The Design and Implementation of a Digital Stethoscope for Remote Exploration

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Abstract:
As NASA moves into the next stage of human space flight with the Constellation Program - going to the moon and the ISS, it becomes especially vital to provide reliable and useful monitoring devices to continuously evaluate the health and fitness of astronauts without impeding their ability to function in a small, weightless environment. In compliance with the objective, the goal of this project is to design and build an experimental, compact, cost-effective and wireless digital stethoscope that is capable of collecting heart sounds, performing basic auscultation diagnostic functions and transmitting digitized data to a host computer for further clinical analysis. Although electrocardiogram (ECG) monitors are available, stethoscope can provide valuable cardiovascular information regarding valve closings and blood circulation of the heart. The proposed research represents a joint effort of multi-disciplines and requires integrated knowledge in areas of cardiology, microprocessor system, and digital signal processing.
NARRATIVE

Introduction
In space travel and any expedition of remote regions, medical support of hardware facilities and doctors which we usually take for granted are scarce. To maximize the health support for human explorers, it is necessary to continuously develop and redesign health-related monitoring devices as modern technologies and new inventions emerge. Of those health monitoring devices, the ones that provide instant information of human heart are of vital importance.

The heart acts as a pump to move blood through the arterial circulation by rhythmically contracting (systole) and relaxing (diastole). Through decades of integrated efforts from many disciplines, modern electronics embedded with advanced signal processing algorithms and clinical intelligence were developed to improve our knowledge of the anatomy and physiology of the cardiovascular system, e.g., electrocardiogram (ECG/EKG), echocardiography, magnetic resonance imaging (MRI), and cardiac catheterization, are routinely used. Heart sounds and murmurs, on the other hand, carry other types of information not available from devices mentioned above regarding the condition of the anatomy and physiology of the cardiovascular system, i.e., vibrations of heart walls originated from the closure of cardiovascular valves and the turbulent flow of blood [1]-[3].

Specific Goals
The target use of the proposed digital stethoscope is for explorers who should be able to move freely without the obstacle of monitoring devices. Without this consideration in mind, the specific goals are set as the following:

1. To record and digitize heart sound without the distortion of tubing effects
   Tubing effects caused by the stethoscope and other noise will contaminate the heart sound measurement. It will be best to digitize the signal inside the stethoscope.

2. To build a compact and intelligent device
   The target device should be small and lightweight, yet with sufficient processing capability for basic auscultation analysis.

3. To transmit digitized data to a host computer for more advanced clinical diagnosis.
   Transmission data between the proposed device and the host computer should be carried out using wireless communication.

In short, the goal is to design and build a compact, cost-effective digital stethoscope that will utilize modern wireless transmission and a microprocessor with sufficient computation capability. In addition, this device will be built with a visual LCD display and a speaker that can be turned on/off by the user.

Methodology and Procedure
To accomplish the goals aforementioned, the design can be divided into and carried out through the following steps:

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1. Fabricate a bell-diaphragm piece with a built-in microphone (Oct. 2006). This will be accomplished by inserting a miniature microphone into a standard stethoscope head. According to most studies, human ears are most sensitive to the frequency band between 1 KHz to 3 KHz, yet, the energy of heart sounds and murmurs concentrate mostly within the range of 5 Hz to 400 Hz. The microphone will be chosen to provide linear frequency response that covers from 5 Hz to 3 KHz.

2. Implement a microprocessor embedded system to perform to covert the analog waveform into digital format and perform basic evaluation (Nov. 2006 - Mar. 2007). A microprocessor embedded system powered by battery will be designed and wire-wrapped on a printed-circuit board.

3. Build a transmitter-receiver pair to allow wireless data transmission (Jan.-Feb. 2007). The range of the transmitter will be in the magnitude of 10-50 meters.

4. Add LCD display and speaker (Mar.-April 2007). With these additions, it will enable visual inspection and auscultation diagnosis on the spot.

The overall implementation is summarized in Fig. 1.

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**Fig 1: Design and Implementation of Digital Stethoscope**

The proposed device differs from what is currently available on the market by being more than a simple stethoscope that doctors normally use. It provides many potential benefits. By using an RF signal, multiple doctors could pick up the signal being sent out by the stethoscope, without having to all gather around a patient. Furthermore, it would be more portable than the majority of multifunction digital stethoscopes on the market. However, such set-ups are quite large and while suitable for use in a hospital, really cannot be practically taken out of such a setting. A digital stethoscope, such as the one presented in this proposal would fill a niche for those people who need to be monitored on a regular basis, but do not need to be bedridden. Such a device could be used in astronaut training programs, to monitor them during tests, exercise, and other activities without getting in their way. It could also be used while in space to send the data from the

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astronauts to a series of receivers built into the new Orion space shuttles, which could then transmit the data to the physicians at ground control.

As shown in Fig. 1, a digital stethoscope would require both mechanical and electrical parts, as well as computer programming. To be useful, a case must be designed to hold all portions of the stethoscope in a compact easy to use way, that allows the batteries to be easily changed, is comfortable in the hand, and will hold together in somewhat adverse conditions. When complete, the project will be a digital stethoscope capable of transmitting and displaying a heart sound waveform.

**Interdisciplinary approach**

The project will encompass many current areas, including electrophysiology, biomechanics, computer and electrical engineering. Although the project is experimental and design-oriented, the process itself will provide invaluable experience of integrating knowledge of multiple disciplines into a clearly defined design. The final stage of the project will encompass the use and design/implementation of microphone, signal conditioning circuits, embedded microprocessor system, wireless transmission and audio and visual data presentation, which broadens its scope significantly.

**Expected Outcomes**

The project is expected to be successfully completed in early April 2007 when every component is complete and integrated with the microprocessor based embedded system. The hardware implementation will be thoroughly tested and confirmed its expected function. Programs that will run on the embedded system will be tested, updated and improved as each new test on volunteers is complete. Microphone, amplifier, transmitter-receiver can be designed and implemented without much difficulties. The most challenging part will be to integrate all using a micro-controller system. And it will be a huge success and all-around achievement when the integration is successfully done.

**Career Potential**

A project such as a digital stethoscope is excellent preparation for my future career plans to study robotics in graduate school. JAUS, a department of defense standard for wireless communication with autonomous ground vehicles is becoming more and more widely used, and people who are familiar with and with working experience in wireless communication protocols will be in demand. [4] Furthermore, robots function in an analog world but the majority process the information they collect digitally. Thus, a project emphasizing analog to digital conversion will be very useful to me in my future work.
REFERENCES:


