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Open Source Software Low Cost Alternatives for Healthcare

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Abstract. Healthcare is the worlds second largest and also the fastest growing service sector. A well-managed and low cost healthcare system is of great importance to a country where large population with diverse social, educational and economical background is to be served. With health care being a government sector service, most of the hospitals are providing services with limited resources thus lacking the best services at time. ICT can play an important role in improving the services by managing the resources optimally and efficiently as ICT based tools can be used for resource management, patient record keeping, sharing the information, faster processing of data, managing the people at hospital etc. The development of an exhaustive healthcare system involves complex issues like finance, performance, security, scalability, and adherence to standards. Further, open source software solutions can help the hospitals to achieve the required services at lower cost.
The paper presents the justifications to use open source solutions for hospitals and at the end will discus a case study about customization of the existing open source Hospital information system CARE2X, to fit into the workflow requirements of an Indian hospital with the advice of doctors. Customized CARE2X is implemented in Pathology department of client hospital.

Index Terms - *Healthcare Information System (HIS), CARE2X, Open Source Software*

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I. Introduction

Healthcare is the world's one of most important service sector consuming over 10 percent of gross domestic product of most developed nations, health care can form an enormous part of a country's economy.

As per Wikipedia "The Indian healthcare industry is seen to be growing at a rapid pace and is expected to become a US$280 billion industry by 2022". Health care systems are designed to meet the health care needs of target populations. There are a wide variety of health care systems around the world. The health care industry includes peoples with variety of skills for a service related to the improvement of the health of individuals or the treatment or care of individuals who are injured, sick, disabled, or infirm. Accurate and error free diagnosis and treatment provided by any modern healthcare delivery system depends on its diversified group of trained professional coming together including ICT professional with unique goal of achieving service excellence.

Healthcare is world's most complex and multifaceted industry, with a large number of rules and policies [12]. Health Information System can help in comprehensive management of medical information and its dissemination among different stakeholders such as government, hospitals, patients etc. Over the time information and communication technologies (ICT) has made healthcare more accessible, interactive, and highly useful through components like telemedicine, Picture Achieving and Communication System (PACS), and Healthcare Information Systems (HIS).In some developing countries like India Government

Hospitals are an integral part of the comprehensive health services. So it is a requirement of time to make these systems more efficient. A proper utilization of limited resources can be assured by using effective computerized systems and procedures. There are an estimated 14,000 hospitals in India, excluding the private clinics and nursing homes. However very few corporate hospitals are using one or other Hospital Information system. The main entry barrier for HIS is high cost of development, customization and deployment of systems in existing setups.

Open source solutions for healthcare can be a boon in such circumstances because of low entry cost and easy customization of system as per needs of different hospitals. Section 2. Of paper gives the justification of open source software in Healthcare context, section 3 presents a case study about customization of an existing open source HIS 'CARE2X' for pathology division of client hospital, New Delhi, India.

II. Open Source Software in Healthcare Context

A major challenge facing healthcare organizations (hospitals, medical centres) is the provision of quality services at affordable prices. Hardware and software are capital goods for an organization. When the price of software drops to zero, it means that information technology is available at a lower cost.This helps an organization to add to its resources and improves its process.

Open Source software is an important and growing class of software. Open Source software is distinguished not by programming language, operating environment, nor

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application domain, but rather by the license(s) that governs the use, distribution, and, most importantly, the rights to access and modify the software's source code [8].

The philosophy of open source permits users to use, change, and improve the software, and to redistribute it in modified or unmodified forms. Together, software source code, licensing, and community have dramatically changed many conventional assumptions about software and the software industry itself. The term open source gained popularity day by day. Some of the reasons for using open source software include low total cost of Ownership, lack of software piracy issues, availability of source code leading to high degree of customizability and scalability and extensive support freely available on Internet. When the source code of a program is available anyone can contribute by improving the code, adding new features, correcting errors, etc.

In a country like India where diversification exists due to language, literacy, geographical and cultural variations [16]. Hospital is place where patients come from different locations using different local languages. Further, Users do prefer their native language instead of English as a medium of communication, thus imposing a requirement on application interface. So using open source software we can easily customize interface in local language.

Demand for healthcare services rapidly growing in developing countries like India. So there is a great need to make some efforts to provide low cost solutions for health care organizations. Open source softwares have potential to be a key player for low cost quality healthcare delivery. Care2x, OpenVista, OpenEMR are some of free and open source healthcare software worldwide used.

III. Case STUDY: ADVANCE PATHOLOGY MANAGEMENT SYSTEM BASED ON CARE2X

This section will discuss about a case study based on customization of pathology module of an existing open source hospital information system CAREX2X for client hospital's Pathology.

Client hospital is one of the premier hospitals in India with 1600 beds. It handles near about 1500000-1600000 in-patient and outpatient yearly.

Client hospital's pathology reports 400-500 cases per day. To improve the work process of pathology there is a requirement of an advance pathology management system.

3 .1. Requirements and Workflow of Pathology of Client Hospital

The main requirement of pathology of client hospital is a low cost pathology information management system which can cover the complete workflow of Lab 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.

Approximately 100 persons are using system at different level for entering details of test conducted, report generation, tracking of samples, updating status and report search. There are two types of pathology in client hospital first one is Histology and second one is Cytology. Each pathology lab is divided into different labs like Grossing lab, block making lab, sectioning lab, IHC lab, special stain lab and reporting lab etc. Table1 can describe different steps of workflow of histology lab.

Table1. Steps of Workflow of Client Histo Pathology Department

Step#1	Clinician generates test request. Test request form contains clinical diagnosis, name of specimen, may be with one line description specimen, Specimen collected date and collected by.
Step#2	In step 2 specimen is received, accession no. allotted and after that specimen receiving person forwards it to Grossing table
Step#3	In Step 3 workflow consists of functions like detail description of specimen ,decision regarding no. of blocks, block description, register maintenance for incoming specimen and outgoing for block cutting/trimming of the specimen ,entry of grossed by, date and time and forwarding sample to block cutting/trimming table.
Step#4	Hard pieces are prepared at block cutting/trimming table then sample forwarded to sectioning and staining table. Here also an incoming/outgoing register is maintained.
Step#5	On sectioning/staining table slides are prepared. Then prepared slides forwarded for report generation table. slicing table also maintains a incoming outgoing register which contains accession no, patient name, no of slides ready/sent , no. of slides pending .
Step#6	On report generation table report can be generated. Otherwise it can be send back to sectioning/staining or grossing table for resectioning, immune histo chemistry, special stain, hormones receptors, regrossing.

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Step#7	If a doctor orders for resectioning then after resectioning new slides will be send back to reporting table, if for special stain then after applying the special stains it will be send back to reporting table,and if the order is for IHC then slides will be send to IHC LAB.
Step#8	After applying different type of for immune histo chemistry, special , slides again send to report generation table where final report being generated.

Cytopathology Workflow consists four major steps. Table2 shows these steps in workflow of cytopathology.

Table2.Steps of Workflow of Client Cyto Pathology Department

Step#1	Clinician generates test request.Test request form contains clinical diagnosis, name and nature of fluids, Specimen collected date and collected by.System automatically generates accession key according to name of fluids. And then sample goes to be process.
Step#2	Types and number of slides decided on processing table. and then it forwarded to reporting table.
Step#3	On report generation table report can be generated. Otherwise it can be send back to special stain lab,ihc lab, stain all lab.
Step#4	After applying different type of special stains,ihcs sample goes back to reporting table.

To accomplish these requirements researcher has customized pathology module of care2x.

3.2. Care2x

CARE2X is an open source Web based Integrated Healthcare Environment (IHE)[2] under GNU/GPL. The project was started in May 2002 Until today the development team has grown to over 100 members from over 20 countries. Its source code is freely distributed and available to the general public.

CARE2X [2] HIS is built upon other open-source projects: the Apache web server from the Apache Foundation the script language PHP [3] and the relational database management system mySQL [4]. CARE2X is modular and highly scalable so its very easy to scale this application as per requirements. CARE2X is currently composed of four major components. Each of these components can also function individually. These components are HIS - Hospital/Health service Information System, PM - Practice (GP) management, CDS - Central Data Server, HXP - Health Xchange Protocol [2].

CARE2X is built upon different modules which include e.g. in- and out-patient administration, admission, pharmacy, radiology (including DICOM image uploads), laboratories, ambulatories, nursing, medocs, DRG, etc.

If a hospital is using network of different programs in its different departments there will be problem of non-compatibility with each other.

 CARE2X HIS solves this problem, as it can integrate almost any type of services, systems, departments, clinic, processes, data, communication, etc. that exist in a hospital.

And its even capable of handling non-medical services or functions like security, maintenance, etc. When configured accordingly, it can support multiple database configurations to enhance data security and integrity. As it is a web based software and all its functions can be accessed with a common web browser thus there is no need for special user interface software. All program modules are processed on the server side so there are no network interruptions. Its design supports multiple server configurations to distribute traffic and improve speed and efficiency. Figure 1 shows the typical CARE2X screen.
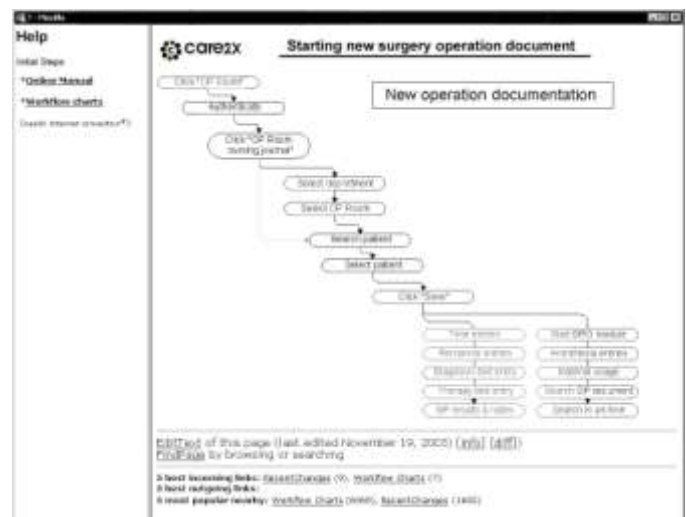

Fig.1. Help page describing the clinical path for starting a new surgery operation document

3.2 Functions of care2x [2]

Any generic hospital will have three major entities namely administration, doctors and supporting staff and patient.

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CARE2X has different functionality available to these entities as per their role in the system.

All modules of CARE2X can be broadly categorized into three category namely Patient care Modules, Hospital's Services Supporting Modules, Hospital's Administration Supporting Modules which covers the complete medical and non-medical services of a hospital.

3.3 Care2x IHE architecture

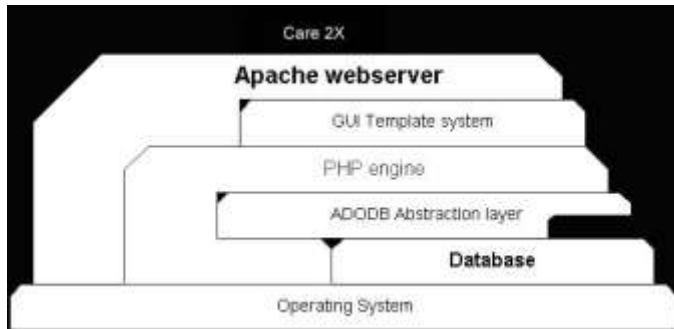CARE2X is basically two tier applications consisting of a web server tier and a database server tier.

Fig.2. CARE2X architecture [2]

Components of CARE2X architecture

All components of care2x are open source. Following are the three major components of care2x architecture.

1. Apache 1.X
2. PHP (4.0.4pl1 - 4.3.4) [3]
3. MySQL (3.2x - 4.0.x) [4]

3.4. Customization of care2x

To fulfil client pathology requirements mentioned in section 3.1 we have customized CARE2X.Initially pathology module of CARE2X was just with two forms one for test request and other for results entry [2].we have customized it as a complete pathology information management system, which covers the complete workflow of histopathology and cytopathology of client hospital with, desired advance features. Followings are the advance features of customized CARE2X.

Sample Tracking

The functionality of this module is to track status of a sample by patient name or by accession key. It will show the complete detail about that sample i.e. in which lab sample is pending and which lab has been completed (on which date).

Fig.3. sample tracking in customized CARE2X

View records of each lab

This module will show you the complete work record of a particular lab including details about completed cases and pending cases on a particular date or between two dates.

Fig.4. Viewing the record of a particular lab in customized CARE2X

Summary of each lab as well as complete pathology.

This module will show the summary of complete pathology as well as individual lab. It will show details about total cases handled by pathology as well as each lab.

Advance reporting table.

Customized CARE2X provide smart reporting table. A doctor can perform each and every activity related to reporting like create report, send a sample for re-grossing re-sectioning, IHC, special stain. And about all theses status of sample will be automatically updated and visible on reporting table.

Security aspects

Customized CARE2X is very much rich in security aspect. It has a role based authorization system. In role based authorization administrator can create different users and

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user can access only that functionality of system for which he/she is authorized.

Interesting report management

This module in customized CARE2X is helpful in managing interesting cases. Interesting cases are those cases, which may be helpful for research as well as teaching purpose.

Disposal management

We can keep the record of sample disposal, and filing of slides. This module manages disposal records as per doctor's decision whether a sample will be used for research, teaching or just discard.

The pathology lab of client hospital handles about 400-500 samples every day. A robust system is used to ensure the availability of software which is deployed with Linux high availability cluster configuration .The application is running on Linux/windows system with apache server configured for execution of PHP and MySql database. The system is being used by different level of users for different operations.

IV. Conclusions

CARE2X is flexible generic multi-language open-source project. CARE2X is a very feature rich HIS, fully configurable for any clinical structure. After customization, it has the potential to become functional software to support workflows of Indian hospital. Efforts were made to explore the possibility of providing a low cost solution to Indian hospitals. Case study mentioned in section.3 shows that open source softwares have potential to be low cost solutions for hospitals in developing countries like India.

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