Nossal Institute for Global Health - Uni. of Melbourne
Low-cost Technology for Health in Developing Countries

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Who we are

A multi-disciplinary group at the University of Melbourne developing mHealth applications and electronic medical diagnostic sensors. Our team includes experts in global health, intelligent software systems, biomedical sensors, physics, clinical medicine, and others. We collaborate with the CSIRO Australia, Grameen Inc., Eduardo Mondlane University (Mozambique), Khalifa University, Microsoft, Accenture, and other groups.

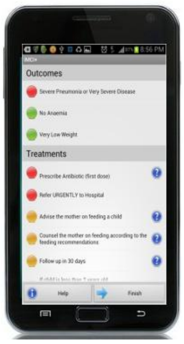
Our Mobile Phone Applications and Medical Sensor Projects

A basic architecture of software and hardware

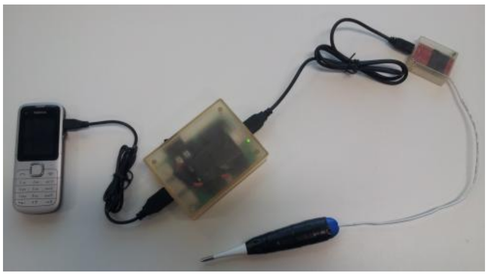
We have developed a basic generic device architecture in two distinct modules:

- **Phone Module**: Mobile phone software applications, both stand-alone apps, and apps that receive data from sensors, both on the phone (e.g. camera, GPS, accelerometer) or from connected sensors (sensor modules).
- **Sensor Modules:** Added hardware and chip firmware allowing for extensions of the phone's diagnostic sensing capabilities. Includes a 'smart cable' that connects and processes data between various pluggable sensing devices

- **Agent-based Clinical Decision Support System - "ADSS"**. An intelligent platform for clinical decision support. First application was the Integrated Management of Childhood Illnesses (IMCI) - which we have dubbed **"IMCI+"**



- **"Smart Cable" medical sensor platform** for connecting low-cost medical sensors to various types of phones. The smart cable has a standard connection protocol designed for other manufacturers to develop their own pluggable sensors. We are developing/have developed our own sensors: thermometer, ECG, PCG, pulse oximeter, non-invasive haemoglobin sensor, and others.



- **Low-cost Fetal Monitoring Device** based on **phonocardiogram (PCG).** Using cutting edge digital signal processing that separates and filters abdominal "noise" to detect fetal heart and body movement, pregnant mothers can be monitored and diagnosed for any maternal complications. **Cheaper alternative to ultrasound, can be widely distributed to save lives.**

- **Collaboration with CSIRO to develop next generation sensors that detect "fingerprints" in breath and urine** (metabolites) that indicate a range of illnesses. These sensors are the gold nano-particle (for urine) and metal oxide (for breath) sensors, and are planned to integrate with the "smart cable".
- **Drug dose app and drug formulary**. A subset of the information in the local pharmaceutical formulary (drug names, indications for use, dosing regimens and presentations), used by health workers to prescribe to patients without need for a physician.
It is straightforward to modify the application for a different interface language and for a different set of formulary data, so that it can be customised for any health service.

- **Other Smaller Apps either** developed or planned for release soon. These include a **drug dose reminder** for the patient's own phone, an **immunisation catch-up app**, an **emergency button** for people from vulnerable groups, **Drip Rate Calculator** (dramatically simplifies adjustment of IV drip), **Pregnancy management app** (determine gestational age of foetus), **Respiratory Rate counter** (simplifies counting breath for breathing rate, a useful measure for diagnosing pneumonia), and others......

Sensors and pluggable devices

We are working on simple-to-use diagnostic devices that can be used as screening tools soon after the patient's arrival at the clinic which will allow the unskilled assistant to triage patients, and also provide the essential diagnostic and assessment information for the health worker.

Diagnostic platform for febrile illness

In collaboration with CSIRO, and with funding from the Science and Industry Endowment Fund (SIEF), we are developing and testing a novel diagnostic approach using two types of 'electronic nose' (eNose), which will eventually become pluggable devices attached to phones using our 'smart cable' platform. One type of eNose uses samples of exhaled breath and the other uses urine, so both are entirely non-invasive.

This project is at the 'proof of concept' stage, using data and specimens collected in two major Melbourne teaching hospitals to differentiate patients with and without bacterial infections. Once this is achieved we will move on to a developing country setting and work on other causes of fevers.

Pneumonia screening device

This device facilitates the diagnosis of pneumonia (globally, the largest cause of death in children under five) by simultaneously measuring body temperature, respiratory rate, pulse rate and the proportion of the respiratory cycle in expiration, using a single non-invasive sensing device under the child's armpit. Where abnormal results are detected an integrated pulse oximeter will assess disease severity. This information will be used to enhance and improve the standard Integrated Management of Childhood Illness (IMCI) algorithms.

A spin-off from this project is 'Team Stethocloud' – a group of University of Melbourne students who recently won the Australian final of the Imagine Cup competition. Their approach is to use a modified stethoscope to record breath sounds from a sick child, send them to the 'cloud' via a smart phone, run a diagnostic algorithm on the sounds, and return the results to the user within one minute. The project is well covered owing to its victory in the competition, but the main announcement and video can be accessed at: http://www.microsoft.com/australia/imaginecup/Finalists.aspx#.T-AlSrU_8TI.

Fetal Monitoring device

This device is a cheaper alternative to ultrasound to monitor pregnant women's fetus, and can be used by health workers or patients themselves for in-home monitoring. It uses a matrix of phonograms (acoustically amplified microphones) to listen to the abdomen with cutting edge digital signal processing (DSP) and agent-based algorithms to determine fetal movements, fetal heart rate and fetal position (e.g. breach position or normal). This will assist health workers to identify pregnant women with possible complications that can either be treated in the primary health clinic, or referred to a specialist obstetrician. It can also be used to monitor pregnancies in home without the use of invasive techniques such as ultrasound, and has the potential to save many lives.

Others

A number of other pluggable devices are at different stages of development. These include a method for non-invasive measurement of haemoglobin and improved methods for anthropometry (weight and height measurement) in children.

Testing and Release

No devices or software will be released without appropriate testing and, where possible, publication in peer-reviewed journals. In each case we test for proof of concept, then that the solution is as accurate (in the hands of health workers) as current methods. It must also have high user acceptability, and be consistently used by unsupervised health workers. In the longer term it may be possible to perform large enough clinical trials to show improved outcomes for patients.
From our devices, the pulse oximeter is in working prototype phase (currently being demonstrated in Mozambique), and the phonocardiogram and haemoglobin sensors are being developed by our electrical engineering and physics teams. From our software applications, all have been developed to "beta version" and are being refined in with our partners.

The problems we address

In developing countries the majority of curative services are provided in small district hospitals, sub-district health centres and other small clinics. In these facilities health workers are continually faced with a relatively small number of presenting syndromes, but they have only clinical signs and symptoms to guide diagnosis and the assessment of severity. The syndromes and clinical processes of interest include:

- **Acute respiratory infections**, including **pneumonia**, from which cases needing referral or those that can be safely treated locally are differentiated
- **Diarrhoea**, where the degree of dehydration and the response to initial treatment must be carefully assessed
- **Febrile illnesses**, where non-life-threatening illness must be distinguished from malaria or dengue.
- **Assessing anaemia non-invasively**
- **Antenatal and Neonatal care:**
    - Midwives can use an application to determine the date of the onset of the last menstrual period to calculate the date of delivery.

- A software and hardware tool can be used to monitor pregnancies, where the mother's haemoglobin levels as well as the foetal heart beat and movements are measured.
- Infants/small children must be screened for signs of growth faltering before its effects become irreversible.

Although accurate diagnostic technology exists for many of these problems, the current equipment is generally expensive and requires training to operate. The needed medical devices are rarely seen outside national and provincial capitals. In other cases suitable technology has yet to be developed **-** *but there is potential to save hundreds of thousands of lives across the developing world.*

Mobile phone networks have expanded into almost every corner of the world. Where they are available a majority of health workers have already bought them and carry them during their working day.

We are developing a flexible hardware/software architecture based on a health worker's own mobile phone with added sensors and processing capacity, to provide point-of-care diagnostic and therapeutic advice to the health worker, and in-home monitoring of chronic illnesses and maternal care for patients. Although not a solution to all global health concerns, the solution aims to enable national health services to raise the standard of care at the most peripheral levels, bringing better health services to currently under-served communities for the most critical health concerns.

We are advocates of sustainable practices, as well as "social business" models that enable growth and extensibility of health programmes.

Working principles

We believe that for any new health-care technology to be sustainable and scalable in developing countries it must conform to some basic principles:

1) **It should create as few costs as possible** – both capital and recurrent. Wherever possible it should use the health worker's own phone.
2) **It should give a response quickly**, preferably during (or even before) the consultation. In particular it should need no reliance on distant experts, who are already very busy and will not have "free" time to respond to new tasks sent them from the periphery.
3) **It should make the minimum demands for health-worker training**.
4) **All systems must be rigorously tested** and be of proven efficacy before they are released.

Ideally the solution will make minimal use of the mobile phone network: voice, data or SMS should only be used if needed, and avoided if possible. Such expenses can be prohibitive in many clinical settings, and can threaten the health budget in many countries particularly for application in widespread use. Low-cost phones are preferred, such as Nokia Series 40 range, or low-end Android phones. health workers' own phones should be used to save cost and reduce training due to familiarity.

We identify four different levels at which work is required on the components for such solutions:

Standalone software applications: Some useful tools can be built as stand-alone software applications that run on the mobile phone, using input from the health workers and providing calculations, reference material and decision support at the point of care.

Sensors that already exist but are too expensive for developing countries: Many devices considered indispensable in industrialised countries are expensive or complicated to run (such as the ECG or pulse oximeter). We are developing simplified, low-cost versions that are cheap enough to be widely distributed in developing countries. Using the same mobile phone and micro-processor platform with multiple different sensors and their associated circuitry both helps to keep the product cost down, and allows for integration and algorithmic approaches to diagnosis.

Sensors for which technologies exist but which have not yet been fully developed: Some diagnostic problems common in developing countries should be amenable to existing technologies. However, these problems are either not common in industrialised countries or are considered simple for well trained health workers, and there are no existing implementations. For these problems it will be necessary to first develop and test functioning prototypes, and then later create low-cost versions.

Sensors in concept, but for which no technological models/products exist yet: A number of important problems currently have no technological solution. These require a certain amount of 'blue sky' scientific work to start from completely new premises. Examples of these include the use of low-cost 'electronic nose' and 'electronic tongue' technology for the diagnosis of febrile illness currently being developed at CSIRO and Nossal Institute (see page 1).

Find out more

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