in control of system. In computer sciences ES is used for design and diagnosis of computer systems, it is mostly used when it comes to the detection of fault and error in system. ES can be used in any environment that required decisions.

Acquisition of knowledge and the representation phases in the design of the Ebola Virus Disease Diagnosis Expert System (EVDDExS) has been defined. IF-THEN rule based and backward chaining technique is used in EVDDExS to make decisions. 450 rules have been constructed based on knowledge collected from experts in the medical environments, the rule production has 11 inputs and 3 outputs. The decision is made based on the response collected from user, the user must give answers to all 11 queries asked.

EVDDExS has been developed with VP expert shell, a rule based expert system. EVDDExS has been tested by 35 medical specialists in the environment and it was found that the accuracy rate of the system is 94%. The system results were compared with the expert's diagnosis and advice in the field.

To conclude, EVDDExS promote the management in diagnosis of EVD, the system is easy to use with Yes or No answers this makes the system much easier and simpler to any user

without enough knowledge. It reduces the effort of medical personnel when it comes to the diagnosis of the disease.

6.2. Future Study and Recommendations

Due to the complex ratio of death, the fatality that the virus can cause, the rapid contamination and the confusion of Ebola with other HF when it comes to symptoms. Ebola Virus Disease Diagnosis Expert System was developed to assist medical personnel to detect the virus easily and to provide faster diagnose. The specialist in the field were pleased with EVDDExS and the facilities that the system offers in diagnosis of EVD, but many recommendations and suggestions given during the test of the system must be taken into consideration for future study. Some recommendations and suggestions are given below:

- Additional input for of other EVD tests diagnosis
- Additional input for age
- Additional input for pregnant women
- Additional input for suggest method of treatment
- Provide the details of other hemorrhagic fever

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APPENDICES

APPENDIX 1

EBOLA VIRUS DISEASE EXPERT SYSTEM

Note: EVDDExS has 450 rules below are just the summary of some rules used in the system.

ACTIONS

DISPLAY "WELCOME TO EBOLA VIRUS DISEASE DIAGNOSIS EXPERT SYSTEM"

FIND advice;

RULE 0

IF Fever = No AND

Fatigue = No AND

Vomiting = Yes AND

Bleeding = No AND

Headache = Yes AND

Weakness = No AND

Diarrhea = No AND

Chest_pain = No AND

Abdominal_pain = No AND

Hemorrhage = No AND

Patient_status= Female AND

RT_PCR = Negative

THEN advice = You_don’t_have_EVD_drink_onsensetrol;

RULE 1

IF Fever = No AND

Fatigue = No AND

Vomiting = Yes AND

Bleeding = No AND

Headache = No AND

Weakness = Yes AND

Diarrhea = No AND

Chest_pain = No AND

Abdominal_pain = No AND

Hemorrhage = No AND

Patient_status= Female AND

RT_PCR = Negative

THEN advice = You_don’t_have_EVD_ondansetrol_and_sleep;

RULE 2

IF Fever = Yes AND

Fatigue = Yes AND

Vomiting = Yes AND

Bleeding = Yes AND

Headache = Yes AND

Weakness = Yes AND

Diarrhea = Yes AND

Chest_pain = Yes AND

Abdominal_pain = Yes AND

Hemorrhage = Yes AND

Patient_status= Female AND

RT_PCR = Positive

THEN advice = You_have_Ebola;

RULE 3

IF Fever = No AND

Fatigue = No AND

Vomiting = Yes AND

Bleeding = No AND

Headache = No AND

Weakness = No AND

Diarrhea = No AND

Chest_pain = Yes AND

Abdominal_pain = No AND

Hemorrhage = No AND

Patient_status= Female AND

RT_PCR = Negative

THEN advice = You_don’t_have_EVD_drink_ondansetrol;

RULE 4

IF Fever = No AND

Fatigue = No AND

Vomiting = Yes AND

Bleeding = No AND

Headache = No AND

Weakness = No AND

Diarrhea = No AND

Chest_pain = No AND

Abdominal_pain = Yes AND

Hemorrhage = No AND

Patient_status= Female AND

RT_PCR = Negative

THEN advice = You_don’t_have_EVD_drink_ondensetrol;

RULE 5

IF Fever = No AND

Fatigue = No AND

Vomiting = Yes AND

Bleeding = No AND

Headache = No AND

Weakness = No AND

Diarrhea = No AND

Chest_pain = No AND

Abdominal_pain = No AND

Hemorrhage = No AND

Patient_status= Female AND

RT_PCR = Positive

THEN advice = You_have_Ebola;

RULE 6

IF Fever = Yes AND

Fatigue = Yes AND

Vomiting = No AND

Bleeding = No AND

Headache = No AND

Weakness = No AND

Diarrhea = No AND

Chest_pain = No AND

Abdominal_pain = Yes AND

Hemorrhage = No AND

Patient_status= Male AND

RT_PCR = Negative

THEN advice = You_don’t_have_EVD_Consult_Doctor;

RULE 7

IF Fever = Yes AND

Fatigue = Yes AND

Vomiting = No AND

Bleeding = No AND

Headache = No AND

Weakness = No AND

Diarrhea = No AND

Chest_pain = No AND

Abdominal_pain = No AND

Hemorrhage = Yes AND

Patient_status= Male AND

RT_PCR = Positive

THEN advice = You_have_Ebola;

RULE 8

IF Fever = Yes AND

Fatigue = Yes AND

Vomiting = Yes AND

Bleeding = Yes AND

Headache = No AND

Weakness = No AND

Diarrhea = No AND

Chest_pain = No AND

Abdominal_pain = No AND

Hemorrhage = No AND

Patient_status= Male AND

RT_PCR = Negative

THEN advice = You_don’t_have_EVD_Consult_Doctor;

RULE 9

IF Fever = Yes AND

Fatigue = Yes AND

Vomiting = Yes AND

Bleeding = No AND

Headache = Yes AND

Weakness = No AND

Diarrhea = No AND

Chest_pain = No AND

Abdominal_pain = No AND

Hemorrhage = No AND

Patient_status= Male AND

RT_PCR = Negative

THEN advice = You_don’t_have_EVD_You_might_have_Malaria;

RULE 10

IF Fever = Yes AND

Fatigue = Yes AND

Vomiting = Yes AND

Bleeding = No AND

Headache = No AND

Weakness = Yes AND

Diarrhea = No AND

Chest_pain = No AND

Abdominal_pain = No AND

Hemorrhage = No AND

Patient_status= Male AND

RT_PCR = Negative

THEN advice = You_don’t_have_EVD_Check_other_HF;

RULE 11

IF Fever = Yes AND

Fatigue = Yes AND

Vomiting = Yes AND

Bleeding = No AND

Headache = No AND

Weakness = No AND

Diarrhea = Yes AND

Chest_pain = No AND

Abdominal_pain = No AND

Hemorrhage = No AND

Patient_status= Male AND

RT_PCR = Negative

THEN advice = You_don’t_have_EVD_Consult_Doctor;

RULE 12

IF Fever = Yes AND

Fatigue = Yes AND

Vomiting = Yes AND

Bleeding = No AND

Headache = No AND

Weakness = No AND

Diarrhea = No AND

Chest_pain = Yes AND

Abdominal_pain = No AND

Hemorrhage = No AND

Patient_status= Male AND

RT_PCR = Negative

THEN advice = You_don’t_have_EVD_Maybe_Malaria;

RULE 13

IF Fever = Yes AND

Fatigue = Yes AND

Vomiting = Yes AND

Bleeding = No AND

Headache = No AND

Weakness = No AND

Diarrhea = No AND

Chest_pain = No AND

Abdominal_pain = Yes AND

Hemorrhage = No AND

Patient_status= Male AND

RT_PCR = Negative

THEN advice = You_don’t_have_EVD_Consult_Doctor;

RULE 14

IF Fever = Yes AND

Fatigue = Yes AND

Vomiting = Yes AND

Bleeding = No AND

Headache = No AND

Weakness = No AND

Diarrhea = No AND

Chest_pain = No AND

Abdominal_pain = No AND

Hemorrhage = Yes AND

Patient_status= Male AND

RT_PCR = Positive

THEN advice = You_don’t_have_EVD_drink_paracetamol;

RULE 15

IF Fever = Yes AND

Fatigue = Yes AND

Vomiting = Yes AND

Bleeding = Yes AND

Headache = Yes AND

Weakness = No AND

Diarrhea = No AND

Chest_pain = No AND

Abdominal_pain = No AND

Hemorrhage = No AND

Patient_status= Male AND

RT_PCR = Negative

THEN advice = You_don’t_have_EVD_Check_thyphoid_fever;

RULE 16

IF Fever = Yes AND

Fatigue = Yes AND

Vomiting = Yes AND

Bleeding = Yes AND

Headache = No AND

Weakness = Yes AND

Diarrhea = No AND

Chest_pain = No AND

Abdominal_pain = No AND

Hemorrhage = No AND

Patient_status= Male AND

RT_PCR = Negative

THEN advice = You_don’t_have_EVD_Consult_Doctor;

RULE 17

IF Fever = Yes AND

Fatigue = Yes AND

Vomiting = Yes AND

Bleeding = Yes AND

Headache = No AND

Weakness = No AND

Diarrhea = Yes AND

Chest_pain = No AND

Abdominal_pain = No AND

Hemorrhage = No AND

Patient_status= Male AND

RT_PCR = Negative

THEN advice = You_don’t_have_EVD_check_malaria;

RULE 18

IF Fever = Yes AND

Fatigue = Yes AND

Vomiting = Yes AND

Bleeding = Yes AND

Headache = No AND

Weakness = No AND

Diarrhea = No AND

Chest_pain = Yes AND

Abdominal_pain = No AND

Hemorrhage = No AND

Patient_status= Male AND

RT_PCR = Negative

THEN advice = You_don’t_have_EVD_check_other_HF;

RULE 19

IF Fever = Yes AND

Fatigue = Yes AND

Vomiting = Yes AND

Bleeding = Yes AND

Headache = No AND

Weakness = No AND

Diarrhea = No AND

Chest_pain = No AND

Abdominal_pain = Yes AND

Hemorrhage = No AND

Patient_status= Male AND

RT_PCR = Negative

THEN advice = You_don’t_have_EVD_maybe_malaria;

RULE 20

IF Fever = Yes AND

Fatigue = Yes AND

Vomiting = Yes AND

Bleeding = Yes AND

Headache = No AND

Weakness = No AND

Diarrhea = No AND

Chest_pain = No AND

Abdominal_pain = No AND

Hemorrhage = Yes AND

Patient_status= Male AND

RT_PCR = Positive

THEN advice = You_have_Ebola;

RULE 21

IF Fever = Yes AND

Fatigue = Yes AND

Vomiting = Yes AND

Bleeding = Yes AND

Headache = Yes AND

Weakness = Yes AND

Diarrhea = No AND

Chest_pain = No AND

Abdominal_pain = No AND

Hemorrhage = No AND

Patient_status= Male AND

RT_PCR = Negative

THEN advice = You_don’t_have_EVD_maybe_malaria;

RULE 22

IF Fever = Yes AND

Fatigue = Yes AND

Vomiting = Yes AND

Bleeding = Yes AND

Headache = Yes AND

Weakness = No AND

Diarrhea = Yes AND

Chest_pain = No AND

Abdominal_pain = No AND

Hemorrhage = No AND

Patient_status= Male AND

RT_PCR = Negative

THEN advice = You_don’t_have_EVD_check_other_HF;

RULE 23

IF Fever = Yes AND

Fatigue = Yes AND

Vomiting = Yes AND

Bleeding = Yes AND

Headache = Yes AND

Weakness = No AND

Diarrhea = No AND

Chest_pain = Yes AND

Abdominal_pain = No AND

Hemorrhage = No AND

Patient_status= Male AND

RT_PCR = Negative

THEN advice = You_don’t_have_EVD_check_thypoid_fever;

RULE 24

IF Fever = Yes AND

Fatigue = Yes AND

Vomiting = Yes AND

Bleeding = Yes AND

Headache = Yes AND

Weakness = No AND

Diarrhea = No AND

Chest_pain = No AND

Abdominal_pain = Yes AND

Hemorrhage = No AND

Patient_status= Male AND

RT_PCR = Negative

THEN advice = You_don’t_have_EVD_maybe_malaria;

RULE 25

IF Fever = Yes AND

Fatigue = Yes AND

Vomiting = Yes AND

Bleeding = Yes AND

Headache = Yes AND

Weakness = No AND

Diarrhea = No AND

Chest_pain = No AND

Abdominal_pain = No AND

Hemorrhage = Yes AND

Patient_status= Male AND

RT_PCR = Positive

THEN advice = You_have_Ebola;

RULE 26

IF Fever = Yes AND

Fatigue = Yes AND

Vomiting = Yes AND

Bleeding = Yes AND

Headache = Yes AND

Weakness = Yes AND

Diarrhea = Yes AND

Chest_pain = No AND

Abdominal_pain = No AND

Hemorrhage = No AND

Patient_status= Female AND

RT_PCR = Negative

THEN advice = You_don’t_have_EVD_maybe_other_HF;

RULE 27

IF Fever = Yes AND

Fatigue = Yes AND

Vomiting = Yes AND

Bleeding = Yes AND

Headache = Yes AND

Weakness = Yes AND

Diarrhea = No AND

Chest_pain = Yes AND

Abdominal_pain = No AND

Hemorrhage = No AND

Patient_status= Female AND

RT_PCR = Negative

THEN advice = You_don’t_have_EVD_maybe_malaria;

RULE 28

IF Fever = Yes AND

Fatigue = Yes AND

Vomiting = Yes AND

Bleeding = Yes AND

Headache = Yes AND

Weakness = Yes AND

Diarrhea = No AND

Chest_pain = No AND

Abdominal_pain = Yes AND

Hemorrhage = No AND

Patient_status= Female AND

RT_PCR = Negative

THEN advice = You_don’t_have_EVD_you_have_malaria;

RULE 29

IF Fever = Yes AND

Fatigue = Yes AND

Vomiting = Yes AND

Bleeding = Yes AND

Headache = Yes AND

Weakness = Yes AND

Diarrhea = No AND

Chest_pain = No AND

Abdominal_pain = No AND

Hemorrhage = Yes AND

Patient_status= Female AND

RT_PCR = Positive

THEN advice = You_have_Ebola;

RULE 30

IF Fever = Yes AND

Fatigue = Yes AND

Vomiting = Yes AND

Bleeding = Yes AND

Headache = Yes AND

Weakness = Yes AND

Diarrhea = Yes AND

Chest_pain = Yes AND

Abdominal_pain = No AND

Hemorrhage = No AND

Patient_status= Female AND

RT_PCR = Negative

THEN advice = You_don’t_have_EVD_you_have_malaria;

RULE 31

IF Fever = Yes AND

Fatigue = Yes AND

Vomiting = Yes AND

Bleeding = Yes AND

Headache = Yes AND

Weakness = Yes AND

Diarrhea = Yes AND

Chest_pain = No AND

Abdominal_pain = Yes AND

Hemorrhage = No AND

Patient_status= Female AND

RT_PCR = Negative

THEN advice = You_don’t_have_EVD_you_have_malaria;

RULE 32

IF Fever = Yes AND

Fatigue = Yes AND

Vomiting = Yes AND

Bleeding = Yes AND

Headache = Yes AND

Weakness = Yes AND

Diarrhea = Yes AND

Chest_pain = No AND

Abdominal_pain = No AND

Hemorrhage = Yes AND

Patient_status= Female AND

RT_PCR = Positive

THEN advice = You_have_Ebola;

RULE 33

IF Fever = Yes AND

Fatigue = Yes AND

Vomiting = Yes AND

Bleeding = Yes AND

Headache = Yes AND

Weakness = Yes AND

Diarrhea = Yes AND

Chest_pain = Yes AND

Abdominal_pain = Yes AND

Hemorrhage = No AND

Patient_status= Male AND

RT_PCR = Negative

THEN advice = You_don’t_have_EVD_check_other_HF;

RULE 34

IF Fever = Yes AND

Fatigue = Yes AND

Vomiting = Yes AND

Bleeding = Yes AND

Headache = Yes AND

Weakness = Yes AND

Diarrhea = Yes AND

Chest_pain = Yes AND

Abdominal_pain = No AND

Hemorrhage = Yes AND

Patient_status= Male AND

RT_PCR = Positive

THEN advice = You_have_Ebola;

RULE 35

IF Fever = Yes AND

Fatigue = Yes AND

Vomiting = Yes AND

Bleeding = Yes AND

Headache = Yes AND

Weakness = Yes AND

Diarrhea = Yes AND

Chest_pain = Yes AND

Abdominal_pain = Yes AND

Hemorrhage = Yes AND

Patient_status= Male AND

RT_PCR = Positive

THEN advice = You_have_Ebola;

RULE 36

IF Fever = Yes AND

Fatigue = Yes AND

Vomiting = Yes AND

Bleeding = No AND

Headache = No AND

Weakness = No AND

Diarrhea = No AND

Chest_pain = No AND

Abdominal_pain = No AND

Hemorrhage = No AND

Patient_status= Female AND

RT_PCR = Negative

THEN advice = You_don’t_have_EVD_Consult_Doctor;

RULE 37

IF Fever = Yes AND

Fatigue = Yes AND

Vomiting = No AND

Bleeding = Yes AND

Headache = No AND

Weakness = No AND

Diarrhea = No AND

Chest_pain = No AND

Abdominal_pain = No AND

Hemorrhage = No AND

Patient_status= Female AND

RT_PCR = Negative

THEN advice = You_don’t_have_EVD_Consult_Doctor;

RULE 38

IF Fever = Yes AND

Fatigue = Yes AND

Vomiting = No AND

Bleeding = No AND

Headache = Yes AND

Weakness = No AND

Diarrhea = No AND

Chest_pain = No AND

Abdominal_pain = No AND

Hemorrhage = No AND

Patient_status= Female AND

RT_PCR = Negative

THEN advice = You_don’t_have_EVD_drink_paracetamol;

RULE 39

IF Fever = Yes AND

Fatigue = Yes AND

Vomiting = No AND

Bleeding = No AND

Headache = No AND

Weakness = Yes AND

Diarrhea = No AND

Chest_pain = No AND

Abdominal_pain = No AND

Hemorrhage = No AND

Patient_status = Female AND

RT_PCR = Negative

THEN advice = You_don’t_have_EVD_drink_paracetamol_stay_home;

RULE 40

IF Fever = Yes AND

Fatigue = Yes AND

Vomiting = No AND

Bleeding = No AND

Headache = No AND

Weakness = No AND

Diarrhea = Yes AND

Chest_pain = No AND

Abdominal_pain = No AND

Hemorrhage = No AND

Patient_status = Female AND

RT_PCR = Negative

THEN advice = You_don’t_have_EVD_drink_paracetamol_and_more_water;

RULE 41

IF Fever = Yes AND

Fatigue = Yes AND

Vomiting = No AND

Bleeding = No AND

Headache = No AND

Weakness = No AND

Diarrhea = No AND

Chest_pain = Yes AND

Abdominal_pain = No AND

Hemorrhage = No AND

Patient_status = Female AND

RT_PCR = Negative

THEN advice = You_don’t_have_EVD_drink_paracetamol;

RULE 42

IF Fever = Yes AND

Fatigue = Yes AND

Vomiting = No AND

Bleeding = No AND

Headache = No AND

Weakness = No AND

Diarrhea = No AND

Chest_pain = No AND

Abdominal_pain = Yes AND

Hemorrhage = No AND

Patient_status = Female AND

RT_PCR = Negative

THEN advice = You_don’t_have_EVD_drink_paracetamol;

RULE 43

IF Fever = Yes AND

Fatigue = Yes AND

Vomiting = No AND

Bleeding = No AND

Headache = No AND

Weakness = No AND

Diarrhea = No AND

Chest_pain = No AND

Abdominal_pain = No AND

Hemorrhage = Yes AND

Patient_status = Female AND

RT_PCR = Positive

THEN advice = You_have_Ebola;

RULE 44

IF Fever = Yes AND

Fatigue = Yes AND

Vomiting = Yes AND

Bleeding = Yes AND

Headache = No AND

Weakness = No AND

Diarrhea = No AND

Chest_pain = No AND

Abdominal_pain = No AND

Hemorrhage = No AND

Patient_status = Female AND

RT_PCR = Negative

THEN advice = You_don’t_have_EVD_Consult_Doctor;

RULE 45

IF Fever = Yes AND

Fatigue = Yes AND

Vomiting = Yes AND

Bleeding = No AND

Headache = Yes AND

Weakness = No AND

Diarrhea = No AND

Chest_pain = No AND

Abdominal_pain = No AND

Hemorrhage = No AND

Patient_status = Female AND

RT_PCR = Negative

THEN advice = You_don’t_have_EVD_Consult_Doctor;

RULE 46

IF Fever = Yes AND

Fatigue = Yes AND

Vomiting = Yes AND

Bleeding = No AND

Headache = No AND

Weakness = Yes AND

Diarrhea = No AND

Chest_pain = No AND

Abdominal_pain = No AND

Hemorrhage = No AND

Patient_status = Female AND

RT_PCR = Negative

THEN advice = You_don’t_have_EVD_drink_paracetamol;

RULE 47

IF Fever = Yes AND

Fatigue = Yes AND

Vomiting = Yes AND

Bleeding = No AND

Headache = No AND

Weakness = No AND

Diarrhea = Yes AND

Chest_pain = No AND

Abdominal_pain = No AND

Hemorrhage = No AND

Patient_status = Female AND

RT_PCR = Negative

THEN advice = You_don’t_have_EVD_Consult_Doctor;

RULE 48

IF Fever = Yes AND

Fatigue = Yes AND

Vomiting = Yes AND

Bleeding = No AND

Headache = No AND

Weakness = No AND

Diarrhea = No AND

Chest_pain = Yes AND

Abdominal_pain = No AND

Hemorrhage = No AND

Patient_status = Female AND

RT_PCR = Negative

THEN advice = You_don’t_have_EVD_Consult_Doctor;

RULE 49

IF Fever = Yes AND

Fatigue = Yes AND

Vomiting = Yes AND

Bleeding = No AND

Headache = No AND

Weakness = No AND

Diarrhea = No AND

Chest_pain = No AND

Abdominal_pain = Yes AND

Hemorrhage = No AND

Patient_status = Female AND

RT_PCR = Negative

THEN advice = You_don’t_have_EVD_Consult_Doctor;

RULE 50

IF Fever = Yes AND

Fatigue = Yes AND

Vomiting = Yes AND

Bleeding = No AND

Headache = No AND

Weakness = No AND

Diarrhea = No AND

Chest_pain = No AND

Abdominal_pain = No AND

Hemorrhage = Yes AND

Patient_status = Female AND

RT_PCR = Positive

THEN advice = You_have_Ebola;

RULE 51

IF Fever = Yes AND

Fatigue = Yes AND

Vomiting = Yes AND

Bleeding = Yes AND

Headache = Yes AND

Weakness = No AND

Diarrhea = No AND

Chest_pain = No AND

Abdominal_pain = No AND

Hemorrhage = No AND

Patient_status = Female AND

RT_PCR = Negative

THEN advice = You_don’t_have_EVD_Consult_Doctor;

RULE 51

IF Fever = Yes AND

Fatigue = Yes AND

Vomiting = Yes AND

Bleeding = Yes AND

Headache = No AND

Weakness = Yes AND

Diarrhea = No AND

Chest_pain = No AND

Abdominal_pain = No AND

Hemorrhage = No AND

Patient_status = Female AND

RT_PCR = Negative

THEN advice = You_don’t_have_EVD_Consult_Doctor;

RULE 52

IF Fever = Yes AND

Fatigue = Yes AND

Vomiting = Yes AND

Bleeding = Yes AND

Headache = No AND

Weakness = No AND

Diarrhea = Yes AND

Chest_pain = No AND

Abdominal_pain = No AND

Hemorrhage = No AND

Patient_status = Female AND

RT_PCR = Negative

THEN advice = You_don’t_have_EVD_Consult_Doctor;

RULE 53

IF Fever = Yes AND

Fatigue = Yes AND

Vomiting = Yes AND

Bleeding = Yes AND

Headache = No AND

Weakness = No AND

Diarrhea = No AND

Chest_pain = Yes AND

Abdominal_pain = No AND

Hemorrhage = No AND

Patient_status = Female AND

RT_PCR = Negative

THEN advice = You_don’t_have_EVD_Consult_Doctor;

ASK Patient_status: “Are you Male or Female”;

CHOICES Patient_status: Male, Female;

ASK Fever: “Do you have Fever?”;

CHOICES Fever: Yes, No;

ASK Fatigue: “Do you have sign of Fatigue?”;

CHOICES Fatigue: Yes, No;

ASK Vomiting: “Do you Vomit?”;

CHOICES Vomiting: Yes, No;

ASK Bleeding: “Do you Bleed?”;

CHOICES Bleeding: Yes, No;

ASK Headache: “Do you have Headache?”;

CHOICES Headache: Yes, No;

ASK Weakness: “Do you have any sign of Weakness?”;

CHOICES Weakness: Yes, No;

ASK Diarrhea: “Do you have Diarrhea?”;

CHOICES Diarrhea: Yes, No;

ASK Chest_pain: “Do you have Chest pain?”;

CHOICES Chest_pain: Yes, No;

ASK Abdominal_pain: “Do you have Abdominal pain?”;

CHOICES Abdominal_pain: Yes, No;

ASK Hemorrhage: “Do you have Hemorrhage?”;

CHOICES Hemorrhage: Yes, No;

ASK RT_PCR: “How is your RT_PCR results?”;

CHOICES RT_PCR: Positive, Negative;