MDphone: A Doctor's Tools in a Phone

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Abstract
It is time to bring better health care to under-served communities. Unfortunately, there is dearth of health care professionals that is unlikely to be filled any time soon. We propose building a modern set of tools typically found in a modern doctor's office (e.g., stethoscope, otoscope, etc.) into a mobile phone. However, we will also enhance the tools so that less trained individuals (as is commonly the case with community health workers) get assistance from the technology in getting good measurements so they provide immediate feedback and can serve for remote diagnosis and archival in the patient's records.

Keywords
ICTD, instrumentation, data collection, signal processing, visualization.

ACM Classification Keywords
General terms: Human Factors, Measurement. H4.m. Information Systems Applications: Miscellaneous.

Introduction
At the University of Washington, the Change group [1] is developing information and communication technologies (ICT) to help with the problems of under-served communities as far-ranging as education, health care, transportation, and agriculture. One of our new

thrust areas is providing modern medical examination and diagnostic facilities in a mobile context.

Our immediate goal is to build a suite of medical instruments around a highly mobile platform that is familiar to its potential users while also providing communication capabilities such that the measurements and images taken with the device can be easily propagated to medical databases (e.g., OpenMRS [2]) or used for remote diagnosis. Building upon existing mobile phone technology allows us to leverage something that is already pervasive to improve healthcare. While the mobile phones used may need to be smart phones, to the user it will be more of an upgrade to a familiar technology rather than moving to an entirely new platform.

Today's mobile phone platforms, such as WindowsMobile, iPhone, and Android, are finally capable enough (with rich I/O capabilities including cameras and USB) and powerful enough to form the foundation for the computational elements of a wide variety of instruments. Mobile phones are the platform of choice because they are relatively easy to power (even from a solar charger) and have rich communication capabilities including GPRS, Wi-Fi, SMS, and Bluetooth. We use the Android platform because it is open-source, has a very flexible and familiar programming environment, and easy access to elements of the underlying hardware (with USB support coming).

We started moving in this direction with our work on Open Data Kit (ODK), a suite of modular tools for mobile data collection [3]. Visits with community health workers (CHWs), at clinics or at households, provide an opportunity to document the state of patients and also make a quick analysis of whether they should require further attention [4, 5]. Referrals to clinics and follow-up interviews are a frequent function for CHWs. Unfortunately, CHWs are not registered nurses or physicians, but rather employees of a non-governmental organization (NGO) or health facility that has received minimal training and is not in a position to interpret medical data for diagnosis or even triage. The World Health Organization (WHO) publishes common protocols for conducting examinations. Among these is the Integrated Management of Childhood Illness (IMCI) protocol for pediatric triage. These protocols are flowcharts of questions that guide a CHW to the right conclusion. The questions may require the taking of measurements such as temperature or breath frequency. A common problem with such protocol is the rate of adherence that has been shown to be boosted when the protocol is in electronic form that can better show the current context of an examination [6].

Our ultimate goal is to be able to have CHWs perform all the measurements common in a modern doctor's office, possibly in a mobile context, and be able to collect high quality data that can be processed locally to help insure it is interpretable by a physician later (whether for remote diagnostics or archiving and future comparisons). By utilizing the mobile phone as a platform for additional diagnostic devices we will create a mobile medical kit that will hopefully improve data collection and analysis. Most importantly, interpretation of the data directly on the phone will help ensure higher-quality data samples from an under-trained workforce.

Common Medical Instruments

The most common medical instruments are mostly non-electronic, e.g., stethoscope, blood-pressure cuffs). We are not suggesting a collection of Bluetooth-enabled devices that would cluster around a phone to provide their data. Devices need to be simple to operate and intuitive. They should not require a separate power source that has to be kept charged nor communication links that are complex to setup and frail in their operation.

There are a common set of instruments and measurements that are part of typical doctor's examinations including (but not limited to): stethoscope, otoscope, thermometer, and electrocardiogram (EKG). Then are observations including: frequency and quality of breathing and coughing. There are also specific low-cost tests including: blood count and fecal occult blood presence. Finally, there is the patient's past record which may raise or lower the importance of the previous measurements and observations. In addition, the data from every examination needs to be recorded for future reference and trend analysis.

These measurements and observations can be classified into audio, image, or data centered. Fortunately, a modern mobile phone has a microphone and speaker, a high-resolution camera, and ample data storage.

Starting with the audio-oriented features, we are working on methods of connecting a stethoscope diaphragm so that the phone can display a waveform on its screen. The objective is to provide feedback to the CHW to better position the stethoscope for a sharp enough signal including providing visual diagrams of placement at different points on the chest or back. The reason for the feedback is to ensure a proper recording that can be analyzed for heart rate and basic EKG-like properties as well as ensuring that any recording is of sufficient quality so that it will be useful in the record for comparative purposes. The stethoscope can also be used in conjunction with a simple blood pressure cuff to signal to the CHW when to take the systolic/diastolic measurements based on the audio input. Of course, we could use an electronic cuff to register the readings directly, however, we are most interested in keeping costs down (including purchase and maintenance).

For visual observations, the situation is similar. An attachment to the phone's camera providing the optics to peer into an ear canal can let the camera take a picture of infections of the ear. We are measuring vision algorithms to detect the position of the eardrum and eventually automatically make a determination of an ear condition. This can be done with a set of training images from the medical literature. However, just enhancing the image onto the phone's screen can already make a functional otoscope, but one that can also record the image. We can take this further and be able to analyze the color spectrum of a fecal occult blood test and determine whether bleeding is occurring. Going further, another attachment can be used to automatically analyze a blood smear for cell counts [7]. We are also considering USB ultra-sound probes that can be connected to the phone and utilize its screen for feedback [8].

Other instruments provide specific data values. Thermometer values can be simply entered into the system as can blood pressure values triggered by the acoustic analysis. Data from patient records can be used to compare to current readings and have the CHW ask for more information related to that situation. In the end, the objective is to help lay people to better detect serious medical conditions. By improving the medical data available to the CHW the medical kit will hopefully enable more accurate medical referrals that will better use scarce human resources and lead to better diagnoses [9, 10, 11]

Conclusion and Larger Impacts

People in low-income countries and regions do not have the resources to purchase specialized medical equipment pervasive in the developed world. Highly connected mobile phones represent a great potential platform to build "ubicomp" medical services for under-served populations as mobile phones have become pervasive even in poor regions. The key to exploiting this existing infrastructure is to enable applications on smart phones that can augment and improve healthcare processes. Designers must rethink some core assumptions to be able to integrate computing with physical processes world-wide. Assumptions such as network connectivity, power availability, literate users, availability of disposable income to spend on multiple devices, etc have become prevalent in system design in the developed world. When designing systems for under-served populations we are pushing into design spaces that may not be normally investigated by conventional design, and we may discover improvements in healthcare processes that can be applied to the developed world that may change the direction of current design even in developed areas.

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