Journal of the Nigerian Association of Mathematical Physics
Volume34,(*March, 2016*), pp 241 – 248

A Mobile-Based Expert System for the Diagnosis of Ebola Virus (ES-DEV)

N.A Azeez andO.MOye

Department of Computer Sciences, University of Lagos, Nigeria.

Abstract

The development of expert system for the diagnosis of Ebola Virus (ES-DEV) is important to both medical industry and Ebola Virus patients. It is heart-rending to see in the past few years how Africans, particularly, those living in the Western part of the continent, are being attacked and ravaged by deadly Ebola Virus. Though, this virus has been in existence for years but its recent attacks call for urgent and immediate solution. Medicine which is one of the popular areas where Artificial Intelligence is being used requires better attention if urgent and technical solutions are to be found for this virus. In an attempt to finding solution to this medical challenge, the authors present a mobile-based expert system for the diagnosis of Ebola Virus (ES-DEV). The aim is to provide the users a first-point contact for the virus on how to guard against it, possible symptoms, measures and immediate solution. The application (ES-DEV) which uses waterfall methodology was developed on Android mobile phone with Java Runtime Environment. ES-DEV is currently working and further recommendation is currently being made to adopt its application in medical institutions.

1.0 Introduction

The Ebola virus disease is a hemorrhagic fever due to a virus of the same name of the *filoviridaeb* family and of the *Filovirus*genus. There are 5 species of the virus: Zaire ebolavirus, Sudan ebolavirus, TaïForestebolavirus, Bundibugyo ebolavirus and Reston Ebola virus, represented by Ebola virus (EBOV), Sudan virus (SUDV), Taï Forest virus (TAFV), Bundibugyo virus (BDBV) and Reston virus (RESTV), respectively [1].

Ebola virus and Marburg virus are from the family Filoviridae. They are known mainly as causative agents of severe hemorrhagic fever with a high mortality in Central Africa. It is believed and established fact that they are usually transmitted through: infected person, biological fluids or cadavers. The virus is contagious. Aerosolized EBOV is responsible for the dangerous and lethal infections in monkeys hence; the virus has a tendency and strong potential for bioterrorism [1-3].

"*Early attempts to develop a vaccine against EBOV based on inactivated viral particles, purified antigens, and other approaches sometimes were protective in rodents but were not protective or poorly protective in non-human primates*" [3].

"More recently, vectored vaccines and virus-like particles proved to be protective in non-human primate models. Human Para influenza virus type 3 (HPIV3) is a common pediatric respiratory virus. HPIV3 is a member of family Paramyxoviridae and is an enveloped virus with a single negative-sense strand of genomic RNA of 15,462 nucleotides"[2].

There is no doubt that the outbreak of Ebola Virus Disease is having monumental effect across the African continent. At present, more than 3000 people have been infected with over 1500 death recorded. Over one hundred health care workers have also been infected[4].

Corresponding author: N.A Azeez, E-mail:nazeez@unilag.edu.ng, Tel.: +234706-683-8551 & 8065123604(OMO)

Table 1: Number of people with Ebola Virus from 1976 – 2014

Year	Country	Town	Number ofCases	Number of Deaths	Species
1976	Democratic Republic of the Congo	Yambuku	318	280	EBOV
1976	South Sudan	Nzara	284	284	SUDV
1977	Democratic Republic of the Congo	Tandala	1	1	EBOV
1979	South Sudan	Nzara	34	22	SUDV
1994	Gabon	Mekouka	52	31	EBOV
1994	Ivory Coast	Tai Forest	1	0	TAFV
1995	Democratic Republic of the Congo	Kikwit	315	250	EBOV
1996	Gabon	Mayibout	37	21	EBOV
1996	Gabon	Booue	60	45	EBOV
1996	South Africa	Johannesburg	2	1	EBOV
2000	Uganda	Gulu	425	224	EBOV
2001	Gabon	Libreville	65	53	EBOV
2001	Republic of the Congo	Not specified	57	43	EBOV
2002	Republic of the Congo	Mbomo	143	128	EBOV
2003	Republic of the Congo	Mbomo	35	29	EBOV
2004	South Sudan	Yambio	17	7	EBOV
2007	Democratic Republic of the Congo	Luebo	264	187	EBOV
2007	Uganda	Bundibugyo	149	37	BDBV
2008	Democratic Republic of the Congo	Luebo	32	15	EBOV
2011	Uganda	Luwero District	1	1	SUDV
2012	Uganda	Kibaale District	11	4	SUDV
2012	Democratic Republic of the Congo	Isiro Health Zone	36	13	BDBV
2012	Uganda	Luwero District	6	3	SUDV
2014	Guinea, Sierra Leone, Liberia, Nigeria	Multiple	1009	574	EBOV

One of the victims was Dr. Sheik Humarr Khan, the chief physician of the Lassa Fever Research Program at Kenema Government Hospital in Kenema, Sierra Leone, who died of EVD on July 29th at age 39 [5].

Khan was born in 1975 in Lungi, Sierra Leone, across the bay from the nation's capital Freetown, the youngest of 10 children. Even as a young boy he envisioned a career in medicine, addressing himself frequently as ''doctor,'' sometimes much to his family's dismay. His dream was realized when he graduated from the University of Sierra Leone's College of Medicine and Allied Health Sciences with his medical degree in 2001, completing his internship in 2004 [5].

In March 2014, the World Health Organization was notified of an outbreak of *Zaire ebolavirus*in a remote area of Guinea. The outbreak then spread to the capital, Conakry, and to neighboring countries and has subsequently become the largest epidemic of Ebola virus disease (EVD) to date[6].

The most severely affected countries, Guinea, Sierra Leone and Liberia have very weak health systems, lacking human and infrastructural resources, having only recently emerged from long periods of conflict and instability. On August 8, the WHO Director-General declared this outbreak a public Health Emergency of International Concern[9].

Figure 1: Ebola virus
Source: Google image

Images of people infected with hemorrhagic rashes all over the body.
Figure 2: People infected with EVD
Source: Google Image

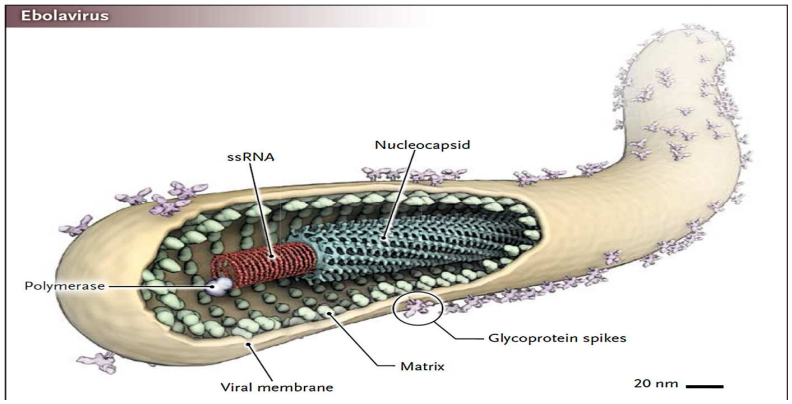

Figure 3: The structure of Ebola Virus
Source: Google Image

Based on the recent widespread of this disease, the authors therefore deemed it fit at this crucial period to develop a mobile expert systemto help in diagnosing a patient suspected to be carrying the virus and provide appropriate measure and recommendation [8].

1.2 Statement of the Problem

Health issue is fundamental to the growths and development of any society. If health is to be guaranteed, adoption of ICT could not be over-emphasized. It is as a result of the prevalence of Ebola in some African countries that a mobile application treatment and diagnosis of Ebola virus is considered important. It is understandable that this disease is contagious; as a result, the health of medical officers is also at risk. Against this backdrop, a mobile-based expert system will go a long way at making accessible, the treatment and diagnosis of the virus and make appropriate recommendation where necessary.

2.0 Literature Review

Ebola is an enveloped, non-segmented, negative-sense RNAvirus that belongs to the family Filoviridae; it causes severe hemorrhagic fever in humans and nonhuman primates with a high fatality of 90%. The Ebola epidemic occurs primarily in central and western Africa and Philippines [10]. A total of five Ebola virus sub-types have been discovered, which are Zaire ebolavirus (ZEBOV),Sudanebolavirus (SUDV), Taï Forest ebolavirus (TAFV), Restonebolavirus (RESTV), and Bundibugyo ebolavirus (BDBV). Among these subtypes, Zaire ebolavirus and Sudanebolavirus are the most toxic subtypes with high pathogenicity and infectiousness. Currently, no effective treatments and licensed vaccines are available for EBOV infection[1].

Ebola virus (EBOV) causes sporadic outbreaks of severe hemorrhagic fever in the rain forests of Central Africa with a lethality in humans of up to 88% for species Zaire . The virus is transmitted by contact with infected patients or fluids and is thought to enter through breaks in the skin or inoculation of mucosal membranes[2].

The largest outbreak of Ebola virus disease (EVD) ever recorded is presently having devastating effects in West Africa, with over 3000 people infected and more than 1500 deaths as well as untold economic, societal, and emotional impacts on the region’s countries and inhabitants. Hundreds of healthcare workers in Sierra Leone, Liberia, Guinea, and Nigeria have been among the infected. One of the victims was Dr. Sheik Humarr Khan, the chief physician of the Lassa Fever Research

Program at Kenema Government Hospital in Kenema, Sierra Leone, who died of EVD on July 29th at age 39. Khan was born in 1975 in Lungi, Sierra Leone, across the bay from the nation's capital Freetown, the youngest of 10 children. Even as a young boy he envisioned a career in medicine, addressing himself frequently as ''doctor,'' sometimes much to his family's dismay [5].

A Mobile Phone-Based Expert System for Diagnosis of Ebola Virus Physicians often diagnose diseases in order to determine the nature of treatment that will be described. According to Oxford Concise Medical Dictionary (2002), diagnosis involves determining the nature of a disorder by considering patient's signs and symptoms. It also involves reasoning based on expert knowledge to determine the nature of illness. With the advent of artificial intelligence, however, software systems have been developed to aid in the process of diagnosis [7].

They have also been used as decision support systems for physicians. These existing automated disease diagnosis systems are, however, either standalone or web-based systems. Considering the fact that computer literacy and the ratio of computers to humans in Africa in general and Nigeria in particular is very low there is therefore, a need to find an alternative and a more readily available means to fill these gaps identified, and cater for the needs of the people in this part of the world [5]**.**

2.1 Diagnosis

It can be difficult to distinguish EVD from other infectious diseases such as malaria, typhoid fever and meningitis. Confirmation that symptoms are caused by Ebola virus infection are made using the following investigations:

- antibody-capture enzyme-linked immunosorbent assay (ELISA)
- antigen-capture detection tests
- serum neutralization test
- reverse transcriptase polymerase chain reaction (RT-PCR) assay
- electron microscopy
- Virus isolation by cell culture.

Samples from patients are an extreme biohazard risk; laboratory testing on non-inactivated samples should be conducted under maximum biological containment conditions [12].

3.0 System Analysis of Expert System on EVD

ES-DEV is a mobile application that provides or facilitates supplemental clinical care, by coaching or prompting, to help patients diagnose EVD in their daily environment. This application supplements professional clinical care by facilitating behavioral change or coaching patients with EVD or identifiable health conditions in their daily environment. The application provides patients with tools to organize and track health information without providing recommendations to alter or change a previously prescribed treatment. It is a mobile application that provides easy access to information related to patients' health conditions or treatments – Thisapplication uses a patient's diagnosis to provide a clinician with best practice treatment guidelines for common illnesses or conditions such as influenza.

3.1 System Design

There are fourteen scenarios basically to show the sequence of events that take place in the body system of the Ebola patient, namely:

i. Diarrhea status
ii. Unexplained bleeding or bruising status of patient
iii. What is the fever status of the patient?
iv. What is the headache status of the patient?
v. What is the muscle pain status of the patient?
vi. What is the stomach status of the patient?
vii. What is the vomit status of the patient?
viii. What is the general malaise orasthenia?
ix. What is the anorexia status?
x. What is the weakness status?
xi. What is the sore throat status?
xii. What is the abdominal status?
xiii. What is the chest pain status?
xiv. What is the dyspnea status?

Clinically, Ebola infection is initially characterized by sudden onset fever with a history consistent with exposure. Confirmation is via detection of viral nucleic acid by the polymerase chain reaction (RT-PCR). Negative means when the Patient is free of Ebola Virus.Positive means when the patient is not free of Ebola Virus.This sequence of events that take place in the body system of the Ebola patient are taken into consideration in the design of ES-DEV application.

3.2 Ebola Symptoms and Signs

Symptoms of Ebola virus infection are similar to those produced by other hemorrhagic fever viruses and include:fever,fatigue, malaise, and weakness,reddened eyes,joint and muscle pain,headache,nausea and vomiting. Additional Ebola symptoms may includediarrhea,stomach pain and loss of appetite,cough, sore-throat, and difficulty swallowing,rash,hiccups,chest pain,breathing problems.As the disease worsens in severity, symptoms can include bleeding at various sites within or outside of the body [11].

4.0 Rules for Knowledge Representation for Ebola Virus

RULE 1

IF symptom is <Diarrhea> AND symptom is <headache> AND symptom is <pain> AND symptom is <fever> AND symptom is <vomit> THEN disease is <typhoid>

RULE 2

IF symptom is <headache> AND symptom is<pain>AND symptom is <fever> AND symptom is <weakness> THEN disease is <malaria>

RULE 3

IF symptom is <diarrhea> AND symptom is <bleeding> AND symptom is <fatigue> THEN disease is <Ebola>

RULES CAN REPRESENT RELATIONS, RECOMMENDATIONS, DIRECTIVES, STRATEGIES AND HEURISTICS:

RELATION

IF the "patient" has the three symptoms
THEN the "patient" has Ebola

RECOMMENDATION

IF the patient has Ebola AND the patient symptom is diarrhea AND the symptom is bleeding AND the symptom is fatigue THEN the advice is "refer to expert"

DIRECTIVE

IF the patient has the symptoms AND the "patient" has Ebola THEN the action is "refer to expert"

STRATEGY

IF the patient has the symptom THEN the action is "check the patient; step 1 is complete" IF step 1 is complete AND the "patient" is refer to expert THEN the action is "check the patient" step 2 is complete

HEURISTIC

IF the patient is vomiting blood AND the "patient" is Ebola positive AND the "patient" has all symptoms THEN the "patient" is Ebola positive

CONFLICT RESOLUTION

RULE1:

IF the patient has the symptoms THEN the action is Ebola positive

RULE 2:

IF the patient does not have the symptoms THEN the action is Ebola Negative

Rule 3:

IF the patient has Ebola THEN the action is positive

4.1 Input and Output Interface Designs

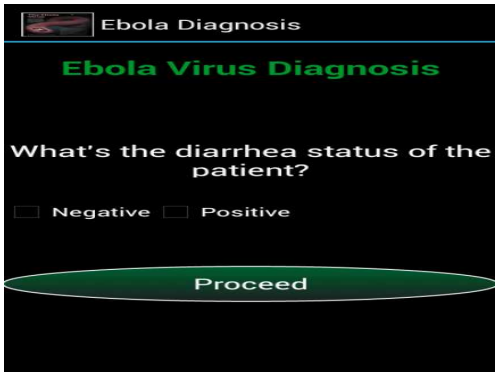

Figure 4: Diagnosis symptom ofdiarrhea

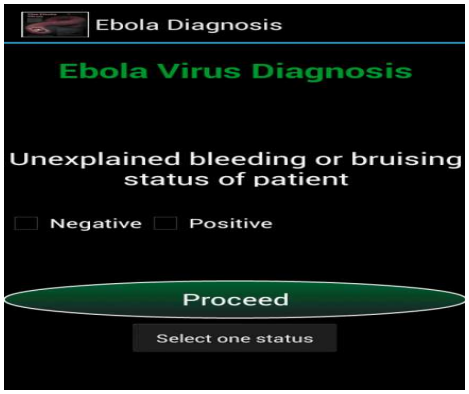

Figure 5: Diagnosis symptom of bleeding

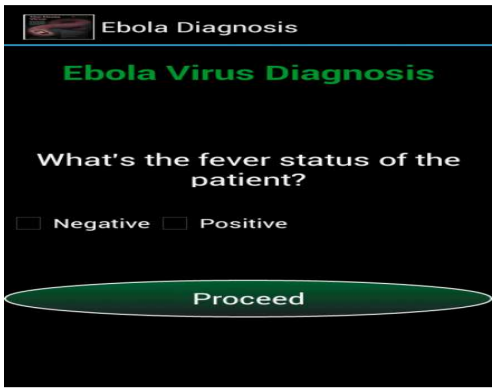

Figure 6: Diagnosis symptom of fever

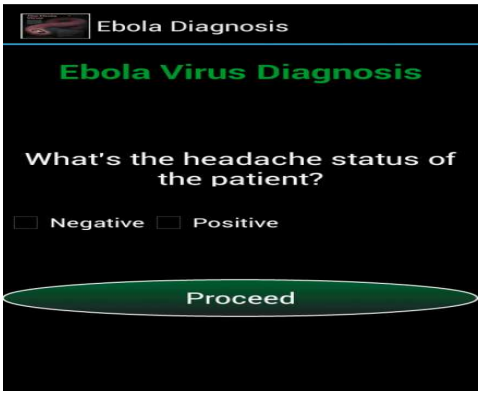

Figure 7: Diagnosis symptom of headache

Figure 8: Shows the diagnosis result
Description: This result shows all the diagnosis disease is Thyphoid

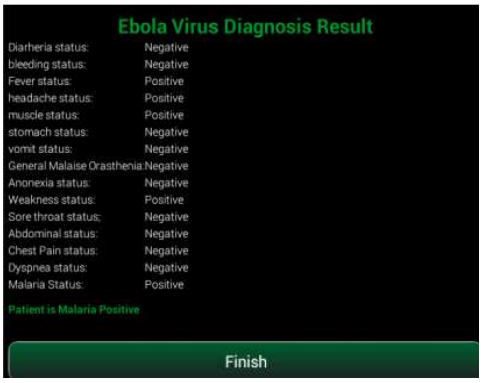

Figure 9: Shows the diagnosis result
Description: This result shows all the diagnosis disease is Malaria

Figure 10: Shows the diagnosis result
Description: This result shows all the diagnosis symptoms of Ebola Virus

5.0 Analysis of the Diagnosis: Symptoms

There are two possible outcomes: Positive (1) or Negative (0).

There are three possible ailments and diagnosis that may show up when ES-DEV is executed. They are: (1) Ebola (2) malaria (3) typhoid. For Ebola, however, three strong indicating symptoms are possible hence, we have the following combinations:

$Cs_E = \frac{n!}{r!(n-r)!} = \frac{14!}{3!(14-3)!} = \frac{14\ x\ 13\ x\ 12\ x\ 11!}{6\ x\ 11!} = 364$…….……..……..... (i)

Also, for Malaria, there are four strong possiblesymptoms; hence we have the following combinations:

$Cs_M = \frac{n!}{r!(n-r)!} = \frac{14!}{4!(14-4)!} = \frac{14\ x\ 13\ x\ 12\ x\ 11\ x\ 10!}{24\ x\ 10!} = 1001$……..……..….. (ii)

For Typhoid, there are $^{14}C_5$, which implies that there are five strong indicating symptoms

$C_{ST} = \frac{n!}{r!(n-r)!} = \frac{14!}{5!9!} = \frac{14\ x\ 13\ x\ 12\ x\ 11\ x\ 10\ x\ 9!}{5\ x\ 4\ x\ 3\ x\ 2\ x\ 9!} = 2002$ ……..……..…..… (iii)

Possible outcomes for the sequence of event that may arise before a person could be pronounced as Ebola patient = 2^{14} = 16,384

Ebola with three strong indicating factors has $\frac{1}{CS_E} = \frac{1}{364} = 0.00274725$

Also, Malaria with four strong indicating factorshas $\frac{1}{CS_M} = \frac{1}{1001} = 0.000999$

Typhoid with five strong indicating factors has a probability of $\frac{1}{CS_T} = \frac{1}{2002} = 0.0004995$

The probability that the chosen 3 symptoms being positive will result to Ebola therefore is $\frac{364}{16,384} = 0.0222168$, the probability that the chosen four symptoms being positive will result to Malaria = $\frac{1001}{16,384} = 0.061609619$, the probability that the chosen 5 symptoms being positive will result to typhoid = $\frac{2002}{16,384} = 0.12219238$

For the common symptom for Ebola, malaria and typhoid, there is $^{14}C_1 = 14$ combinations. Hence, the probability that the common symptom for Ebola, malaria and typhoid will occur.

$\frac{^{14}C_1}{16,384} = \frac{14}{16,384} = 0.00085449$ and finally, the possible Ebola outcome = $^{14}C_3 + {}^{14}C_4 + {}^{14}C_5 + \ldots + {}^{14}C_4$

5.1 Statistical Analysis

It could be recalled that there are fourteen symptoms of Ebola Virus with two possible outcomes: positive (1) or negative (0) for the following:

(1) Ebola Virus
(2) Malaria
(3) Typhoid

Also, for Ebola, there are three strong indicating symptoms, that is,$^{14}C_3 = 364$.For Malaria, there are four strong indicating symptoms $^{14}C_4 = 1001$ possible ways.ForTyphoid, there are five strong indicating symptoms, which is$^{14}C_5 = 2002$. All these amount to possible outcomes of $2^{14} = 16,384$

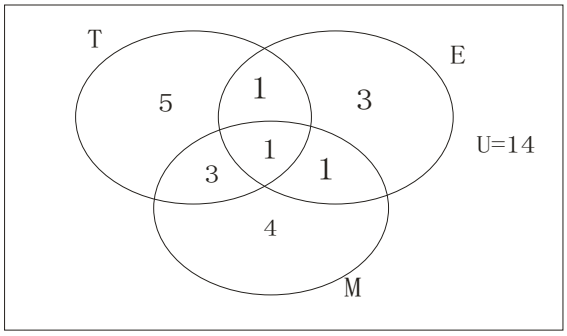

Figure 11: Venn diagram for Ebola, Malaria and Typhoid

Probability that one of these symptoms is going to be present;
Ebola = 0.00274725
Malaria = 0.000999
Typhoid = 0.0004995
Typhoid = 0.0004995
Probability that a chosen 3 symptombeing positive is 0.0222168.
Probability that a chosen 4 symptom being positive will result to malaria is 0.06109619.
Probability that a chosen 5 symptom being positive will result to malaria is 0.12219238.
T represents Typhoid, E represents Ebola and M represents Malaria. The following relationships were established for the three cases

E n T = 1, The symptom that is common to Ebola and Typhoid
E n M = 1, The symptom that is common to Ebola and Malaria
T n M = 3, The symptom that is common to Typhoid and Malaria
E n T n M = 1, The symptom that is common to Ebola, Typhoid and Malaria
n E = 3, The symptom that is common to only Ebola
n T = 5, The symptom that is common to only Typhoid
n M = 4 , The symptom that is common to only Malaria

5.2 Venn Diagram

From the Venn diagram, the following deductions were made:
Probability that the common symptoms for Ebola, Malaria, Typhoid will occur is 1.
Probability that the common symptoms for Ebola and Malaria is 1.
Probability that the common symptoms for Ebola and Typhoid is 1.
Probability that the common symptoms for Malaria and Typhoid is 3.
Probability that the common symptom for Ebola only will occur is 3.
Probability that the common symptom for Malaria only will occur is 4
Probability that the common symptom for Typhoid only will occur is 5.

6.0 Conclusion

In this work, a mobile base expert system for the diagnosis of Ebola Virus Diseases (ES-EVD) was proposed mainly to achieve effective and reliable access to mobile Android phone forthe diagnosis of EVD. With experimentation carried out, it is believed that a real life implementation of this proposed application will assist towards improving in the diagnosis and treatment of EVD.

7.0 References

[1] Wang Y, Zhuguo L. Dai Q. (2014). "A highly immunogenic fragment derived from Zaire Ebola virusglycoprotein elicits effective neutralizing antibody" volume 189, 30 August 2014, Pages 254-261.

[2] Yang L, Sanchez A., Ward J., Murphy B., Collins P.L. and Bukreyev A. (2008). "A paramyxovirus-vectored intranasal vaccine against Ebola virus is immunogenic invector- immune animal. *Virology*, Volume 377, Issue 2, 1 August 2008, Pages 255-264.

[3] http://wwhttp://www.cdc.gov/vhf/ebola/outbreaks/2014-west-africa/case-counts.htmlw.cdc.gov/vhf/ebola/outbreaks/2014-west-africa/case-counts.html. Accessed on 16 October, 2015.

[4] Ahmed I M, Mahmoud A M, Aref M, Salem A. "A study on Expert Systems for Diabetic Diagnosis and Treatment" Recent Advances in Information Science, Volume 14, Page 363-367.

[5] Bausch D.G, Bangura. J., Garry R.F, Goba A., Grand D., Jacquerioz F.A and McLellan S.L (2014) "A tribute to Sheik Hummarr Khan and al the healthcare workers in West Africa who have sacrificd in the fight against Ebola Virus Disease: Mae we hush. Antiviral Research, Volume 111, November 2014, Pages 33-35.

[6] Masizana-Katongo A.N, Leburu-Dingalo T.K. and Mpoeleng D. (2009). "An Expert System for HIV and AIDS Information" Proceedings of the World Congress on Engienering 2009 Vol. 1, WCE 2009, July 1-3, 2009, London, U.K.

[7] Abdelhamid Y and El-Helly M. (2013). "A New Approach for Developing Diagnostic Expert Systems on Mobile Phones" Communicatons in Information Science and Management Engineering Aug. 2013, Vol. 3 Iss. 8, Pp, 374-384.

[8] Ali S.A, Saudi H.I (2014, March 11). "An expert system for the diagnosis and management of oral ulcers". *Tanta Dental Journal*, Volume 11, Issue 1, April 2014, Pages 42-46.

[9] Bah E.I, Marie-Claire M.D., Tom Fletcher M.D. and Shevin T.J (2014). "Clinical Presentation of Patients with Ebola Virus Disease in Conakry, Guinea. *The new England Journal o f Medicine* (N Engl. J. Med.) 2015; 372:10-17, January 1, 2015, Page 40-46.

[10] Ghadirli H.M and Rastgarpur M. (2012). "AnAdaptive and Intelligent Tutor by Expert Systems for Mobile Devices" International Journal of Managing Public Sector Information and Communication Tehnologies (IJMPICT) Vol. 3, No. 1, September 2012.

[11] Guidances/default.htm., w. (2013). Mobile Medical Applications: Guidance for Industry and Food and Drug Administration Staff. In *Mobile Medical Applications: Guidance for Industry and Food and Drug Administration Staff* (pp. 4-43). Document issued on February 9, 2015.url:http://www.fda.gov/downloads/medicaldecivces/…/UCM263366.pdf

[12] Patel M. Patel A. and Virparia P. (2013). "Rule Based Expert System for Viral Infection Diagnosis". International Journal of Advanced Research in Computer Science and Software Engineering, Volume 3, Issue 5, May 2013. ISSN: 2277 128X.