A Proposal to Develop a Cellphone-based Auscultation Device for the Preliminary Diagnosis of Heart Conditions

Section 1. The Idea

We propose to develop a cellphone-based heart monitoring device that could be used to radically improve the early diagnosis of conditions such as fetal distress, arrhythmias and aortic aneurisms. The affordability and wide availability of cell phones make them an innovative platform for the development of simple medical diagnosis capabilities for use in the field - especially in underdeveloped countries - where skilled medical practitioners and their more sophisticated devices are often thin on the ground.

Our cellphone-based prototype auscultation (or medical phonography) device will be coupled with specially developed cellphone application software to make possible a detailed analysis and preliminary diagnosis of individual heartbeats through digitized audio obtained from the patient's heart sounds. To ensure that the heart sounds are of sufficient signal strength we intend to couple the cellphone to a modified passive stethoscope. This system will allow users to make an initial "probably normal"/"refer to doctor" decision for a patient. In addition, since the recorded heart sound can be stored on the cellphone as a digital file (WAV/MP3) it can be sent on later for expert analysis, e.g. via Multimedia Messaging Service (MMS).

Scientific Basis of our Idea: Auscultation/Medical Phonography is an old and trusted technique that is part of the skill set of every doctor, and is the first technique used when the functioning of the heart needs to be evaluated. The listener can obtain information on rate and rhythm, valve functioning, and anatomical defects, collectively referred to as "murmurs." The successful use of auscultation to classify murmurs as innocuous or pathological depends on the listener's experience and training.

A cellphone-based auscultation device would prove to be an invaluable tool for making a first diagnosis of life threatening conditions in situations where a doctor is unavailable. In settings such as rural Uganda, for example, where lack of adequate medical care is a well-known problem, our proposed device could help users monitor the fetal heart at home, and detect potential fetal distress and related complications. Likewise, such a device could help provide diagnosis of diseases such as a ruptured aortic aneurism, which pose an extremely high mortality rate, since they are difficult to diagnose in time, despite having a characteristic and detectable signature.. Arrhythmias are at times difficult to catch and diagnose since they can be fleeting: by the time the patient gets to the physician's clinic or even ER they are gone. Using the cell phone device to immediately record sensation/symptoms would be of enormous help in diagnosing these cardiac rhythm anomalies. In these examples, the proposed system could act as a first response and potentially significantly decrease mortality rates by identifying conditions requiring immediate action and treatment much more quickly than is currently possible.

Section II: Experimental Plan and Testing

Experimental Plan: The auscultation device will involve coupling a stethoscope to a cellphone. A stethoscope is an acoustic device that in essence consists of a diaphragm, which is placed against the body and moves in response to vibrations, and a tube connecting the air behind the face of the diaphragm to the listener's ear. The

air pressure waves created by the motion of the diaphragm are thus heard. Every cellphone has an electronic audio subsystem that basically consists of a microphone and electronic circuitry that digitizes the microphone's electrical signals. These digital signals can then be processed and sent off the device encoded in radio waves. Typically, the electronic circuitry used is optimized for the frequency range of voice signals, and has limited response at the low and high ends of the audio spectrum. Most devices allow software access to the digitized audio from the microphone, for example, so that it can be recorded. Since the base frequency of heartbeats is of the order of Hz, the application software we propose to develop needs to overcome the bandwidth limitations. Possible methods we plan to investigate involve the use of Low Pass Filters, Averaging and Decimation, and other filtering and signal extraction techniques.

We propose to investigate schemes for acoustically coupling the earpiece or listening tube of a standard stethoscope to the cellphone's microphone. The latter is usually mounted inside the device, at the end of a small bore hole that opens to the outside. The coupling technique must be secure to prevent noise from vibrations and motion of the device or the stethoscope tube: we are confident that a successful method can be found.

Project Timeline and Essential Data: A small exploratory project in this area, involving two Caltech undergraduates, is planned for summer 2009. In this project, a prototype will be built and tested with software. Digitized heart sound data will be collected and methods explored for improving the signal to noise ratio and feature analysis. The results from that project will directly benefit to the work described in this proposal, and allow us to make much more rapid progress than would otherwise be possible.

We are in contact with Prof. Idris Rai of Makerere University in Uganda about both the innovative use of cellphones to help with healthcare delivery in parts of Africa, and this project in particular. Uganda has excellent physicians and facilities in Kampala, but the distribution of healthcare capabilities across the country is uneven. Makerere University has a strong information technology program: Prof. Rai and other faculty and students there are enthusiastic about participating in this project.

Budget Plan: We plan to devote 20 percent of the funding to supporting undergraduate and graduate students at Caltech and Makerere, with about 70 percent to partial salary support of a postgraduate researcher with strong programming skills and interests in medicine. Student research, with direction by faculty and staff, will focus on fundamental issues of understanding treatment of disease in places such as Uganda and the designs of inexpensive cellphone-based systems for this purpose. A staff person will ensure that the application is robust and runs on a variety of cellphones. About 10 percent of the funds would be used to purchase a variety of inexpensive stethoscopes, a small number of commonly available cellphones, and materials for building prototype, affordable, mechanical couplings between the stethoscopes and the cell phones. Some funds would be allocated to software licenses.