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UBIQUITOUS CREATION OF ELECTRONIC MEDICAL RECORD AND CLINICAL DATA MANAGEMENT USING TABLET PC

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Abstract— Traditional medical record systems are predominantly hard copy paper based models with or without variable components of electronic data such as laboratory results and X-ray reports. The paper record is not always legible and poor indexing of data makes the finding of information difficult or impossible. Electronic Medical Record (EMR) uses the alternative method of storage of all health care data in electronic format. The advent of EMR has not only changed the format of medical records but also increased accessibility of information contained in the repository, especially for research purposes. However, the system for creation and maintenance of EMR presents a new challenge to the designer of the Hospital Information and Management System (HIMS). Many HIMS provides a Manual entry system for EMR. The health care staffs are required to manually enter the data into the computer system using a screen provided for this purpose. Even though this is easy to conceive and implement, it is a major source for increased workload, manual errors, and delays in capturing data into the EMR. Ubiquitous creation of EMR has the potential to solve these problems. It has the promise to streamline the data collection process for EMR creation with least disturbance to the clinical staff .This paper presents a system for the creation and management of EMR using a set of tablet PC's interconnected over a Wi-Fi network. The system is currently under implementation in National Institute of Research in Tuberculosis, in Chennai, a premier research institute of Indian Council of Medical Research.

Index Terms— *Electronic medical report (EMR), Hospital information management system (HIMS), Tablet PC, Ubiquitious Computing.*

1 INTRODUCTION

Tablet PCs are becoming increasingly popular for various applications. Present day tablet PCs are powerful microprocessor devices built on a mobile operating systems, with computing capability equivalent to laptop and desktop computers. The Patient Medical Record is a systematic documentation of an individual's medical history. Traditional PMR systems are predominantly hard copy paper based models with components of electronic data such as laboratory results and X-ray reports converted into paper formats. The major disadvantage of this system is that it requires considerable amount of space, time and effort to maintain. The paper record is not always legible and poor indexing of data makes the finding of information difficult or impossible. The information contained in the repository of medical records is of great value in medical research. However, due to the difficulties indicated in above, it is clear that paper based PMR is not very useful for this. Electronic Medical Record (EMR) uses the alternative method of storage of data in electronic format. The advent of EMR has not only changed the format of medical records but also increased accessibility of information contained in the repository. It gives the opportunity to the hospital to adopt it as the standard for all patient related records. Associated information processing and knowledge support tools could be used to seamlessly manage the system. However, the system for creation and maintenance of EMR presents a new design challenge. Many system designers resort to manual entry in which, the health care staff enter the data into the computer system using a screen provided for the purpose. Even though this is easy to conceive and implement, it is a major source for increased workload, manual errors, and delays in capturing data into the EMR.Automation of Patient Medical records using tablet PCs is a possibility that should be given a serious consideration. The small form factor, light weight, and various multimedia features of the tablet make it an ideal choice for this. We have proposed a network of Tablet PCs interconnected over a WiFi network to provide the required interface to the clinical staff for the ubiquitous creation of the EMR in National Institute of Research in Tuberculosis in Chennai. NIRT is a premier institute of the Indian Council of Medical Research (ICMR) internationally recognized for Tuberculosis research.The proposal was accepted in principle and we are currently in the process of setting up a trial implementation of the system. This paper presents the salient features of the system. It is organized as follows: Section 2 describes the current workflow for clinical management in NIRT. It may be seen that the current workflow is predominantly manual. Section 3 gives an analysis of the advantages and disadvantages of this manual system. The proposed automation system uses a set of Tablet PCs for the HMI interface and a separate Clinical Management Server for the business, logic and control functions. Section 4 gives the architecture of this system. The HMI interface consists of a large number of elementary tasks each implemented as an Android application that would ubiquitously create the EMR. Section 5 describes the major applications and their functionality. Section 6 gives an impact analysis of this system from the perspectives of patients, operators, clinicians and researchers along with the expected improvement in turnaround time.

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2.EXISTING WORKFLOW FOR CLINICAL MANAGEMENT AT NIRT.

All the patients coming to NIRT are referred from other hospitals. NIRT first determines whether the patient is a case fit for enrolment purposes. This is called the pre-treatment phase. In cases they are enrolled, they undergo a treatment that normally lasts six months to one year. Subsequent to this is the follow-up phase. In the following we describe the workflow of the patient for each of these phases.

A. Pre-treatment Phase

This is the phase that determines whether the patient is to be enrolled for the study. It lasts up to 4 days. Figure 1 shows the workflow for the 1st day of investigation. These are further described below.

1) **Pre-treatment Phase day 1:** On the first day of pre-treatment, the patient arrives at NIRT with a reference letter. He presents this at the registration desk. The registry clerk will register the patient by entering the demographic details in the main register and assign a 5 digit Registration number. He issues an ID card and makes entries in the basic assessment form. The patient is directed to the X-ray room with a Requisition for X-ray. The X-ray section takes the X-ray of the patient and directs him back to the reception counter. The reception counter issues a sputum card and a numbered sputum bottle. The bottle number is entered into a form for subsequent cross verification. The patient is now instructed to collect the sputum into the bottle provided and submit the same at the sputum collection centre along with the sputum card. From the lab reception, the patient is directed to the original reception. Here the patient awaits his call from the doctors desk. Meanwhile the doctor views the patient's X-Ray. Doctor would examine this before examining the patient. When the patient arrives in his desk, the doctor examines him and finds out details regarding previous treatment. He fills all information in a Basic Assessment Form (BAF). Then the patient is instructed to collect the urine and submit the specimen in the clinical laboratory reception. Based on his assessment, the doctor may determine that this case is not suitable for enrolment. In this case, he advises the patient to return to the original hospital or clinic with an advice slip to the clinician there. In this case, the patient goes back and doesn't come back to NIRT. Otherwise, the patient is directed to visit the social worker.The social worker counsels the patient about the disease, the treatment, the implications of enrolment, etc. During this, he makes an assessment about the suitability of the patient for enrolment, based on his social and psychological conditions. In case he finds the unsuitable for enrolment, he is directed back to the doctor, who would refer him back to the original clinic. Otherwise, the patient is directed to medicine counter. At the medicine counter patient gets the symptomatic drugs and another numbered sputum bottle for collecting the home sputum the next day and the symptomatic drugs. This completes the workflow of the first day.

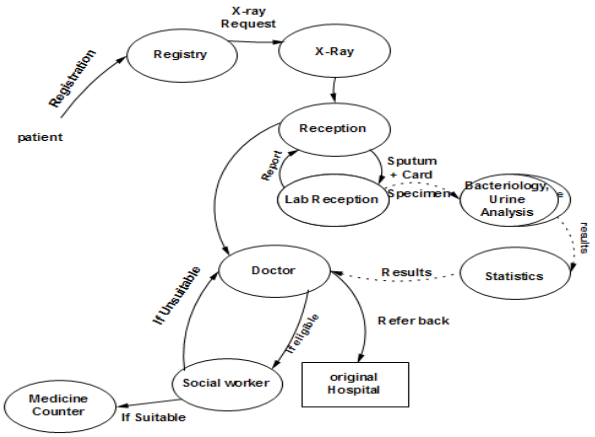

Figure 1.Pre-treatment Workflow for Day 1 - patient perspective.

2) Pre-treatment phase day 2: Figure 2 shows the patient workflow for the second day. It starts with the patient giving attendance at registry followed by visit at reception counter. Here, the sputum card corresponding to the collected home sputum is filled up and the patient is directed to lab reception to submit the collected sputum. He returns to reception, whereupon he is directed to ECG section with an ECG requisition form. After taking the ECG the patient is directed to the social workers room for counseling. During this time the ECG results and urine Results are available for the doctor. After the social workers assessment, the patient is directed to the doctor's desk for examination. The doctor examines the patient, reviews the ECG and Urine results and marks entries on the BAF. If the smear results for the previous day is available and it is positive, he directs the patient to the laboratory for blood investigations. Finally the patient goes to the medicine counter to receive the prescribed drugs.

3) Pre-treatment phase day 3: Figure 3 shows the patient workflow for the third day. It starts with the patient giving attendance at registry followed by visit at reception counter. Here, the sputum card preparation and submission of sputum follows as in the previous day. After this the patient is directed to the doctor's desk. The doctor fills up the entries in BAF corresponding to day 3. If the blood sample was not taken before and the smear result is positive, the patient is directed to the laboratory for blood investigation. Finally the patient goes to the medicine counter to receive the prescribed drugs.

4) Pre-treatment phase day 4: Figure 4 shows the patient workflow for the fourth day. This is the last day of pre-treatment and by now the doctor has all results needed to determine the course of treatment. The workflow is very similar to that of day 3.

B. Treatment phase

During the treatment phase, the patient is directed to report at NIRT every month. Figure 5 shows the patient workflow during his monthly visit. The workflow is very similar to that of his first visit described previous section.

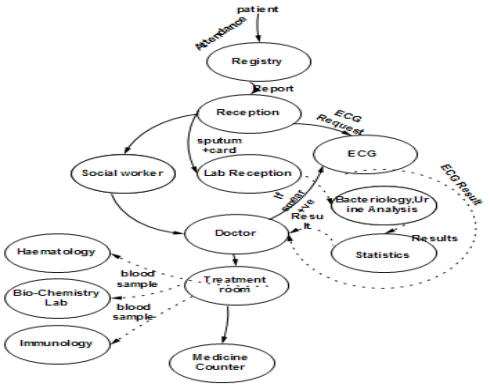

Figure 2: Pre-treatment Workflow for Day 2- patient perspective.

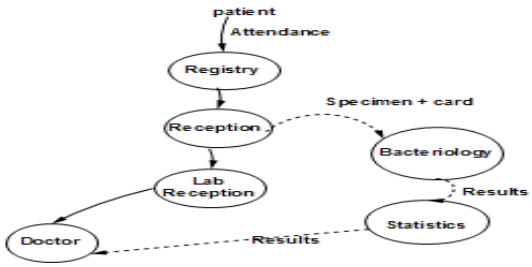

Figure 3: Pre-treatment Workflow for Day 3 - patient perspective.

C. Follow-up Phase

During the follow-up phase, the patient is directed to report at NIRT at intervals as directed by doctor. Figure 6 shows the patient workflow during this visit. The workflow is very similar to that of his first visit described in previous section.

3.ADVANTAGES AND DISADVANTAGES OF CURRENT WORKFLOW

It may be seen that the current workflow of patient management is primarily manual.

Figure 4: Pre-treatment Workflow for Day 4 patient perspective.

Figure 5: Workflow for treatment phase patient perspective.

Figure 6: Workflow for follow-up phase - patient perspective.

It involves only manual entry into case sheets kept in a folder that becomes thicker and thicker as the case grows. The technician, doctors, nurses, social worker, statisticians, etc., who are the major contributors of the information does not require any computer knowledge or training. Another advantage is that it is very flexible and is adaptable to any changes. Since all information is captured in hard copy form, the system is considered to be more robust than storing same information in computer disks that is susceptible to hardware failures and virus attacks. However, the current work flow has many disadvantages. The major among
them are:

- Increased turnaround time
- Difficulty in Information Exchange for Collaborative Research
- Impossibility of using Knowledge Extraction Tools

These are described in the following subsections.

A. Increased turnaround time: Increased turn-around time is the most important lacuna of the system indicated by the practicing doctors. The time taken for the lab results to reach the doctor can sometimes take up to a few days. The copying of data from sheet to register back to tables and sending the same to statistics department before it is made available in the case sheet sent to the doctor, increase the turnaround time

B. Difficulty in Information Exchange for Collaborative Research: One of the most important disadvantages of manual record keeping is the difficulty in exchanging information

between research communities spread across large distances. Had the information be available in digital form, clinicians could have shared it over the cyberspace to get valuable opinions from their peers working in other establishments. Currently, this is difficult.

C. Impossibility of Using Knowledge Extraction Tool: This is another difficulty with manual system. A lot of research is going on in automatic extraction of knowledge from large data sets. Many open source and commercial tools also are available in this segment. However, all of
these require the data to be organized in digital form in database tables whose structure can be made available to the tools. In a manual system, this is clearly not viable.

4.ARCHITECTURE OF CLINICAL MANAGEMENT SYSTEM WITH TABLET PCS

Figure 7 gives the architecture of the proposed system. It is spanned over 15 segments of the centre. A brief description about their functions and the hardware proposed in each is given in Table 1. The segments termed registry, reception, x-ray room, ECG room, doctors, desk, Social workers desk, etc. are adjacent to each other. Due to this separate WiFi modems are not required in these sections. Most of the other sections are not within the Wi-Fi radius of this modem. Hence, additional modems are required at these locations.Note that the Tablet PCs in various sections talk to each other through the central server only. The DBMS and application servers are hosted there and these will determine the access rights of various users for viewing the information. Normally, statistics department will be the owner of the information and others will get access to it once the statistics department has validated the data. However, the current status of the various information will be available to everyone.

5.THE HMI IMPLEMENTATION AS A SET OF ANDROID APPLICATIONS

Table II gives the list of Android applications proposed for clinic management automation. The list is not Complete, since the development is presently on going. It is expected that more applications will be added during implementation and operationalization phases. Login application is provided to each user who uses the tablet PC. This application is needed by the users like Admin, Registry clerk, Medical Officers, laboratory technicians and Statistician. Separate usernames passwords are assigned to each user. Only legitimate users can enter in to the system. The access to various system facilities can be restricted to selected personnel or group of personnel based on access privileges set up for their purpose. Registration application is done by the registry clerk. A separate user interface is given to the registry clerk to perform this application.

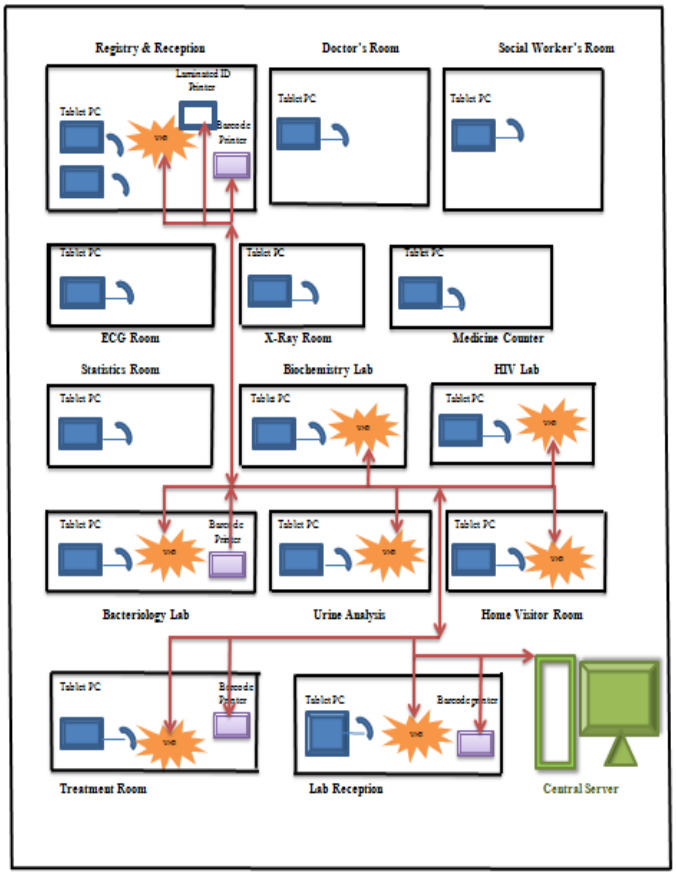

Figure7: Network Architecture of Proposed System.

This application consists of following functionalities:

- New patient registration
- Issue id card
- Entering the patient details
- Attendance marking
- X-ray requisition

Doctors Desk application screen will show the patient details required for the doctor to know about the patient. It has options to enter the diagnostic details after examination and fields to prescribe the medicine etc. The screen shows the following:

- Access the patient details by using patient id.
- Enter the basic assessment details to patient profile in appropriate fields
- Prescribe medicines enter it in the patient profile
- Review test result
- Enter next appointment date.

Admin application is responsible for monitoring the entire system. A separate user interface is provided to admin. Admin performs all functionalities needed for providing user access to the systems and data base tables. It also monitors system usage and performance.

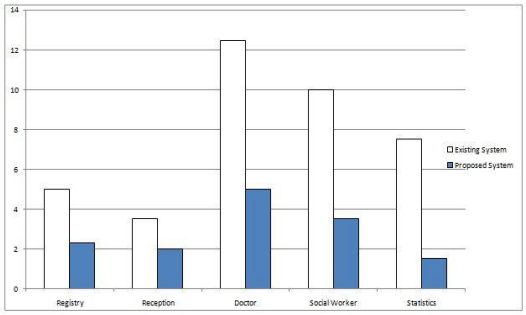

Figure 8: Performance Evaluation of Different Sections

Table I: SECTIONS, FUNCTIONS, HARDWARES

Sections	Hardware and Functions
Central Server	A low end workstation will be used initially. Once system is operational, it will be migrated to central computing facility. Function consists of providing computing and storage requirements of total system.
Registry and Reception	Two tablet PCs with bar code readers, a barcode printer, a laminated id card printer and an optional scanner.
X-Ray room .	A tablet PC with bar code reader. Functions include reading the patient id from the x-ray slip carried by patient and take the x-ray.
ECG room	A tablet PC with bar code reader. Functions include reading patient id from the ECG slip and taking ECG. On completion report will go to central server..
Doctors room	Ideally, each doctor will have a tablet PC that he carries with him. Functions include examining patient after examining EMR available so far and entering observations onto the tablet
Social Worker's room .	A tablet PC with bar code reader. Functions include counseling the patient and determining whether he is fit case for enrollment
Statistics room	A tablet PC with bar code reader. Functions include connecting lab Id with patient-id and collating lab information into patient EMR.
Medicine Counter	A tablet PC with bar code reader. Functions include giving medicines to the patient...
Lab Reception	Tablet PC with bar code reader and bar code printer. Main function is reception of samples. Lab number is given here.
Bacteriology Lab .	Tablet PC with bar code reader and bar code printer Main function is bacteriological analysis of the sputum. Smear, culture and other tests are performed here.
Biochemistry Lab	Tablet PC with bar code reader. Main function is analysis of the blood. Automated tests are performed here. Results are sent to central computer..
HIV Lab	Tablet PC with bar code reader. Main function is HIV analysis of the blood. Results are captured by tablet PC and sent to central computer.
Urine Analysis Lab	Tablet PC with bar code reader. Main function is analysis of the urine. Results are captured by tablet PC and sent to central computer.
Home Visitor room	A tablet PC with bar code reader. Function is similar to social worker.
Treatment room	Tablet PC with bar code reader and bar code printer. Main function is providing medicines and treatment to patient.

Section	Existing System	Proposed System
Registry	10	5
Reception	7	4
Doctor	25	10
Social Worker	20	7
Statistics	15	3

Table II: ANDROID APPLICATIONS

Sl. No	Android Apps	Functions
1.	Login	Help to enter into the system
		Enter the demographic details of a patient and assigns a unique

2	Registration	treatment number using barcodes.
3	Examination	The application is purpose built for the tablet PC in doctor's room. It enters diagnostic information by the doctor.
4	X-Ray monitoring	The application is purpose built for the tablet PC in X-ray room. It reads patient id from the x-ray slip carried by patient and take the X-ray.
5	ECG monitoring	The application is purpose built for the tablet PC in ECG lab. It reads patient id from the ECG slip carried by patient and take the ECG.
6.	Counselling Application	The application is purpose built for the social worker
7	Route Marker	The application is The application is purpose built to enter route to the locality of the patient in case the field worker needs to go there.
8	Lab Reception	It generates a lab number, prints four bar codes with this number and paste one on top of the bottle and clips the rest with sputum card.
9	Medicine dispenser	The application now gets the medicines to be given to the patient from the central server. Once the medicines are given, the stocks updated.
10	Bacteriology Lab Automation	This is a set of applications is purpose built to cover activities in the bacteriology lab.
16	Administration	An administrative application

6.CONCLUSION

Patient medical records are invaluable as a means of understanding the effectiveness of various regimes of treatments for various types of diseases which in turn will result in better practices for patient care. However, the most effective way of using them is to hold the medical records in an electronic form. This allows DBMS and knowledge extraction tools to work on them. It ensures data availability over the cyberspace allowing quick data transfer, retrieval, linkage, data views, abstraction and reporting. It reduces turnaround time and manual errors. The use of Tablet PC in the manner proposed herein will make creation of EMR ubiquitous. Tablet PC can be viewed as a ubiquitous computing platform as well as a hybrid of mobile-phones and personal digital assistant. The proposed system based on them is very flexible and cost effective. The future work should consider cloud enablement of the server system proposed and inter connecting a number of hospitals so as to pave way in making the patients EMR available over the internet.

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