Portable Health Clinic: A Pervasive Way to Serve the Unreached Community for Preventive Healthcare

Ashir Ahmed[1], Sozo Inoue[2], Eiko Kai[1], Naoki Nakashima[3], and Yasunobu Nohara[3]

[1] Faculty of Information Science and Electrical Engineering, Kyushu University
744, Moto'oka, Nishi-ku, Fukuoka, Japan
{ashir,kai}@soc.ait.kyushu-u.ac.jp
[2] Faculty of Engineering, Kyushu Institute of Technology
1-1 Sensui-cho, Tobata-ku, Kita kyushu, Japan
sozo@mns.kyutech.ac.jp
[3] Kyushu University Hospital, 3-1-1, Maidashi, Higashi-ku, Fukuoka, Japan
{nnaoki,y-nohara}@info.med.kyushu-u.ac.jp

Abstract. One billion people (15% of the world population) are unreached in terms of accessing to quality healthcare service. Insufficient healthcare facilities and unavailability of medical experts in rural areas are the two major reasons that kept the people unreached to healthcare services. Recent penetration of mobile phone and the unmet demand to basic healthcare services, remote health consultancy over mobile phone became popular in developing countries. In this paper, we introduce two such representative initiatives from Bangladesh and discuss the technical challenges they face to serve a remote patient. To solve these issues, we have prototyped a portable health clinic box with necessary diagnostic tools, we call it a "portable clinic" and a software tool, "GramHealth" for archiving and searching patients' past health records. We carried out experiments in three remote villages and in two commercial organizations in Bangladesh by collaborating with local organization to observe the local adoption of the technology. We also monitored the usability of the portable clinic and verified the functionality of "GramHealth". We display the qualitative analysis of the results obtained from the experiment. GramHealth DB has a unique combination of structured, semi-structured and un-structured data which can be considered as BigData. We have partly analyzed the data manually to find common set of rules to build a better clinical decision support. The model of analyzing the GramHealth BigData is also presented.

Keywords: Portable Clinic, Personal Health Records (PHR), Remote Health Consultancy, BigData, CDSS (Clinical Decision Support System).

1 Introduction

There are 1 billion people are unreached in terms of accessing to quality healthcare service [1]. About four thousand children die of diarrhea in a day, one pregnant mother dies in every 90 seconds. This scenario can be dramatically changed if we can simply convey few simple medical tips to the target unreached community. Most of the unreached people are from rural areas in developing countries [2]. Healthcare

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service does not exist there for two major reasons: (1) Doctors do not want to stay in the village as they do not find their livelihood requirements fulfilled (2) Quality hospitals/clinics cannot sustain without stable income. Recently, mobile phone became available in each corner of rural areas. Health consultancy over mobile phone became popular in Bangladesh as an alternative solution. One such service holder receives 15000 calls per day for health consultancy [3]. Consultancy over mobile phones brought many benefits to the people especially to the remote female patients. Female patients can consult with a remote male doctor anonymously for discussing private diseases. People can call at any time of the day from anywhere in the country. A doctor can prescribe OTC (Over The Counter) medicine, can interpret clinical records and also can introduce a hospital or doctor near the patient's place. However, in order to diagnose a disease properly, doctors need to see the clinical records measured by diagnostic tools. Kyushu University in Japan and Grameen Communication's GCC (Global Communication Center) Project in Bangladesh have prototyped an affordable "portable clinic" [4] to be deployed in a community and to measure basic health data. The collected data will be made available at the doctor's side before the patient make a call. The "portable clinic" project started checking health data as a "health check up service" in the remote areas in Bangladesh. The health records were analyzed locally with a predefined logic and categorized them in four groups: green (healthy), yellow (caution), orange (affected), and red (emergent). Patients with orange and red have unusual clinical results and are selected to consult with the doctor over video conferencing tool to be equipped with the portable clinic.

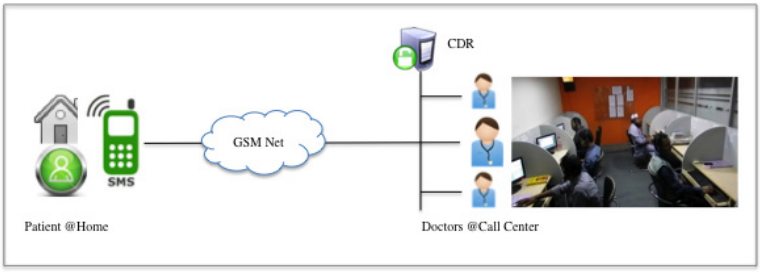

Fig. 1. A typical mobile based remote health consultancy system. A patient from home calls using a mobile phone. An urban doctor in a call center picks the call and provides health consultancy.

In this work, we introduce the current status of two representative remote health consultancy systems, case study results obtained from one of the health consultancy service providers in Section 2. We also describe the technical challenges. Section 3 describes the anatomy of our portable clinic and introduces a mechanism which can serve patients in a mass scale in rural community. GramHealth tool is also explained in this section which collects and archives personal health records. We have served 8690 patients and collected their health records to discover meaningful medical information. The results are discussed. Section 4 summarizes our work with future directions.

2 Remote Health Consultancy for the Unreached Community

Remote health consultancy in developing countries is applied quite differently than developed countries. Presence of mobile phone connectivity is higher than the Internet connectivity. Therefore, the patients in the remote areas use mobile phone for communicating a doctor. In a typical mobile phone based healthcare consultancy system, the doctor is located in an urban area in a call center. The doctor has a facility to receive phone calls, a computer based hospital database to support the patient. At the patient side, there is only a mobile phone. The patient calls to a hot-line number of a call center (Fig. 1). The call is usually routed to a doctor in a round-robin fashion. The consultancy has three major phases.

(a) Introduction phase: the doctor introduces him/herself, and then asks for patient basic information (name, age, sex, location etc.). Location is important to introduce a nearby hospital.
(b) Diagnosis phase: the patient explains the symptom and then the doctor interrogates the patient based on the symptoms to find out the cause of the symptom.
(c) Advice phase: the doctor then either prescribes medicine (over the counter medicine only because of the medical policy issue), or suggests a nearby hospital for further checkup and consultancy. An advanced healthcare service provider keeps the patient-doctor conversation records in a CDR (call details record) and uses special software tool to keep the patient profile details including the list of medicines prescribed.

We have gathered the patient-doctor conversation records archived in December 2009. We have found that there were more than 10,000 audio call records. We have clustered the records in 100 groups and randomly selected 400 audio records for our case study. There are a good number of female patients making calls (33%) by themselves. This is quite amazing to observe because a female patient is usually attended by the husband or parents. In many cases, they feel shy to share their private diseases with a male doctor. However, over a mobile phone, the female patients are less hesitant. This is an amazing advantage of remote consultancy over mobile phone. The following table [Table I] has the summary results of our observations. The detail explanations can be found in our previous work [8].

Table 1. Analysis of doctor-patient conversation in a call center

Observed Item	Results (n=400)
(a) Caller	Patient: 60%, Relatives: 40%
(b) Age distribution of the patient	0-10 years: 29%, 11-20 years: 15% 21-30 years:24%, 31-40 years:17% 41-50 years: 9%, 50+ years: 7 %
(c) Sex	Male: 67%, Female: 33%
(d) Location	Rural: 30%, Urban: 70%
(e) Call completion	Complete: 68%, Incomplete: 32%
(f) Time of call	Day (8:00-15:30): 57 % Evening (15:30-23:00): 18% Night (23:00-8:00): 25%

Table 1. (*continued*)

(g) Time occupancy of a single call	Introduction phase: 8%, Diagnosis phase: 27%, Advice phase: 67%
(h) Consultancy about	Disease related: 79%, Preventive healthcare related: 21%
(i) Type of advices	Prescribed medicine: 54% , Advice: 28%, Referred to specialist/hospital: 17%,
(j) Patients	Follow up: 17%, New: 83%
(k) Patients' satisfaction	Fully satisfied: 71%, unsatisfied: 21%, average: 8%
(l) Major diseases consulted	Gastro-intestinal: 22%, Respiratory: 17%, Reproductive:10%, skin: 10%

2.1 Technical Challenges

Although our study shows that 71% people are satisfied with the present mobile phone based consultancy service. There is however, a big room for improving the service by introducing simple additional functions into the present system without making any substantial changes in the infrastructure. In this section, we discuss the technical challenges followed by our ideas to address these issues.

1. Maintaining a patient ID: A patient ID is a key element to keep and maintain individual healthcare records. The present system does not offer a unique ID to their patients. A CDR keeps the mobile phone number of the caller, however there are cases when a patient calls from relatives' phone or uses a family-owned share phone. Therefore, the phone number cannot be a unique ID.
2. Disease diagnosis process: In the present system, there is no diagnostic tool at the patient side. The doctors are afraid of making inaccurate assumptions from the symptoms expressed by the caller. A physical measurement is necessary to better understand the degree of a symptom and to make a better clinical decision. Diagnostic tools for most of the common diseases are available in a nearby pharmacy. But there is no good way to transfer the data to the remote doctor.
3. Patient profile archive: The doctors at the call center are offered and trained to insert the patient profile during the conversation. Many doctors do not feel comfortable to use a computer during the conversation. Also it will take extra time to insert the patient profile keeping the patient on the phone which irritates the patient. As a result, the patient profile never gets sufficiently stored. Without past records, it is difficult to take care of the follow-up patients.
4. Patient's location: Currently the call center has to ask a series of questions to identify the geographical location of a patient. A doctor cannot accurately refer a patient to a hospital or to doctor if patient's location is not known. Recently Bangladesh Directorate General of Health Services (DGHS) provided a standard code for geo-location for every union (the smallest administrative unit) [http://app.dghs.gov.bd/bbscode/] in Bangladesh. However, the codes are not known to the villagers neither it is widely adopted in the country.

5. Prescription: Most of the medicines in Bangladesh have English names. The low-literate patients have difficulties to understand the names prescribed by the doctor and take a memo. Some providers started using SMS to send the medicine names. There is a policy that the doctor can only prescribe OTC medicine. Therefore, the doctors can treat only limited number of diseases.
6. Health Data Portability: Some patients have the past clinical records in hard paper format. It is difficult to read out the clinical data for the remote doctor. Some hospitals keep the past records in digital format. Currently there is no scheme to transfer the digital data from one hospital to another. The same is true for the developed countries.

3 Our Preventive and Pervasive Healthcare Approach

In this section, we describe our portable clinic concept and explain how to archive PHR of the villagers in an efficient way.

3.1 Portable Clinic and GramHealth to Efficiently Serve the Remote Patients

We considered "disease diagnosis issue" as the primary missing item in the current mobile phone based remote health-consultancy system and proposed an affordable, usable and sustainable concept "portable clinic" [5] to be added in the current initiative for preventive healthcare.

Portable Clinic: is a device equipped with essential diagnostic tools (for temperature, blood, blood pressure, ECG, urine, etc). The clinic is designed to be affordable (<US$300, this is an amount that village nurse can borrow from micro-finance institution such as Grameen Bank in Bangladesh) and can be carried by a village female health assistant. A prototype of the concept has already been developed and is in the field for our experiment (Fig. 2).

The portable clinic box will be owned and operated by a village health assistant. In an ideal situation, she will visit the patients' doorstep for regular and on-demand physical checkup. The personal health records will be stored in the local portable clinic as well as in the central GramHealth database.

GramHealth: is a software tool developed by our department considering the needs of the villagers. The call center doctor can access GramHealth through the Internet or have a copy of the database in their call center server. Upon receiving a call from a patient, the doctor now can find patient's previous record. This way, the doctor doesn't need to repeatedly ask questions about the patients' personal profile. The doctor's precious time is saved and also the cost burden of the patient will be less. It also provides a good mental impression to the patient when the doctor reads out patients' past records and asks follow up questions. A past record contains previous prescribed medicine and the doctor can easily ask the status for the follow-up patients.

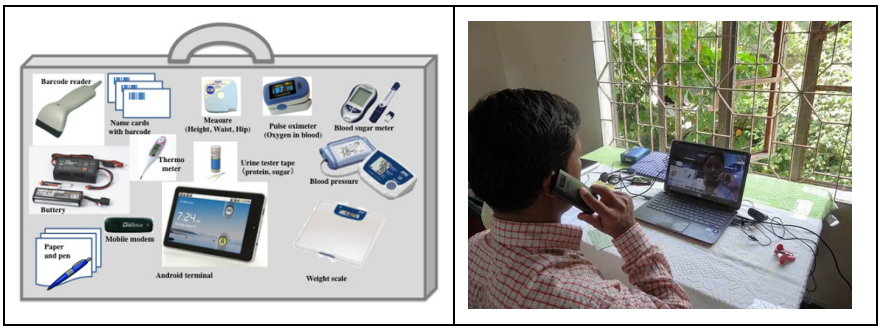

Fig. 2. (left) a prototype of the portable clinic with 12 basic diagnostic tools. (Right) a rural patient is consulting with a doctor by using mobile phone for voice and skype for video communication.

3.2 Experimental Environment

We carried out experiments in urban, sub-urban and rural areas in Bangladesh from September 2012 to January 2013. Our experiment environment consists of the following facilities: (a) a small call center in Dhaka (the capital city of Bangladesh) with two female and two male doctors, and one transcript writer (b) A portable clinic with 12 diagnostic tools (as in Fig. 2) (c) GramHealth software tool to obtain and maintain the patient health records (d) A portable clinic health check up team consisting two health assistants, 3 program assistants and one quality check officer. GramHealth does not automatically capture data from all the diagnostic tools, BAN supported tools automatically uploads measurement results through wireless; others are manually inserted into our GramHealth database through a user-friendly web interface (d) considering the network infrastructure facility in the village, we have developed a off-line version of GramHealth to store the obtained health profile locally and send to the central server when the sufficient network bandwidth is available.

In order to save time and cost, we designed a group checking methodology and introduced a triage to classify the patients by observing their health status and considering their level of emergency. There are four steps.

(a) **Registration**. A patient registers his/her vital information such as name, age, sex, location and disease complaints, if they have any. A data entry operator inputs the data into GramHealth DB. A patient ID is given to the patient.

(b) **Health Checkup**. A healthcare assistant takes the patient's physical check up (body temperature, weight, height, BMI, Waist, Hip, Blood test, Urine test etc.) and send the data to GramHealth server. Few diagnostic tools are equipped with wireless BAN (Body Area Network) to automatically send the measurement data to GramHealth DB. We have also developed a B-logic (Bangladesh Logic) to determine the risk satisfaction intro 4 grades, green (healthy), yellow (caution), orange (affected) and red (emergent) as depicted in Fig. 4. The "green" patients are given the health checkup results. The "yellow" marked patients are given a healthcare manual developed by us. The "orange" and "red" marked patients consults with a call center doctor.

(c) **Tele health consultancy**. As mentioned above, only "yellow" and "red" marked patients talk to the doctor for further investigations of their disease and explanation of their medical records. Tele health consultancy is over voice and video. The audio record is archived in GramHealth DB.
(d) **Prescription and Suggestion**. The doctor identifies the disease after checking the clinical data, discussing with the patient for their symptom analysis and his/her past health records, if any. The doctor then fills up the prescription and a technical assistant helps the doctor to insert the necessary information into the database.
In this experiment, we aim to (1) observe how the technical challenges mentioned in section 2.3 could be efficiently solved, (2) monitor whether the system can work with the compromised infrastructure- where unstable bandwidth and regular power-outage is common (3) Study the properties of GramHealth DB and find rules to feedback the CDSS system.

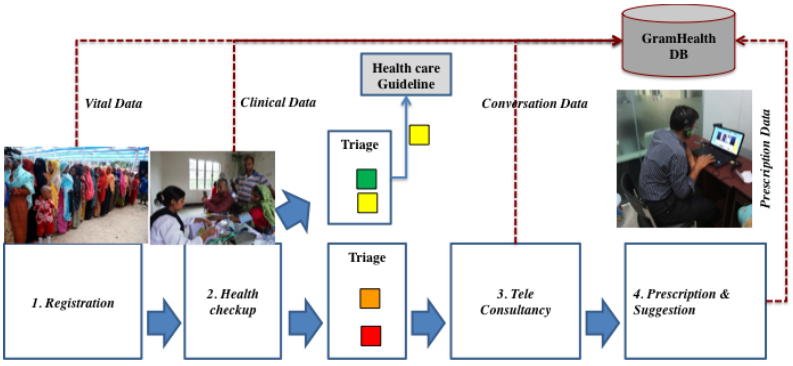

Fig. 3. Experimental environment with Portable Clinic and GramHealth systems and the 4 steps methodology to efficiently carry out group health check up in remote areas

3.3 Results and Discussion

We have checked up 8690 patients and accommodated the records in GramHealth DB. The experiment was carried out in two rural areas: Ekhlaspur in Chandpur district and Chhoygaon in Shariatpur distrcits. Total rural patients from rural areas were 2728 (31.28% of the total patients). We also carried out experiments for the women in a garment factory and for the daily laborers in a construction company totaling 2890 (33.3% of total patients). They are considered as sub-urban patients. 3032 patients from three different industries in urban area participated in our program.

We have developed necessary features in GramHealth to solve the issues described in Section 2.1. Our experiment confirmed that 5 of the 6 issues are functioning. We have not worked on the data portability issue yet. This will be a future work for us.

In one of our experimental areas in Ekhlaspur, there is no communication network. Our offline mode of GramHealth perfectly analyzed the data on the spot to classify them into four groups. Consulting with the doctor from the spot was not possible.

Properties of GramHealth DB: As depicted in Fig. 3, Gram Health DB collects data from four types of data from four different sources.

1. **Registration Data.** Registration data has personal data and inquiry data. Personal data (Name, Age, Sex, Address, Check-up date) is structured, but inquiry data (complain, symptom, family information and life style information) is Q&A text type and semi-structured.
2. **Check-Up Data.** Check-up data contains clinical measurement data. All data is structured and used for triage of patients, cohort analysis and comparison with past data. Triaged and colored sensor data items give us not only the value on each item for doctor but also some quantitative and educational information (crucial, risky, attention, healthy) for patients.
3. **Conversation Data.** Conversation data is captured by an audio recorder. These data are completely unstructured. In order to analyze these data, it is necessary to convert the data from speech to text. Unfortunately there is no efficient Bangla speech-to-text tool. At this stage, we have to manually listen to all the audio records and input the narration into the DB.
4. **Prescription Data.** Prescription data contains prescription from the doctor e.g. cheap complains, suggested medications and guideline to take the medications. In prescription data, the disease names are not mentioned, so they need to be classify into disease categories.

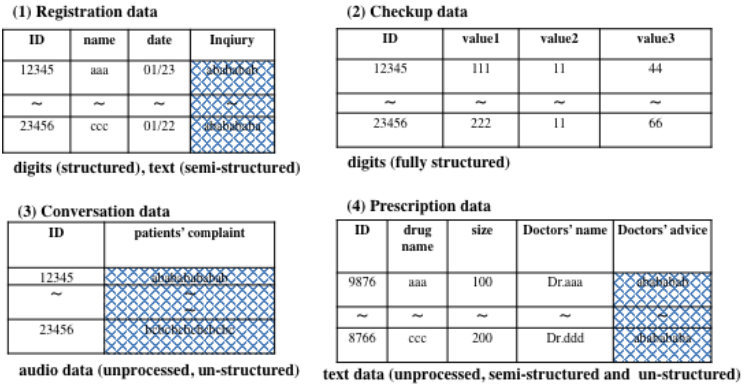

Fig. 4. Properties (variability) of GramHealth DB

As shown in Fig.4, GramHealth DB has heterogeneous types of data. In order to analyze GramHealth DB to discover meaningful medical information, we face two major issues: each data has different structure and is kept scattered; there is no connection between each silo of database. We have focused on health check-up data and prescription data and discovered few meaningful information. The information is under investigation and will be published elsewhere. The investigated items are- (1) Influence of clinical data on triage (2) Geographcal pattern in clinical data (3) Discovery of clinical diagnosis (disease name) from drug name (4) Disease pattern of patients (5) Influence on choosing drugs from doctors' preference (6) Tuning of triage (b-logic) (7) Relationship between prescribed drug name and clinical data and (8) Potential meaning in the inquiry data.

We came up with a model to analyze GramHealth BigData. Fig. 6 explaines the process. Firstly, we preprocess the GramHealth DB for easier analysis. Preprocess

includes converting the audio data into text, shape the unstructured data into structured manner. This part needs further investigation. The processed data will be linked to produce meaning medical information. Once the data is ready, it will be fetched by the applications (CDSS, trending etc) to serve the patients and the doctors.

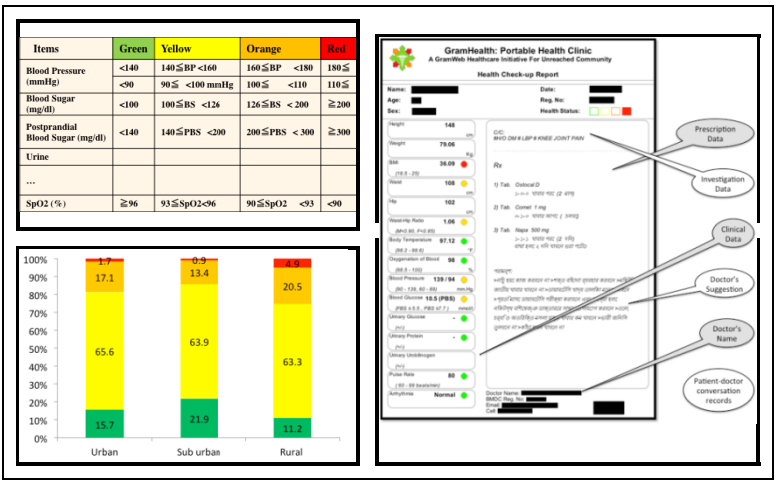

Fig. 5. (Left up): B-logic. Based on International Standards. This logic is applied to classify the patients in four groups. It is partially shown but full data is available in [8]. (Left bottom): after applying b-logic to 8690 patients. The bar graph shows the triage level in urban, sub-urban and rural areas. (Right): GramHealth prescription filled up by the doctor. The left side shows their health status for individual clinical results. The principal complain and investigation is mentioned on the top right area. The prescription, suggestions for health maintenance is also mentioned. Call center doctor's name is also recorded for the follow up consultancy in future.

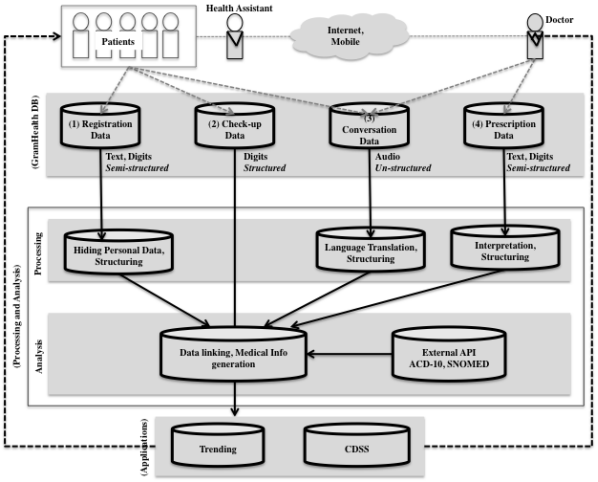

Fig. 6. GramHealth DB to produce useful medical information for the doctors and patients

4 Conclusion and Future Works

In this work, we introduced the technical anatomy of mobile phone based remote consultancy services in developing countries. We carried out a case study to analyze one-month long patient-doctor voice records logged by a healthcare service center. We reported our findings which reflected the demand and the adoption of technology based on the socio-economic culture of the country. We explained the technical challenges in the highly compromised infrastructure and proposed the affordable and usable "portable clinic" to collect health care data from the patients' door in an efficient way. We also developed a software tool "GramHealth" to collect and store the data for the remote doctor in the call center. The health records are producing a BigData of 10,000 villagers to be populated by end of March 2013. As a future work, we will analyze the collected BigData to turn our Database into a knowledgebase so that the patients, researchers and common people find the system more useful as a source of info-medicine.

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