Measuring Tuberculosis Treatment Response: Cough Detection

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Cough detection can be used to diagnose and properly treat a variety of respiratory diseases, including tuberculosis. The Purple Team's capstone project implements of cough detection using a microphone and an accelerometer. The data is processed and cough count is output via a clinician portal. This Note will discuss our method used to detect cough.

Introduction

Tuberculosis is one of the world's deadliest infectious diseases (World Health Organization, 2015). In 2015, 9.6 million people suffered from tuberculosis, and the disease contributed to approximately 1.5 million deaths. Multidrug resistant tuberculosis (MDR TB) represents 3.6% of cases worldwide, but makes up 28% of cases in certain developing regions (Larson, S., et. al, 2011).

MDR TB represents all strands of TB that are resistant to more than one medication. MDR tuberculosis is harder to treat, since treatments are more expensive and harder to obtain. MDR tuberculosis is generally diagnosed using laboratory cultures, however there is a shortage of laboratories and staff in the developing world. Currently, patients without laboratory access will be treated for basic tuberculosis, and treatment outcome will be determined four to six months later (Larson, S., et. al, 2011).

The Purple Team's capstone project implements a laboratory free method of MDR TB diagnosis by measuring and monitoring a patient's coughs. This method is cost effective and decreases diagnosis time of MDR TB from months to weeks.

What are cough and cough detection?

Coughing is defined as expelling air from lungs with sudden sharp sounds. Therefore, coughing can be defined using two main characteristics: movement and sound. The movement of the cough corresponds to movement in the chest as air is expelled. The sound of the cough differentiates it from other sounds such as wheezing, sneezing, and speaking. A cough occurs when nerve endings in a person's airways (tubes that carry air into and out of lungs) become aggravated. Coughs are used to clear a patient's airways of lung irritants.

History of Cough Detection

Coughing was first described as a symptom, and its properties recorded, 2000 years ago by ancient physicians. (Korpas, et.al, 2002). Cough itself was first recorded on a device and counted in 1960, using a system with a free-air microphone and cassette tape recorder. (Subburaj, et.al, 2002). Since then, various approaches have been designed and tested to automate an accurate cough detection process. Systems can be used to measure cough counts (coughs per hour), bouts, intensities, and latencies. (Subburaj, et.al, 2002).

Why is cough detection important?

Recording and assessing cough can be used for much more than diagnosis of tuberculosis in the developing world. Coughing is a symptom of over 100 diseases and medical conditions (Korpas, et. al, 2002). Since cough does not occur in healthy patients, the presence and persistence of coughs is of great significance to clinicians. (Korpas, et. al, 2002). Changes in cough can indicate the effectiveness of a treatment or the progression of a disease. (Korpas, et.al, 2002). Measurements and observations of the quality and quantity of cough can aid in the diagnosis of respiratory diseases.

Why is cough detection used in our capstone project?

Original research by the Purple Team shows that accurate detection and analysis of cough can provide a low-cost means for detecting success or failure of tuberculosis treatment after four to six weeks. This decreases diagnosis time from four to six months. If a patient is not responding to treatment for basic tuberculosis, which can be seen by measuring the patient's cough rate, the patient can be instead treated for MDR tuberculosis (Larson, S., et. al, 2011). This project provides an automated, low-cost method of detecting cough in order to decrease tuberculosis diagnosis time in the developing world.

Our Cough Detection System

The Purple Team has built a device to record and count a patient's coughs. The device has been designed to be cost effective and minimally invasive. There are two main modules: a microphone module and accelerometer module (Figure 1). The accelerometer is a sensor that picks up the user's movement, or acceleration, in the x, y, and z directions. When a person coughs, the accelerometer values show a specific change that does not occur during other movements. When this change occurs, the microphone is then triggered to record the possible cough event. A patient wears this device for about 4 hours, and then all of the small data files (which may or may not be coughs) are processed using an algorithm to determine the number of actual coughs. This method protects a user's privacy, as no conversations are recorded, and allows the algorithm to work much faster, as it is not processing 4 continuous hours of data. After each user period, the algorithm produces a number corresponding to the total number of detected coughs. The details of this algorithm and how the data is displayed is described in Purple Team member Tara Watson's Tech Note.

Testing in Peru

In March of 2016, our team brought the original prototype to Peru. We received feedback on the functionality and design of the device from Peruvian doctors, nurses, and engineers. Although they appreciated the small size of the design, the slow recording speed needed improvement. They also

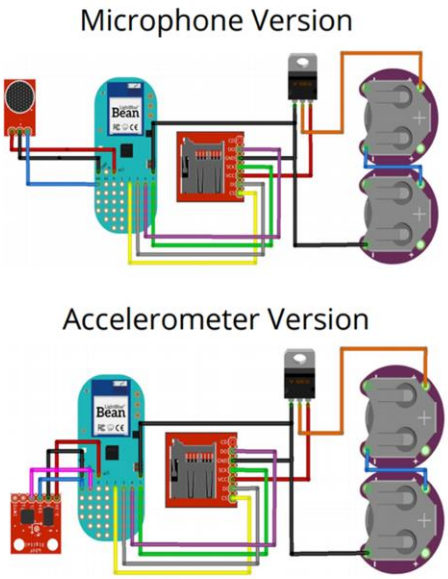

Figure 1. Cough Detection System showing the two main modules

alerted us to problems specific to the area and culture, including theft and the stigma associated with wearing medical devices. After the trip, a second prototype was designed to meet those requirements.

Conclusion

Tuberculosis is a serious problem in developing regions of the world, such as Lima, Peru, the focus of the Purple Team's research. Due to limited resources, these countries lack sufficient staff and laboratory equipment for the diagnosis of multidrug resistant tuberculosis. An effective, low-cost, laboratory-free method of diagnosis can decrease the amount of time patients spend waiting for proper treatment. Our device employs a cough counting method to provide this type of diagnosis and improve quality of life for millions of people. Using a cough monitoring system also can be helpful for monitoring a variety of respiratory diseases beyond TB, such as the 335 million people suffering annually from asthma (World Health Organization, 2015). This device has many possible avenues of use in aiding diseases with cough symptoms.

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