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Proceedings of the 15th European Conference on e-Government

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18-19 June 2015

Edited by

Carl Adams
University of Portsmouth, UK

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Contents

Improving Rural Healthcare Delivery in Nigeria using Distributed Expert System Technology

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Abstract: Provision of adequate healthcare for the citizens is the responsibility of governments. This involves recruiting qualified medical personnel, and providing quality medical services nationwide. The ratio of medical doctors to patients in Nigeria is 1:6,800, which means the citizens are grossly underserved in terms of medical services. Hence, there is need for new strategies that will ensure that more citizens access healthcare services, particularly people in the rural areas. In this paper, a framework for an SMS-based expert system for rural healthcare delivery is proposed, which takes advantage of the wide coverage of telephony services in the rural areas in Nigeria. A preliminary evaluation of the expert system for pulmonary heart disease that was developed reveals that it emulates human expert capability at a reasonable level. This makes it suitable for deployment on a national scale to cater for the shortage of medical practitioners particularly in the rural areas.

Keywords: Medical services, healthcare delivery, expert system, mobile technology, e-governance, Fuzzy logic

1. Introduction

One of the responsibilities of the government to their citizens is the provision of adequate and reliable health care services. The prerequisite for a reliable healthcare provision is recruitment of qualified and experienced medical personnel to deliver quality healthcare for the citizens. This, however, might not be realistic in Nigeria, where currently there is a poor doctor to patient ratio. In 2012, there was doctor to patient ratio of 1:3500 as against the World Health Organisation (WHO) standard of 1:600 (Onyebuchi, 2012). Again in 2014, this ratio went down to 1:6400 (http://www.nigeriaintel.com/2013/05/03/official-one-doctor-to-6400-patients-in-nigeria/). According to the survey carried out in (Oche and Adamu, 2013) on determinants of patient waiting time in the General Outpatient Department of a Tertiary Health Institution in North Western Nigeria, Sixty-one percent (59/96) of the respondents waited for 90-180 minutes in the clinic. While 36.1% (35/96) of the patients spent less than 5 minutes with the doctor in the consulting room. The commonest reason for the long waiting time in the Nigerian healthcare centres is the large number of patients with few healthcare workers. This shortage of medical practitioners in Nigeria was not because of lack of new medical school graduates but due to economic distress in Nigeria, and this has resulted in the migration of many Nigerian doctors to other countries in recent times (Onyebuchi, 2012).

In (Emelumadu and Ndulue ,2012), the analysis from an urban centre was reported such that out of 350 patient sample, 38% of the sample sought care at General Outpatients Department (GODP) in order to receive medical attention by qualified doctors and nurses, 36% desired efficient and quality service and 14.5% went there for cheaper and affordable drugs. The patient waiting time was also analysed and it was reported that 25 % of the sample waited for up to one hour to register, while 38% spent more than an hour before being attended to by a doctor.

With these statistics, it is obvious that Nigerian citizens are grossly underserved in terms of medical services, especially in the rural areas of Nigeria where 53%of the entire national population of more than 160 million live (http://data.worldbank.org/indicator/SP.RUR.TOTL.ZS.). In terms of accessibility to good medical care, the rural populace is far behind. The main reasons for this is that most medical practitioners are not ready to stay in the rural centres due to poor development and infrastructural facilities like bad roads, poor water, lack of good accommodation, lack of Internet facility and so on. Hence, there is need for new strategies that will ensure that more Nigerian citizens have easy access to healthcare services, particularly those in the rural areas. In this paper, a framework for distributed expert system initiative for rural healthcare delivery is proposed. The framework will enable rural dwellers to send their requests for medical care/attention via their

mobile phones using the Short Messaging Service (SMS). They will in return obtain a help response from an expert system or a remotely based medical personnel in form of diagnosis or medical advice also through their mobile phones. The proposed approach, which takes advantage of the wide coverage of telephony services in the rural areas of Nigeria will ensure that more people in the rural areas gain access to lightweight medical services via a distributed network of expert system technology. This initiative will help to minimize the effect of shortage of medical personnel in the rural areas of Nigeria.

The rest of the paper consists of the following. Section 2 presents a review of some important while Section 3 describes the proposed framework. Section 4, provides the justification for the adopted expert system architecture, while the paper is concluded in Section 5with some recommendations.

2. Rural Healthcare in Nigeria

For every citizen in Nigeria, living in the rural or urban area quality health is a fundamental right. Sound health and medical fitness is a goal of every human being (Asabere, 2012). For a large number of citizens of a country to be unhealthy will be a minus and disastrous for such a country. This is because it will adversely affect the economy and cause mass migration of experts in various fields (Asabere, 2012). The target of primary healthcare in Nigeria was to make healthcare accessible to all citizen by the year 2000 (Asabere, 2012). This goal is yet to be a reality in Nigeria and it seems it is not going to be, despite the fact that the Nigerian government had established healthcare centres in both rural and urban centres. Regardless of these provisions, about two-third of Nigerian population are still underserved for so many reasons. In (Ruxwana et. al., 2010) a survey on ICT applications as e-health solutions in rural healthcare in the Eastern Cape province of South Africa was carried out using questionnaire. From the report it was obvious that so many factors are limiting the use of ICT application in the rural areas. These factors are common to all African countries. Some of the challenges of rural healthcare in Africa include lack of Internet connection, unreliable equipments, and lack of computer skills. According to (Abdulraheem et. al., 2012)), the primary healthcare in Nigeria is currently catering for less than 20% of the potential patient. While most primary healthcare facilities provided by the government are no longer in use because of poor maintenance, and some are obsolete. More than this, as against the World Health Organisation (WHO) standard of 1:600, the ratio of doctor to patient in Nigeria is 1:3500 as of 2012 and in 2014 it went down to 1:6400 (Onyebuchi , 2012). With these factors, it is obvious that there is need for a better means of providing healthcare services for rural centres

2.1 Expert System

An expert system is an intelligent computer program that accepts input via the user interface and uses knowledge in the knowledge base to make logical conclusions through the inference mechanism, in order to solve problems that are difficult enough to require significant human expertise to solve(Turban and Aronson, 2001)(Feigenbaum, 1982).Therefore, typically a medical expert system is an intelligent system that accepts patients' complaints via the system's user interface and uses the knowledge in the knowledge base through the inference mechanism to give diagnosis, and drug prescriptions to the patient. In order to enhance the capability of medical expert system the application of fuzzy concept is very important. Medical expressions have more linguistic terms than crisp terms. For example, it is not enough to know that a patient has migraine, but it is important to know the degree of it, whether it is mild, high or severe. This kind of scenario creates the need for fuzzy logic. Also because of the quantitative nature of medical data, the application of fuzzy logic will prevent the Sharp Boundary Problem (Verlinde et. al., 2006)(Oladipupo et. al., 2010), where some values are overestimated and some underestimated, when describing a patient's condition. This will improve the overall efficiency of the expert system. The fuzzy expert system architecture is shown in Figure 1.

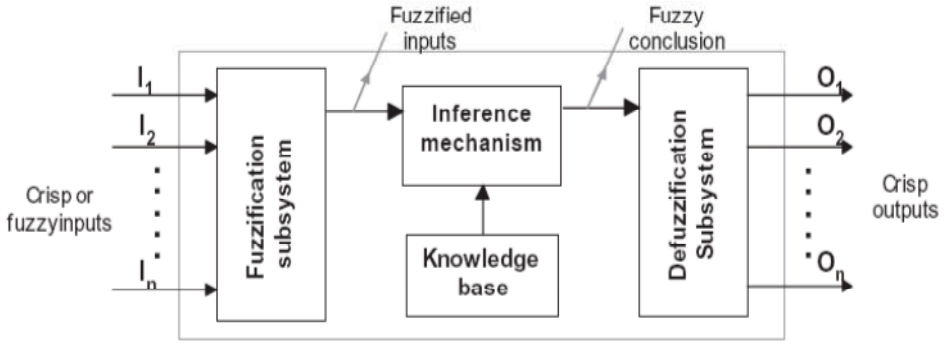

Figure 1: Standard Fuzzy expert system Architecture (Aly and Vrana, 2006)

The efficiency of a Fuzzy Expert system depends upon how effectively one executes the fuzzy reasoning, using the knowledge stored in form of rules and facts (Aly and Vrana, 2006)(Song et. al., 2009). To this effect, the mode of acquiring the knowledge is very important in determining the efficiency of the system. This process is called knowledge acquisition. Since there is a shortage of experienced doctors in Nigeria versus the national population, It is crucial to seek how to maximize the available experts.

In the medical domain, expert systems have been widely used for diagnosing different type of diseases. A novel fuzzy-neural based medical diagnosis system was designed in (Moein et. al., 2008). For diagnosing the Hepatitis B intensity rate a fuzzy expert system was designed in (Neshat and Yaghobi, 2009). The authors in (Saritas et. al., 2003) described a fuzzy expert system design for diagnosis of Prostate Cancer. The study revealed that it was not quite possible to diagnose prostate cancer fully based on only ultrasonography and image processing. There is need to develop a rule-based expert system that uses laboratory and other data and simulate expert-doctors' behaviour. A diagnosis system for diabetics was developed in (Khan et. al., 2014).An expert system for first aid treatment was described in (Khan et. al.,2014). In (Allahverdi et, al., 2007) a fuzzy expert system for determination of Coronary Heart Disease was designed. All possible rules were evolved in the knowledge base using standard rule-base formulation. The experimental report shows 98% accuracy of the system compared to domain expert. In order to enhance the expert system comprehensibility, compactness and reduce rule base unwieldiness, in (Olufunke et al., 2012) a fuzzy association rule mining expert system (FARMES) for determining coronary heart disease was designed using automated fuzzy association rule mining expert-driven (FARME-D) knowledge acquisition approach. The system was evaluated and the report revealed 100% accuracy of the system with 27% rule reduction, and saves 20% of memory size utilized by standard rule base formulation in (Allahverdi et. al., 2007). With the good result of this evaluation, the expert system framework proposed in this paper is based on FARMES architecture that was proposed by the authors of this paper in (Olufunke at. al., 2012).

2.2 Mobile Technology for Rural Healthcare

For more than a decade the deployment of applications has move drastically toward mobile technology due to new innovation in mobile technology, and reasonable improvement in telecommunication service. In literature, different platforms of communication between the patient and the expert system have been used, such as web, desktop (application system interface) and Mobile platform (Asabere, 2012)(Allahverdi et. al., 2007)(Upkar, 2006) . SMS is an acronym for Short Message Services via a mobile system. SMS platform is more realistic in the rural area because of different constraints, such as lack of Internet facility and inability to use computer by the rural people. More importantly, most expert doctors are not ready to leave the urban centres for the rural areas. Therefore, in order to take advantage of the wide coverage of telephony services in the rural areas in Nigeria,it is more realistic to use the SMS platform. In (Guirong and Daoliang, 2001), a SMS-based expert system was proposed to compensate for lack of computer and the inconvenient use of web-based diagnosis. The SMS platform was used as the input and output media for the expert system. The system was developed using Java. In (Khan et. al., 2014) an SMS based first AID Treatment management system for rural area of Baltisan in Pakistan was proposed. For health institutions in Ghana a mobile expert system was proposed in (Asabere, 2012). Most of these reviewed expert systems were evaluated by the authors and were reported as working at a high level of accuracies when compared with the performance of domain experts.

Therefore, since expert system technology is well established, it has good potential to help to alleviate the challenges of shortage of doctors in the rural areas in a country like Nigeria.

3. The Proposed Framework

In this paper, a Short Message Services (SMS) based expert system Framework is proposed to enhance rural healthcare delivery in Nigeria. The framework has three major actors. The patient, the expert system and the remote doctors. The patients are the people that need medical assistance in the rural area. The expert system is the server-based computer that stands in the place of a doctor to diagnose and prescribe for the patient. The third in the chain are the remote medical practitioners in the cities. The proposed framework adopted a Fuzzy Association Rule Mining Expert System model (Olufunke et. al., 2012) with distributed knowledge base. The knowledge is acquired by an automated FARME-D approach (See section 4) and from remote doctors in order to maximize available experts, by making use of experiences of experts that are stored a priori. The typical deployment architecture of the proposed system framework is shown in Figure 2.

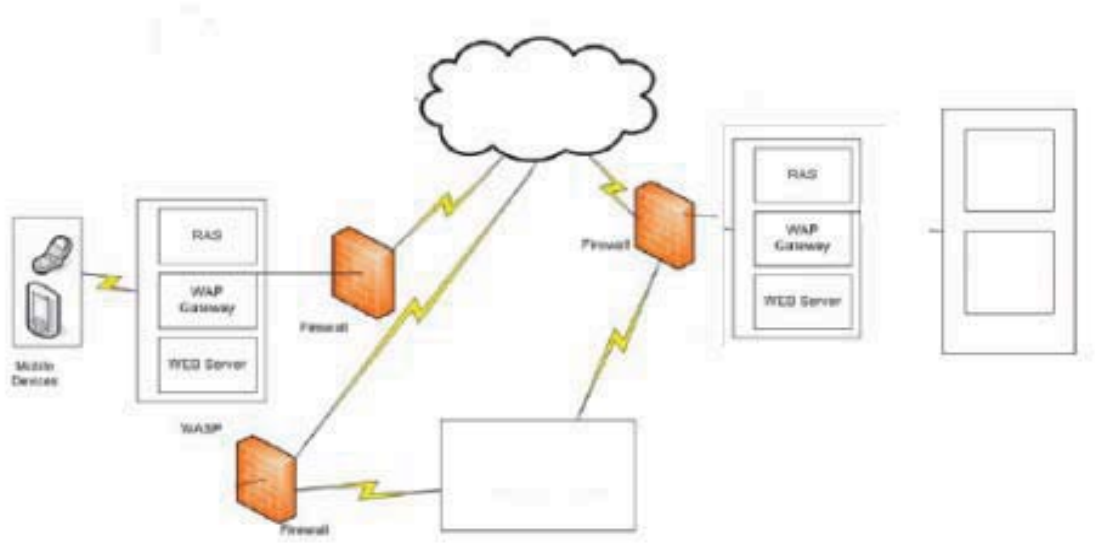

Figure 2: The proposed Framework for SMS based Expert System

The Framework is about constructing a system that can allow patients to register and send their symptoms or complaints via SMS to the expert system. The expert system will extract the SMS message and also send it to the remote doctors (registered doctors) to submit their diagnoses to the knowledge base as facts if there is any one available. The system will then reason through the knowledge base in order to send the diagnoses, and prescribe appropriate drugs for patients via SMS. In case the patient still has further complaints or the message is unclear, the patient can communicate via SMS with the Expert system. The patient will only have to travel to see the physical doctor if there is an emergency, and this will be sent to the patient via SMS. The expert system server could be placed in a central location such as the Local Government Healthcare centre, where the network and Internet services have been provided, which is uninterruptedly for 24 hours, and probably, where there are medical practitioners.

The deployment architecture shown in Figure 3 consists of SMS gateway to facilitate communication between patient and expert system server, and doctor and expert system server and vice-versa when text messages are sent. GSM coverage is a key component and security firewalls to ensure protection of system resources. FARME-D is an important component of this architecture. It accepts the input symptoms from the patient, as well the doctors' suggestion based on the symptoms and give appropriate diagnosis and prescription as an SMS response to the patient.

4. Justification of the FARMES Architecture

FARMES is an expert system based on automated knowledge acquisition approach called FARME-D. Figure 3 shows the FARMES architecture. FARME-D was able to evolve a comprehensible,compact and unwieldy

knowledge base with 27% rule reduction while 100% accuracy is maintained, and saves 20% of memory size utilized by standard rule base formulation (Verlinde et. al., 2006). FARME-D knowledge acquisition uses machine learning approach to evolve knowledge from existing past experience on the field, stored in a medical repository and allows for instance update of the knowledge base as new experience is acquired by the domain experts. The knowledge acquisition approach was able to breach the gap of medical expert scarcity and make room for dynamic knowledge base (Olufunke et. al., 2012). From the expert system point of view (FARMES) in (Olufunke et. al., 2012) a preliminary evaluation of the expert system performance for Coronary Heart disease risk determination was reported. The report reveals that it emulates human expert capability at a reasonable level, which makes it suitable for deployment on a national scale to cater for the shortage of medical practitioners, particularly in the rural areas. The system also make the best use of past expert experience in the domain so that even when the trusted hands in the field are dead their knowledge can still be speaking after them. The reliable results obtained from the evaluation of FARMES make it suitable for application in the context of supporting rural healthcare initiative in Nigeria.

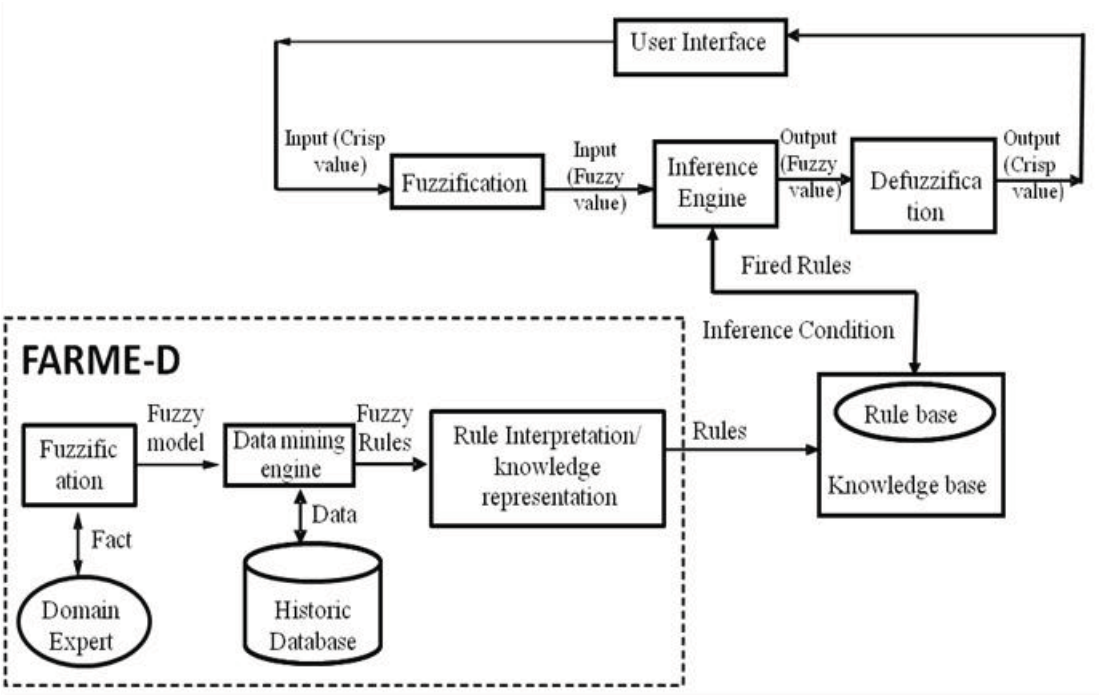

Figure 3: Fuzzy Association Rule Mining Expert system (FARMES) architecture

5. Implementation of the Framework and Benefits

In order to implement this framework in such a way as to enhance the health delivery in Nigeria, the Government has to make provision for the following: IT infrastructure in all local governments, computers with preloaded expert system application,power backup units, computer network equipments, Internet (optional), GSM coverage in all rural areas, a good management and supportive policy, and medical personnel to monitor the servers. There should also be provision of alternative power supply, since the serve must be on at all times. A free-to-send-SMS messages to and from the Expert system line from prominent mobile service providers. Above all, proper awareness should be created within the rural community about the healthcare provision, how to use it, the advantage and disadvantage of using the system.

In terms of benefits, the proposed distributed expert system framework offers the following:

- It will provide a potentially efficient and efficient way to tackle the problem of shortage of medical doctors in the rural areas in Nigeria.
- It offers a convenient way for rural people to access healthcare services.
- The platform makes it possible to share the expertise of the few available medical doctors for the benefits of many people in the remote areas.

- The platform makes it possible to share the expertise of the few available medical doctors for the benefits of many people in the remote areas.
- It creates a relatively cheaper way out of the national problem of poor ration of doctor to patient. The unreached rural community will have access to several medical experts at little or no cost, and within reasonable time.

6. Conclusion

In this paper, a framework for improved rural healthcare delivery has been proposed. The framework is SMS-based and uses the expert system technology to cater for the shortage of experienced medical practitioners in the rural areas of Nigeria. The proposed framework relies on a tested expert system architecture called FARMES, which is a product of a previous research effort that have been adjudged efficient in the diagnosis of coronary heart disease risk. Therefore, the FARMES can be adapted to generate diagnosis for other diseases. In conceiving the framework, critical issues such as insecurity, lack of regular power supply, Internet and the like were considered in order to evolve a robust framework that combines human expertise and credible expert system capability to support the administration of rural healthcare in Nigeria. If this framework is adopted there will be a great relieve in time wastage by the patient in the hospital in order to do registration and to see the doctor. Also it will enhance the rural settlement citizens' accessibility to heath care facilities made available by the government. This concept can also be extended to other developing countries.

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