

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

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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.

Introduction

Ebola disease is a hemorrhagic fever due to a virus of the same name of the *filoviridae* family and of the *Ebolavirus* genus. There are 5 species of the virus: Zaire ebolavirus, Sudan ebolavirus, TaiForestebolavirus, Bundibugyo ebolavirus (BDBV) and Reston virus (RESTV), respectively [1]. 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 from an infected person, biological fluids or cadavers. The virus is contagious. Aerosolized EBOV is responsible for the fatal infections in monkeys hence; the virus has a tendency and strong potential for bioterrorism [1-3]. "The development of a vaccine against EBOV based on inactivated viral particles, purified antigens, and other components were protective in rodents but were not protective or poorly protective in non-human primates" [3]. "Attenuated vectored vaccines and virus-like particles proved to be protective in non-human primate models. Human influenza virus type 3 (HPIV3) is a common pediatric respiratory virus. HPIV3 is a member of family *Paramyxoviridae* and is a single negative-sense strand of genomic RNA of 15,462 nucleotides" [2]. The outbreak of Ebola Virus Disease is having monumental effect across the African continent. At least 3000 people have been infected with over 1500 death recorded. Over one hundred health care workers have been infected [4].

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

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

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 seven children. Ever as a young boy he envisioned a career in medicine, addressing himself frequently as "doctor," somewhat to the chagrin of 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 Sierra Leone. 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 World Health Organization Director-General declared this outbreak a public Health Emergency of International Concern [9].

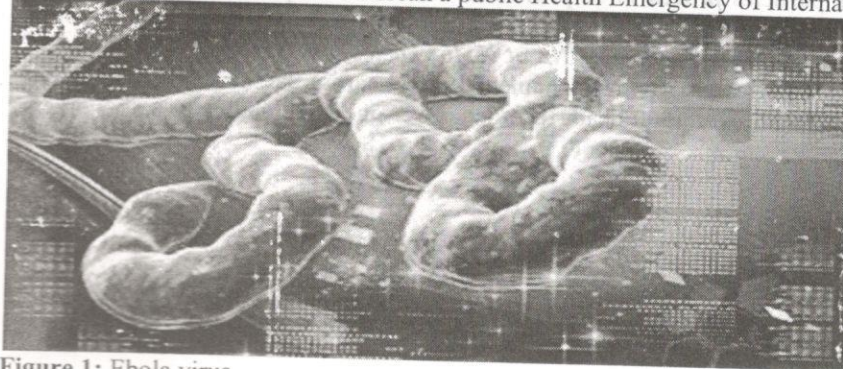
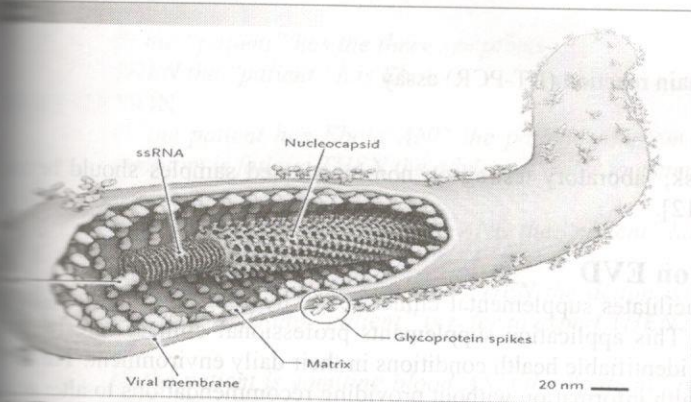


Figure 1: Ebola virus  
Source: Google image



Figure 1: People infected with hemorrhagic rashes all over the body. People infected with EVD. Google Image



The structure of Ebola Virus. Google Image

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

**Statement of the Problem**

Health is fundamental to the growths and development of any society. If health is to be guaranteed, adoption of ICT is being over-emphasized. It is as a result of the prevalence of Ebola in some African countries that a mobile application for diagnosis 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 its accessible, the treatment and diagnosis of the virus and make appropriate recommendation where necessary.

**Literature Review**

Ebola is an enveloped, non-segmented, negative-sense RNA virus 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 West and central Africa and Philippines [10]. A total of five Ebola virus sub-types have been discovered, which are Zaire ebolavirus (ZEBOV), Sudan ebolavirus (SUDV), Taï Forest ebolavirus (TAFV), Reston ebolavirus (RESTV), and Bundibugyo ebolavirus (BDBV). Among these subtypes, Zaire ebolavirus and Sudan ebolavirus are the most toxic subtypes with high mortality and infectiousness. Currently, no effective treatments and licensed vaccines are available for EBOV [11].

Ebola virus (EBOV) causes sporadic outbreaks of severe hemorrhagic fever in the rain forests of Central Africa with a fatality in humans of up to 88% for species Zaire. The virus is transmitted by contact with infected patients or fluids and is usually transmitted 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 20,000 people infected and more than 1500 deaths as well as untold economic, societal, and emotional impacts on the affected countries and inhabitants. Hundreds of healthcare workers in Sierra Leone, Liberia, Guinea, and Nigeria have been 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 medical 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 more readily available means to fill these gaps identified, and cater for the needs of the people in this part of the world [8].

### 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 patients to 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 discontinue previously prescribed treatment. It is a mobile application that provides easy access to information related to patient's health conditions or treatments – This application uses a patient's diagnosis to provide a clinician with best practice management 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 or asthenia?
- 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 common infectious diseases. Confirmation is via detection of viral nucleic acid by the polymerase chain reaction (RT-PCR). Negative results mean the patient is free of Ebola Virus. Positive results mean the patient is not free of Ebola Virus. This sequence of events takes place in the body system of the Ebola patient are taken into consideration in the design of ES-DEV application.

**Ebola Symptoms and Signs**

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

**Rules for Knowledge Representation for Ebola Virus**

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

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

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

REPRESENT RELATIONS, RECOMMENDATIONS, DIRECTIVES, STRATEGIES AND HEURISTICS:

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"

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

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

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

**RESOLUTION**

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

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

IF the patient has Ebola THEN the action is positive

**Input and Output Interface Designs**

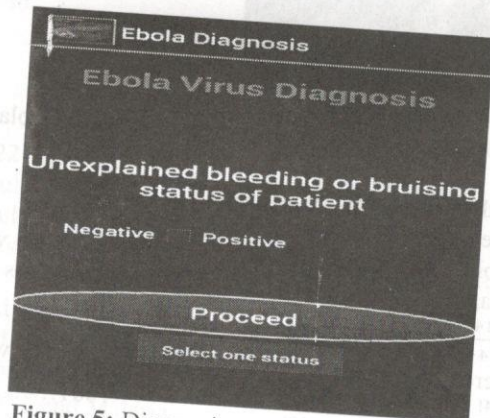
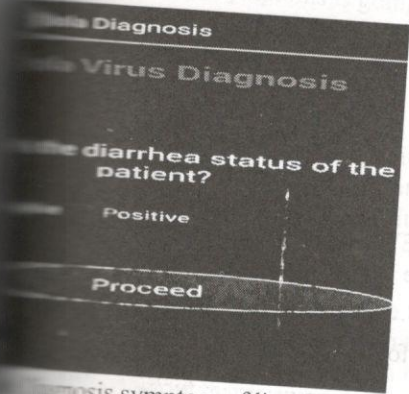


Figure 5: Diagnosis symptom of bleeding

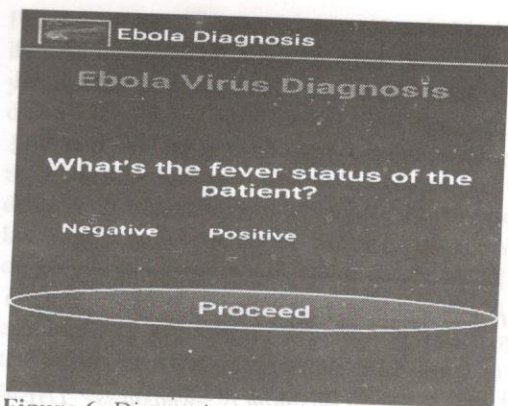


Figure 6: Diagnosis symptom of fever

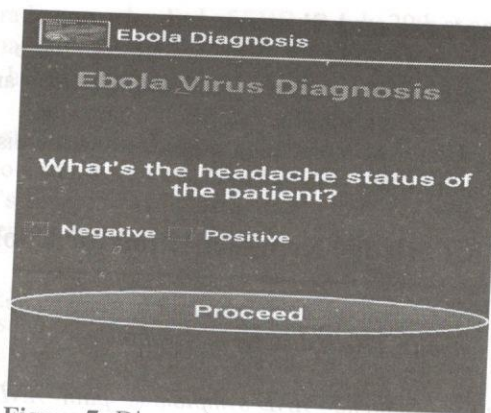


Figure 7: Diagnosis symptom of headache

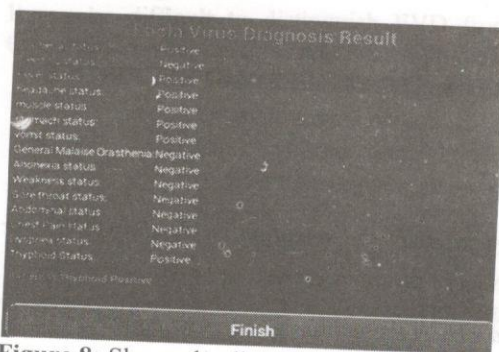


Figure 8: Shows the diagnosis result  
 Description: This result shows all the diagnosis disease is Thyphoid

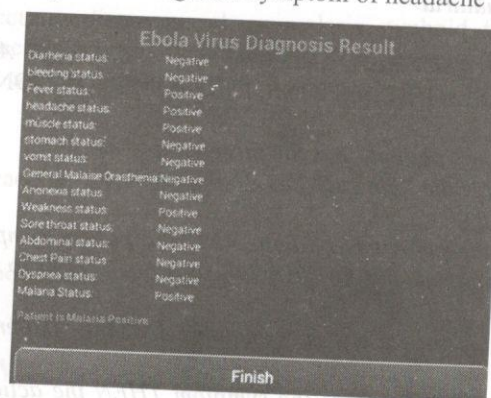


Figure 9: Shows the diagnosis result  
 Description: This result shows all the diagnosis disease

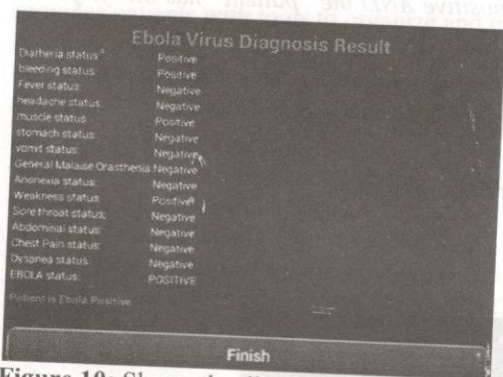


Figure 10: Shows the diagnosis result  
 Description: This result shows all the diagnosis symptoms of Ebola Virus

**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:

$$C_{SE} = \frac{n!}{r!(n-r)!} = \frac{14!}{3!(14-3)!} = \frac{14 \times 13 \times 12 \times 11!}{6 \times 11!} = 364 \dots \dots \dots (i)$$

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

$$C_{SM} = \frac{n!}{r!(n-r)!} = \frac{14!}{4!(14-4)!} = \frac{14 \times 13 \times 12 \times 11 \times 10!}{24 \times 10!} = 1001 \dots \dots \dots (ii)$$

For Typhoid, there are five strong indicating symptoms

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

comes for the sequence of event that may arise before a person could be pronounced as Ebola patient =  $2^{14} =$

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

with four strong indicating factors has  $\frac{1}{CS_M} = \frac{1}{1001} = 0.000999$

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

probability that the chosen 3 symptoms being positive will result to Ebola therefore is  $\frac{364}{16,384} = 0.0222168$ , the

that the chosen four symptoms being positive will result to Malaria =  $\frac{1001}{16,384} = 0.061609619$ , the probability

chosen 5 symptoms being positive will result to typhoid =  $\frac{2002}{16,384} = 0.12219238$

common symptom for Ebola, malaria and typhoid, there is  ${}^{14}C_1 = 14$  combinations. Hence,

probability that the common symptom for Ebola, malaria and typhoid will occur.

$\frac{1}{14} = 0.00085449$  and finally, the possible Ebola outcome =  ${}^{14}C_3 + {}^{14}C_4 + {}^{14}C_5 + \dots + {}^{14}C_4$

**Statistical Analysis**

recalled that there are fourteen symptoms of Ebola Virus with two possible outcomes: positive (1) or negative (0)

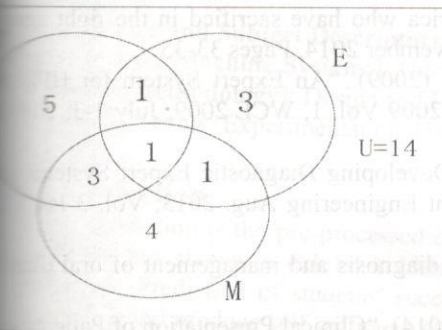
showing:

Ebola Virus

Malaria

Typhoid

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



Venn diagram for Ebola, Malaria and Typhoid

that one of these symptoms is going to be present;

0.00274725

0.000999

0.0004995

0.0004995

that a chosen 3 symptom being positive is 0.0222168.

that a chosen 4 symptom being positive will result to malaria is 0.06109619.

that a chosen 5 symptom being positive will result to malaria is 0.12219238.

Typhoid, E represents Ebola and M represents Malaria. The following relationships were established for the

The symptom that is common to Ebola and Typhoid

The symptom that is common to Ebola and Malaria

The symptom that is common to Typhoid and Malaria

The symptom that is common to Ebola, Typhoid and Malaria

The symptom that is common to only Ebola

The symptom that is common to only Typhoid

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 to achieve effective and reliable access to mobile Android phone for the diagnosis of EVD. With experimentation it is believed that a real life implementation of this proposed application will assist towards improving in the treatment of EVD.

## 7.0 References

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