Handheld computers for rural healthcare: Experiences from research concept to global operations

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ABSTRACT

We describe the Ca:sh project and our experiences in scaling it up from a research project to the foundation of a global operation. The Ca:sh project is a handheld-based electronic medical record (EMR) in operation in Ballabhgarh, India. The system is designed for paramedical health workers serving remote areas, giving them access to large medical databases in the field. The system addresses two important problems in developing countries: prenatal care and child health. It is open source software based on the free Linux operating system. Currently the system has been operational for 8 months and is used by 10 health workers to track over 70,000 patients.

This paper first describes the technical challenges and innovation needed in the design, development, adaptation and implementation of the handheld EMR in a rural setting in India. The paper further describes the adaptations needed to scale up this pilot project to larger, diverse settings and our path from research to developmental entrepreneurship.

INTRODUCTION

Maternal and child health constitutes a major area of health concern in many developing countries. The maternal morbidity ratio (number of maternal deaths per 100,000 live births) is 440 in India, as compared to 12 in developed countries like the United States [1]. This problem can be addressed among other methods by providing routine medical care for all pregnancies and identification of high-risk pregnancies [2].

Rural healthcare in India is decentralized. The health care system is hierarchical. The smallest component in this health care system is a sub-center. Each sub-center serves a population of 7000-8000 people. The area served by a sub-center varies from 10 sq km to 50 sq km. The center is staffed by 2 paramedical health workers: a female health worker or ANM (Auxiliary Nurse and Midwife) and a male health worker. The ANMs are primarily responsible for maternal and child health. Thus, they are responsible for the health of pregnant and nursing mothers and children under five. The next component of the health care system is the Primary Health Care Center (PHC). Typically, a PHC serves a population of 25000-28000 people and is staffed by several paramedical health personnel, as well as medical doctors. The PHC is the first referral center for commonly occurring diseases in primary care. The community health centers (CHC) are the next in hierarchy.

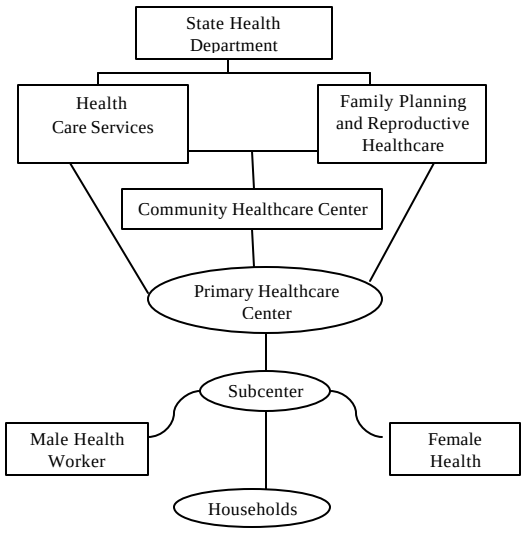

Figure 1 : Healthcare system in rural India((Shariff and Singh December 2000) (Adapted)

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These centers have facilities for surgical procedures and are a referral center for various specialists. This 3-tiered health system is prevalent all over India, covering the entire population of one billion people. The country is thus served by about 100,000 ANMs.

The advantages of an Electronic Medical Record (EMR), as compared to a paper-based record, are well documented in literature. EMRs have shown to improve cost–effectiveness [3-5] and improve quality of health care [6]. An electronic medical record in a rural setting has other important public health implications. The data collected by the mobile health workers can be used for better understanding of disease patterns in a community and can be used for optimal health resource allocation. It is also useful to link data from ongoing public health surveys and this can be used in public health research programs [7].

The accurate recording of maternal progress of pregnancy is important from a medical standpoint. It is useful to identify high risk cases early in the pregnancy so that appropriate medical action can be taken to reduce pre-natal morbidity and intra-natal complications. This is particularly important in a rural health setting in India where close to 75% of all child-births are conducted at homes by untrained or inadequately trained personnel [8]. The recording of pregnancy risk factors and thus identification of high risk pregnancies can result in appropriate referral of these high risk cases to referral centers for better care and hospital delivery.

Child health is of prime importance for any country. Child health at primary care is aimed largely at preventive care. This is done mainly through the immunization of infants (children under the age of one year) and prophylactic administration of Vitamin A drops. Children under the age of one year receive one dose of BGC (for tuberculosis), four doses of OPV (Oral Polio Vaccine), three doses of DPT (for Diphtheria, Pertussis and Tetanus) and one dose of Measles vaccine as a part of the Expanded Immunization Program recommended by the WHO [9] and modified for Indian setting as a part of the National Immunization Schedule [10]. As a part of the Indian health policy they also receive two doses of Vitamin A drops for the prevention of Vitamin A deficiency. The availability of a mobile EMR potentially allows the ANM to view this information at point of care and receive alerts regarding scheduled immunizations, thus preventing over/under dosages.

METHODS

HARDWARE/SOFTWARE

The need for storing over 7,000 medical records on a single handheld required the use of a stable platform that could perform consistently and reliably, as the ANM would be dependent on it for her day to day activities. There was also a need for a fast processor since querying operations on a large database can take significant amount of time. In view of the above issues, we decided to use Linux running on the Compaq iPAQ as the platform for development.

The Compaq iPAQ™ 3765 was used in the project. This device has 32MB of ROM and 64 MB of RAM. Compact Flash cards were used to store the records. The device was fitted with an expansion slot that can accept Compact Flash cards. Qt/Embedded was used as the software development platform [11]. For the window system, we chose to use Qtopia, which is a simple, powerful, intuitive, efficient, and flexible mobile palmtop environment. One of the primary objectives of using the Linux operating system was to allow easy migration to the popular Simputer [12] hardware platform when commercial offerings of the same are available.

For the database we use MySql version 3.22.32 as provided by the open source Debian Linux project. The database on the handheld synchronizes with the central database (FoxBASE) in the community health center.

DESIGN OF USER INTERFACE

The software user interface was designed after studying the routine activities of the ANM. The entire design was created with active participation of the ANMs. Iterative changes in the user interface design with continuous feedback from the ANMs contributed towards the easy adoption of the technology. This early involvement at design stages also helped in creating an interface that was intuitive for the ANMs. The India Health Project, where Apple Newtons were used, relied heavily on the use of intuitive iconic interface to allow the health workers to grasp the system better [13]. However, in our approach, the ANMs were comfortable with a text based input and this also allowed us to deploy the system rapidly. The focus was to ensure structured data entry.

The software is divided into 4 modules:

HOUSEHOLD VIEW

The point of entry for viewing patients is through the 'household view', in which the ANM can view each member of the household by entering the house number.

DEMOGRAPHIC MODULE

The demographic module allows the ANM to modify parameters such as *Name, Age, Relation to the head of the household*, etc. (**Figure 2**). There are also the obvious provisions to remove a person from the database (in case of death or emigration from outside the village), and addition of persons and new households. A new unique number is automatically generated when a new person is added.

ANTENATAL CASE MODULE

The Antenatal Case module has two sub-modules: the first is the *registration* of a new Antenatal case, and the second is the *encounter* module. The registration module records date of last menstrual period, history of previous pregnancy, and past medical and obstetric history. All the data are collected in a manner that requires the health worker to merely check or uncheck a box (**Figure 3**). Care was also taken not to overwhelm the ANM with too many fields on any given form (each form corresponds to one screen in the handheld).

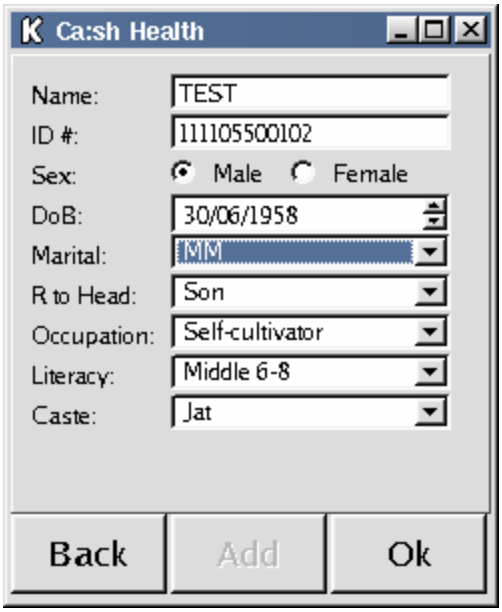

Figure 2: Demographic Module

The encounter module gives an overview of the current state of the pregnancy, including alerts about the due date of the pregnancy. It also alerts the ANM about pending immunizations and medication due (iron and folic acid tablets). The various clinical data that is input are used for risk assessment of the pregnancy.

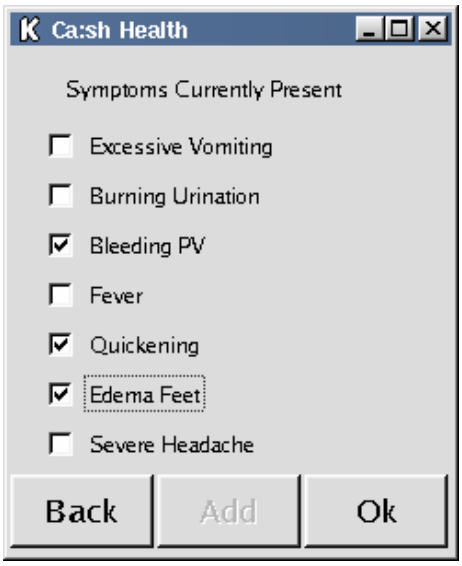

Figure 3: Sample form: Antenatal Case Module

IMMUNIZATION MODULE

The *Child under 5 years* module provides logistic support for immunization of children. It allows entry of various clinical data about morbidity in children. The immunization module provides alerts regarding pending immunizations (**Figure 4**).

Contraceptive use is included in a separate module due to its importance in a country like India, where population control is an important issue in health policy. This module includes fields for maintenance of methods of contraceptive use. This module is under development.

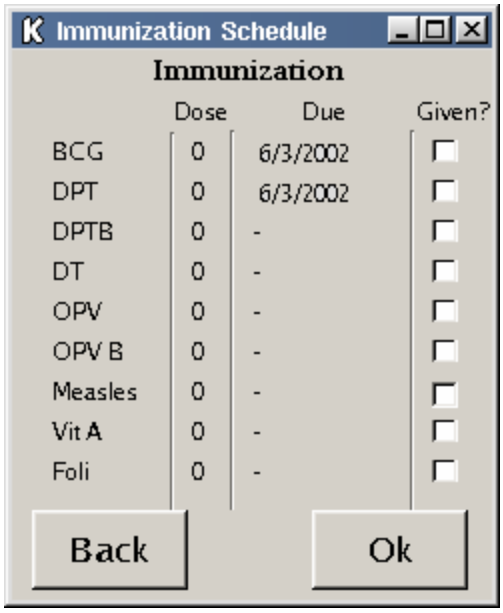

Figure 4: Immunization Form and Alerts

INNOVATION IN TECHNOLOGY

COMPACT FLASH FOR DATA TRANSFER

In a rural setting with little access to communication technology, transmission of data that is collected by healthcare workers poses a serious challenge. While the handheld device in itself helps the ANM to have access to patient records, one of the prime objectives of a data-collecting device is to allow doctors and other healthcare personnel quick access to the collected data to analyze trends and patterns in diseases, both short term and long term and also to re-allocate resources in real time. With telephone systems still not reliable in many rural parts of India and other developing countries, our approach was to store the data securely on a compact flash device (which can store several hundred megabytes of data) and transport the same physically to the healthcare center. This has two advantages:

1. The healthcare worker does not need to come to the central server for synchronizing the data.

2. The Compact Flash cards act as a backup media for the data on the device itself.

DATABASE ARCHITECTURE

The handheld device runs both the SQL server and the client and hence is a self-contained database. This was important as typically PCs are difficult to maintain in a rural setting. Most current handheld systems in hospital settings depend on the central PC for retrieving records and are designed to store a limited number of records on the handheld device. Having a complete database on the handheld required the optimization of querying techniques to ensure that the records can be assessed without significant delay even on low memory handheld devices. This architecture allows the handheld to plug into any other database system without significant changes to the source code and data-schema.

USER INTERFACE

The system was designed using UNICODE standards that allow easy translation to any other UNICODE supported local language. Although most ANMs in India are able to read and write English, this is important if the system needs to function in different settings all over the world. While designing the user interface, care was taken to ensure minimal free text entry. Wherever necessary, a virtual keypad was incorporated on the screen directly that allowed the health workers to rapidly enter numbers.

RESULTS

The system was implemented in the Ballabhgarh area in Northern India. The area is served by the Community Medicine Department of All India Institute of Medical Sciences and covers a population of over 70,000 people and has 10 ANMs among other medical personnel.

The initial phase involved the test implementation lasting for 5 months and four ANMs were selected for the trial. In the selection of the ANMs, care was taken to ensure inclusion of both early adopters of technology and potentially late adopters (including the older ANMs and those who had never used a computer before).

Training of the ANM was done with the help of 2 engineering students and 3 doctors from the local area. This allowed them to interact in the local language. The training was divided into 2 phases. In Phase 1, the ANMs were taught the basics of switching on the iPAQs and using the stylus. They were also trained to insert the Compact Flash and overall structure of the Qtoptia windows system on the iPAQ. This entire training took 3 hours. It was designed to

be an interactive one-on-one exercise. Despite the fact that none of the ANMs had used a handheld computer before, they were able to use it after this training. We evaluated their proficiency by testing some of the tasks, such as starting an application, entering text data, resetting the device (rebooting).

Phase II of the training involved the use of the EMR system. The initial training for the first version of the software took 2 hours. Since the design of the system was done iteratively and changes to system took place everyday over a period of two weeks, every new version required 20-30 minutes of retraining.

Current evaluation of usability, accuracy and reduction of time for entry of data for the 4 users is encouraging. Previous studies have shown healthcare providers' satisfaction with replacement of paper based records with handheld electronic records [14]. Current evaluation of this system indicates high acceptance of the technology and reduction in total time for entry of data [15]. The ANMs were satisfied with the user interface and were able to depend entirely on the handheld, replacing their existing paper based records.
At the end of the first phase of testing, the system was scaled up to have all the 10 ANMs of the health center use the system.

DISCUSSION

We have implemented an EMR for addressing a unique problem of providing logistic support to a paramedical health worker providing primary healthcare in rural areas. The current system is stable and replaces the existing paper-based system. This system will benefit the local community for better delivery of maternal and child health. The alerts that the system provides are considered useful by the ANM. The adoption of 'disruptive technology' is best achieved by involving the end users in the design process.

NEXT STEPS – FROM RESEARCH TO OPERATIONS

The experience with the successful implementation of the Ca:sh project and it's enthusiastic acceptance by the medical community, led to the starting of a larger operational arm (Dimagi, Inc) in June 2002, with the intention of providing additional tools and scaling up of the project to address several similar problems in healthcare in different developing countries. The challenges in starting a company focused on cutting edge technology and at the same time creating products for developing markets are many. Below are some of the challenges that were faced:

1. Redesign of the research concept : The original project was done using iPAQ computers which are expensive (approx $400-$500). The main reason in using them was to allow flexibility in programming and to create a platform for further development. It was necessary to address an important need in keeping the cost of the device low, particularly since the target market was aimed at developing countries and NGO organizations. The need was also to use a device that is proven to be scalable and robust in different settings. The Simputer[12] with its promise of ruggedness and simplicity was the obvious choice during the initial stages of development. However with hardware prices of Simputer in the current market (June 2002) being close to US$300 and given that the device is not yet easily available for large scale deployments, it was decided to use Palm-based devices. The Palm-OS based devices such as the Palm m125, Palm 105 and Handspring Visors have matured to be a stable platform for variety of applications. The software that is currently being developed is intended to be work on these devices which are in the US$100-$125 range. The software had to be re-designed completely to allow further generalization to be used in different rural healthcare scenarios. The software was designed with modules for both maintenance of medical records as well as conducting paper-less surveys in the field setting. The system allows integration of other technology such as GPS for disease surveillance, wireless modules for interactive telemedicine, low-cost cameras for teledermatology and use of other telemetry devices. There was also emphasis on creating a general framework for point of care evidence based medicine using Clinical Guidelines. This includes abstraction of rules and adaptation of rules for local settings [16]. Thus while the research project was designed with to solve a specific problem in a specific setting, the commercial product required generalization at the design level to ensure wider applicability of the platform.

2. **Funding issues**: Given the nature of the mobile healthcare software business, which requires highly skilled engineers and doctors to make a successful product, adequate financial support is necessary.. Unlike traditional companies focused on creating products for so called 'lucrative' markets where traditional Venture Capital is sought, a venture of this type requires a careful approach to potential investors. There are several Social Venture firms which are more likely to fund such operations. Another approach is to target socially responsible angel investors who are often enthused by technology that can potentially change lives of millions of people. Many startups also seek funding through government (US and Non-US) and non-governmental (Philanthropic foundations) research grants. These typically take longer cycles to obtain funding compared to Venture Funds, but have the added advantage preventing loss of equity for the founders.

3. **Market focusing**: One of the key lessons learnt was to have an approach that will allow the technology created for rural healthcare markets in developing countries to be used in other affluent countries too. In this case the same platform that is being used for healthcare workers to deliver vaccines in India can be adapted to be used for clinical trials by pharmaceutical companies. There is also a relatively untapped market of elder-communities in developed countries served by home-care nurses who conduct home visits for routine medical care of the elderly and disabled. This kind of dual focus at two different markets requires a lot of effort from the founders, but in the long run allows building of a robust business model.

4. **Customers** : In the current economy with many sources of venture funds drying up, for a successful business, the ability to acquire customers and generate revenue is the key. Just as the first round of funding is the most difficult part, finding and delivering a satisfactory solution to a customer is the most important thing. With customers also comes better definition of the problem and valuable insight into real world practical issues which can often be different from research objectives.

5. **Partnerships** : Partnerships can help a new operation in both acquiring new customers and better focusing on products. Any partnerships which include research organizations, NGOs and commercial entities are often time consuming from a legal point of view but very productive in the long run

A finally a few golden rules :

1. Always hang in there, never give up
2. Network with people and get the word across
3. Be passionate and have a well-defined vision
4. Get the right people, they are the most important asset

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Figure 5: Health worker in Ballabhgarh, India using a PDA

Figure 6: The iPAQ with the Ca:sh application