

# Analyzing the Role of Data Mining in Design and Development of an EBM Enabled Open Source APMIS

Mohammad Taha Khan, Shamimul Qamar, Prashant Kumar Moharana

**Abstract:** *This research has investigated open source software solutions and clinical data to provide a low cost improved advanced pathology management information system [APMIS]. This APMIS facilitate the Evidence Based Medicine (EBM) to provide accurate and error-free diagnosis. In the most of developing countries healthcare is mainly government sector service, due to the limited available resources most of the hospitals are lacking in providing the best services at time. Finance is one of complex issues in the development of an exhaustive healthcare system. Open source software solutions can be proved as a best alternative for achieving the required services at very low cost. While treating a patient any poor clinical decision is unacceptable as it can lead towards a disastrous situation where life of a patient is on stake. Healthcare providers must go for employment of computerized management information (MIS) and/or IT based decision support systems (DSS). These systems use to generate huge amount of data. A hidden wealth of information use to be available with these data and it can be very supportive in process of clinical decision making. How we can support decision making in healthcare by extracting and utilizing useful information from these data is one of the main themes of this research.*

**Keywords:** *Big Data, EBM, Knowledge Discovery and Data Mining (KDD), Decision Support System, e-Healthcare, Management Information Systems, Open Source Software.*

## I. INTRODUCTION

Healthcare sector is one of the rapidly growing and second largest service sectors of the world. According to researchers and academics estimations the total contribution of healthcare sector in gross domestic product (GDP) of developed countries is 10% of total GDP of a particular country. On the other hand in case of developing countries like India healthcare sector started growing at alarming rate. Research suggest in India the total worth of healthcare sector can reach up to US \$280 billion in the year 2020 (Cognizant 20-20 Insights).

In year 2015 it was predicted to reach US \$160 billion by end of year 2017 [6] which were currently of US \$100 billion at that time.

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Above all data suggest that healthcare sector can play a vital role in improving the economy of any nation. In modern days healthcare is greatly impacted by Information Technology (IT). Globalization, governmental policies and legislations and intense competition are some of major driving factors of healthcare which makes this industry complex. Effective and comprehensive management of medical information and its dissemination among different stakeholders such as government, hospitals, and patients can be achieved through proper use of Health Information System (HIS). Information and communication technologies (ICT) has enriched healthcare by providing the components like telemedicine, Picture Archiving and Communication System (PACS), and Healthcare Information Systems [20]. Use of ICT has made healthcare more accessible and interactive. Government Hospitals are an integral part of the comprehensive health services in developing countries like India and thus it is necessary to make these systems efficient. The construction as well as operating and maintaining hospitals is difficult and expensive process and therefore, it is essential that information technology tools and systems are applied to provide excellent quality care to patients, while striving for innovation and improving business operations. If we exclude the private clinics and nursing homes there are an estimated 14,000 hospitals in India, however apart from corporate hospitals very few Government hospitals are using one or other Hospital Information system. Higher cost of development, customization and deployment is major barrier in adaptation of HIS in any existing healthcare setup. E-Health is basically use of information technology and electronic communication technology in area of healthcare for the purpose of revolutionizing the healthcare organizations and the way healthcare operations work. To improve the healthcare outcomes it is necessary to provide high quality service by healthcare sector which means diagnosing correctly and providing efficient treatment accordingly. Any failure in correct diagnosis will have negative outcome and can lead to negative impact on patient. These types of errors are not acceptable in healthcare. Hospitals always look for cost reduction of medical tests. Computer based information and decision support systems can be proved as one of the best tool to achieve the goal of cost reduction. The use of patient data for decision making process is very rare in developing countries.

Effective and proper use of these data can help in avoiding the medical errors and reduce the cost significantly. A huge amount of data is getting generated and collected by healthcare organizations.

This situation raise a very basic question regarding utilization these hugely generated data in clinical decision making that how the useful information for decision making can be extracted from these data? One of the major aims of this research is to answer the above question. The availability of large quantities of data has pushed a new evolving area in field of information technology. The era of open information is currently underway. According to one research conducted by IBM, in year 1992 globally total 100GB of data was getting generated per day which was increased up to 50000GB per second in year 2017. More than 90% of today's total collected data has been generated in last 10 years due to mass adaptation of information and communication technologies worldwide [9]. Datasets for business, clinical, medical, geographical and image data have been created today which cover all the areas of human endeavor. Knowledge extracted from these data can be proved a very useful resource to improve decision making in healthcare. In the era of electronic healthcare Evidence Based Medicine (EBM) has been recognized as one of the best approaches to support clinical decision making and improve the healthcare other processes. EBM equipped a clinician or user with best available evidences for decision making at point of care of individual patient. EBM has provided a new direction of care to modern healthcare. The primary task of EBM can be define as proper use best available evidences derived from medical data and records to avert, analyze and propose medical treatment of a disease in an efficient manner [20]. To apply medical evidences timely and effectively external as well as internal knowledge are required. External knowledge will fail if some gap is there with patient's health condition. To fill up this gap and avoid the errors internal expertise is required.

This paper investigates the Care2x, one of the most used open source HMIS and use of data mining to develop a low cost Advance Pathology Management Information System (APMIS) which is equipped with EBM support.

## II. OPEN SOURCE SOFTWARE FOR HEALTHCARE IN CONTEXT OF DEVELOPING COUNTRIES

This section addresses the benefits, issues and complexities of using the open source for healthcare in Indian scenarios. The term open source gaining popularity day by day as the use of internet is increasing. Open source software comes with its own philosophy, open source philosophy gives the permission to users to modify and enhance the software according to his or her own needs and requirements. Furthermore, he/she can distribute it without facing any legal battles. The source code of the product is available to the user efficiently.

Acceptability of open source software is increasing because of several reasons. Firstly, it is economical and readily available, it can be shared and distributed with other users and the source code is available to all users, which increases customizability and scalability [8]. Finally, since it has large number of users, the support available on the internet is diverse and wide ranging.

Since the source code is readily available, it can

be modified by the end user according to his/her needs and requirements. New features can be added to improve it. In the same manner, errors can be corrected by modifying it.

Hardware and software are capital goods for an organization. The availability of information technology at economical price suggests that software prices are equal to zero, thus, allowing organizations to implement it to enhance its business operations and processes. Demand for healthcare services rapidly growing in India. So there is a great need to make some efforts to provide low cost solutions for health care organizations.

### A. Open Source Software is something more than source code

Open source software is based on the principle that it is free and readily available. There is little misconception regarding open source software. People generally thinks that only difference in open source software and other software is availability of source code, but the reality is open source software is much more that only source code. To understand the open source software, it is essential to understand its main characteristics, which are discussed as follows:

- Software licensing model. Open source software has a free license and it is readily available to users. Licenses used have different terms and conditions. Healthcare organizations are required to familiar themselves with the terms and conditions and specifications of the license, which they would use or modify according to their own needs and requirements.
- Political philosophy. The philosophy of the open source software is based on the philosophy that the product can be used freely by any individual and can be modified or distributed. From healthcare community, the concept of sharing the software is compatible with high quality medical care. However, it should be noted that the open source software is not always available freely. Some of the software is on sale but the code is available with it. Figure 1 shows the basic development model of open source software.

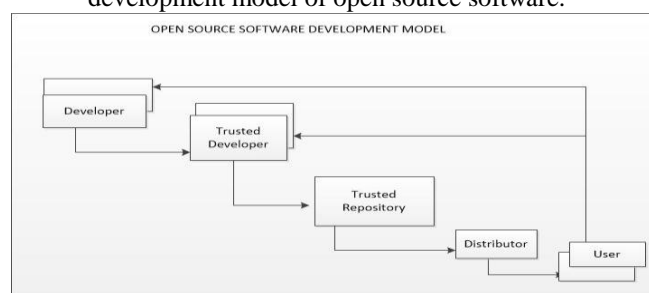


Fig. 1. Open source software development basic model

### B. Why open source is better alternative for healthcare in developing countries?

The analysis of literature suggests that open source software is easy to use and is available readily, which makes it an attractive option for the healthcare organizations.

Furthermore, hospitals or payers can fully use the software and integrate it within the organization, without the need of additional costs and resources.

Programmers can effectively modify the source code because it is visible and therefore, issues and problems can be identified to make the desired changes. In open source projects, the participants of the community are connected to one another and have mutual aim. Their primary goal is to develop software, which is readily available to all users. The cost of the software development in case of open source software is achieved by providing support, which because of the supply and demand. The main advantage of the open source software is that it has multiple vendors, thus, reducing the dependency on single vendor, which is evident in the case of propriety software. Users can efficiently get the software from any source.

The less dependency on the single vendor makes it ideal for healthcare organizations. It should be noted that the development of software in the next ten years for the healthcare sector would require sophisticated and developed applications along with infrastructure, which would promote EMRs in an efficient manner and would help in ensuring that it can be shared among health information networks at regional and national levels. Thus, vendor-neutral open source platform is considered to be an ideal option for improving healthcare organization efficiency, while at the same time, reducing operational costs and providing high quality, economical medical care to patients and providing them patient oriented care. Empirical research suggests that only 15% of the physicians have employed EMRs at large level [22]. In case of sharing of records, the national network is required to achieve this but this is in the development phase. Research suggests that the implementation of national electronic healthcare information exchange systems with their supporting IT applications and infrastructure can efficiently save \$77.8 billion. However, implementation of such networks would require investment of \$156 billion in the next five years.

Let's have a look on affordability; one of the major advantages of open source software is low cost. If we take the example of some hospitals using open source software like CARE2X and OpenVista generally it costs 60-70 percent less cost as compare to other propriety software [10]. Same time open source solutions successfully address the other major barriers like interoperability and adaptation. The Mirth project is one of the pioneer examples of how open source eliminates the interoperability challenges [23].

### C. Major barriers in adaptation of open source software in healthcare

Smaller healthcare organizations such as clinics, hospitals and healthcare centers do not participate in the development of the software.

They recruit consultants or programmers, who are in-charge of developing or modifying the software. Such organizations adopt open source software because it is economical as compared to propriety software.

The security of the open source software is considered to be a major issue. Some organizations feel hesitation in adopting the open source software due to some wrong perception about open source software security.

It is true that up to some extends malicious individuals get a chance to view the source code and identify the potential

vulnerabilities due to transparent nature of open source software. Drupal and WordPress are two properly managed open source applications which are no less secure than any propriety software product. To make open source software more secure an ongoing maintenance is required. In order to prevent data loss, defacement and unauthorized access these software must kept current. Open source software like WordPress, CARE2X and Drupal are equipped with capabilities and features like login history, version control, CAPTCH validations, SSL certificate compatibility and audit trails along with Kerberos, NTLM authentication and LDAP.

### III. APPLICATION OF DATA MINING TECHNIQUES IN MEDICAL DATA

The goal of this section is to describe how the different data mining techniques are applied on medical or clinical data in order to extract the useful information. Rise in utilization of ICT in healthcare has been already discussed in above sections. Day-by-day use of ICT in healthcare resulting in a rapid grow of medical databases [3][4]. The information rich databases are encouraging the medical as well as IT researchers to use data mining with respect to medical databases to obtain knowledge. Data mining can answer the several unanswered questions such as:

1. For given records of dialysis patients, what are the actions required to be undertaken in order to improve the patient treatment?

2. Chemotherapy, radiation or chemotherapy and radiation together will be more useful to help cancer patient recovery grounding on the patient historical records?

For small data set customary statistical methods are to be used in order to find the data patterns, in case of huge data set these conventional methods cannot work properly. The data mining extracts the hidden patterns from huge amount of data. It facilitates with the automatic pattern identification and more importantly it can work with huge amount of data where traditional statistical methods usually fail to work. Data mining entails the group of techniques it is not a single technique. It encounters the idea behind and finds hidden information which is not visible from outside. Data mining uses group of different techniques and approaches for knowledge discovery purpose. Statistical techniques, visualization, neural networks, machine learning, etc., are the base for the data mining techniques and methods.

▪ Classification: Predictive data modeling is used for prediction. Classification is one of the important tasks of predictive modeling; it predicts the class of any particular data. It classifies the data into predefined classes.

▪ Medical diagnosis is one of the most important areas for application of classification techniques. Based on the patient system it can help in diagnosing the disease. For example one patient having heart problem he may be classified in various heart diseases with help of classification techniques.

Prior knowledge about the data considered is required to apply the classification technique [4].



- Take an example of patient database PD as set of sequences  $(s_1, s_2 \dots s_n)$ ,  $s_1, s_2 \dots s_n$  are values of different attributes  $A_1, A_2 \dots A_n$  of any disease. Patients can be classified in different classes  $CP = \{CP_1, CP_2, \dots, CP_n\}$  based on gravity or specific classification of disease.
- Regression: This is another task which helps predictive modeling in data mining. Major focus of regression is to help in uncovering the exact relationship between two (or more) variables in a given data set.
- Time series analysis: A time series is a sequence of data points recorded at specific time point, most often for period of time. This technique is also use for trend prediction. In healthcare, characteristics and behaviors of a particular disease patient can be predicted and utilized for proper and timely treatment.
- Predictive Modeling: Includes the major tasks like classification, time series analysis and regression which we have already discussed in above section. It determines and provides forthcoming data trends on basis of past and present data values.
- Visualization Technique: are used to represent information through charts, graphs, digital images, and movies and are considered to be a descriptive model of data mining. Interesting subsets of medical data sets can be identified by using scatter diagrams in a Cartesian plane of two medical traits of interest. For instance, interesting subsets related to blood sugar can be found in patients with heart diseases.
- Association Rule: This technique is widely used to help discover correlations in in medical data sets. It can be expressed as " $A_1 \wedge A_2 \dots \wedge A_i \Rightarrow B_1 \wedge B_2 \dots \wedge B_j$ ", that is,  $B_1, B_2, B_3, \dots$  and  $B_j$  turn up with objects  $A_1, A_2, A_3 \dots$  and  $A_i$  in the target data.

**IV. DATA MINING AND WAREHOUSING INTEGRAL COMPONENT OF MODERN EVIDENCE BASED MEDICINE (EBM)**

EBM has been emerged as a new direction in modern e-healthcare. The major task of EBM is proper and efficient use of medical evidences to prevention, diagnosing and medicating diseases. To obtain most reliable evidence for a given disease external clinical expertise and internal clinical expertise are equally important.

In-house and external clinical expertise should be conveniently available to healthcare practitioners. Application of external evidence-based knowledge to the patient is not advisable without tailoring it to the patient's health condition.

In today's health industries, the combination of data warehousing and data mining technologies along with evidence-based medicine provides a new field for application of information and communication technologies. Figure 2 depicts how data flows in an EBM system.

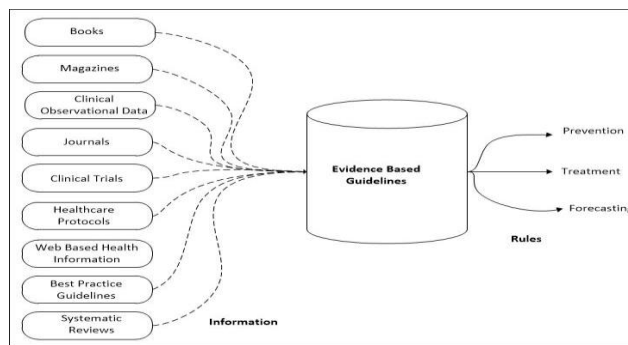


Fig. 2. Figure 2. Data flow in EBM

**A. Practicing Evidence Based Medicine (EBM)**

The major steps followed during practicing evidence-based medicine are listed below (P. J. Devereaux, R. B. Haynes, 2002):

- Formulate proper and relevant questions
- Find the most suitable available evidences
- Evaluate the evidence under real circumstances for utility and validity
- Administer and apply the selected evidence
- Evaluate the performance

**B. Application of Evidence Based Medicine (EBM)**

Some of the applications of evidence based medicine are as follows:

- Making a diagnosis: It helps a clinician in making the right diagnosis.
- Administering appropriate therapy to patients: keeping in view health risks and preference of patient, EBM guidelines will offer different treatments from data-base. One best suited to the patients can be applied.
- Making a prognosis: Having information of various similar cases at hand, clinician can make educated prognosis of a patient's future state of health.
- Clarifying an etiology: EBM provides expert knowledge about the possible causes of a particular medical condition. For example, it may help find the correlation between consumption of nicotine and heart disease.

**V. CASE STUDY: RULES GENERATION USING CLASSIFICATION TECHNIQUES**

This section focuses on explanation of a case study of rules generation by using the data mining on medical data freely available online. To support decision making at time of reporting developed Advanced Pathology Management Information System (APMIS) for this research is loaded with EBM support.

To provide EBM support in APMIS, this developed system is integrated with external evidence sources like Cochrane library and some rules generated by classification algorithms applied on publically available data for breast cancer.

Classification technique of data mining is used for prediction in healthcare. It is helpful in predicting the disease based on symptoms.

Target classes are divided into data samples. Target class for each data points is then predicted. Decision trees are generated by applying classification algorithms C4.5 and C5.0 on publically available breast cancer data, which is considered to be an important aspect of discovering the knowledge. University of Wisconsin Hospitals, Madison (Dr. William H. Walberg) has breast cancer data freely available for research purpose [15]. This online available data is used for the breast cancer prediction for this research. Total 599 cases of breast cancer have been considered in this research. C4.5 and C5.0 support three types of files. Name files provide the name of classes, attributes and attribute values. Data files describe training cases for decision tree generation. Target attribute (a class that can only have one of the two values) has either value 2 (Benign) or value 4 (Malignant) are described by target file. Benign means non-cancerous tumors these tumors do not spread, while malignant means cancerous. Malignant tumors can invade and destroy nearby tissues and spread to other body parts. The values of 2 and 4 are given to class attributes to avoid confusion with values of other attributes. There are several other attributes which can have values from 1 to 10.

**Decision Tree and Rules Generated:**

After using C4.5 algorithm a tree of size 29 with 5 train errors is generated. By 5 train errors indicate that there were five cases where error was noted down after 599 records were run on C4.5.

After pruning to reduce the complexity of classifier and improve the predictive accuracy, tree size is reduced to 17.

**VI. DESIGN AND DEVELOPMENT OF OPEN SOURCE APMIS**

This open source low cost APMIS is deployed at one of the leading hospital UrgentCare in New Delhi, India. Development of APMIS is based on CARE2X customization. Client hospital’s details are shown in following table 1.

Table- I: Details of UrgentCare hospital.

List of Provisions	Totals(in numbers)
Beds	110
Medical departments	5
Diagnostic laboratories	6
Surgical departments	2
Operating rooms	4
Nursing wards	16
Central Pharmacy	1
Central material departments	1

APMIS is used for diagnosis purpose in Histo and Cyto pathologies of client hospital. Complete workflow of Lab is automated with help of APMIS and provide advance features like automatic accession key generation, sample tracking, interesting report management, disposal management, advance record search, role base authorization for security purpose and decision support at the table of reporting. APMIS is simultaneously used at different level by multiple users like doctors, technicians and data entry operators.

To support the decision making, conflict management and avoiding errors at point of reporting Cochrane library and MEDILINE are integrated with APMIS as external source of evidence based guidelines.

**CARE2X:** This is an open source comprehensive healthcare system. The CARE2X development is based on the open source technology Linux, Apache, MySQL and PHP (LAMP) stack [12]. CARE2X provide solution to fulfill the objectives of centralized database server, business logic and multi-location clients who can access the web based application through Intranet. This open source healthcare system is available under General public license GPL v2.0. The download statistics of open source software shows that the development efforts of the original free version have been concentrated in developing countries during the last few years. Almost 85% Out of 16500 downloads to different countries in the last year goes to developing countries. This shows the how the acceptability of open source software is rising exponentially.

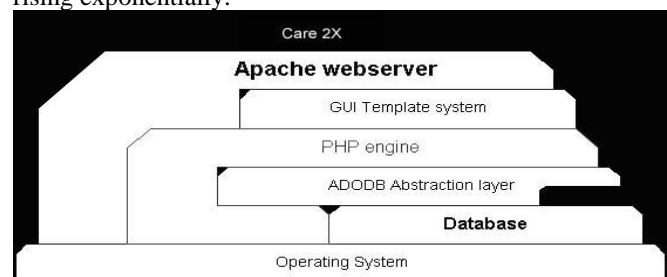


Fig. 3.CARE2X architecture [12]

APMIS development is based on Model View Controller (MVC) architecture; it separates the business logic and presentation layer from each other. MVC architecture is equally popular for web based application as well as mobile application development. HTML, JavaScript and CSS have been used to implement presentation tier, PHP to implement service layer and MySQL to implement Database or Model layer. CARE2X architecture is depicted in figure 3.

**VII. INTEGRATION OF EXTERNAL EVIDENCE SOURCES IN APMIS**

In healthcare lots of research work has been done for treatment of different diseases, now a days number of proved evidences are available online. Some rules generated in case studies (above discussed) and some other external evidences like MEDILINE and Cochrane database of systematic reviews have been integrated with APMIS to provide a help to clinician at the point of reporting. Figure 4 show some features of developed open source APMIS.

**VIII. CONCLUSION**

Open source software is very useful for developing countries as open source philosophy has been merged as low cost alternatives of proprietary software. Use of open source software can reduce the cost of HMIS up to 40- 50%. CARE2X is one of the most acceptable integral healthcare environments.



A low cost open source advanced pathology management information system (APMIS) based on CARE2X customization has been implemented in Indian client hospital.

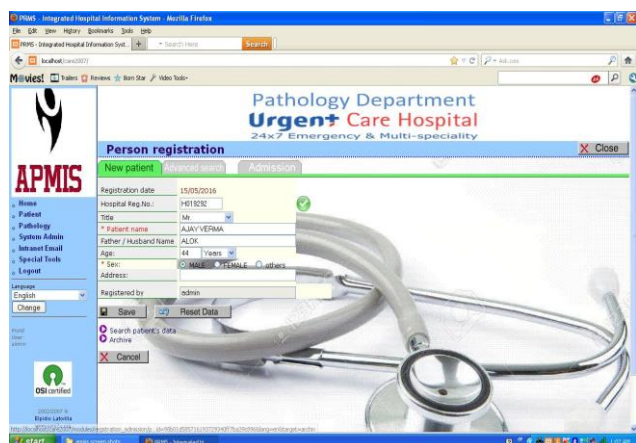


Fig. 4. Requesting a test in APMIS

This research has a detailed discussion on transformative role of data mining and data warehousing in healthcare sector. These technologies can be used to achieve compatibility between disparate medical information systems. Effective decision support system for healthcare can be developed with help of data mining and data warehousing. EBM integration into decision making process of healthcare has also been discussed. Application of data mining and data warehousing (DWH) technology can play important role in accelerating the rules creation and equally important in verification of evidence-based therapies. These evidence based rules have the capacity to become blue prints, once they are well proved.

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