Tracking Lung Function on any Phone

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1. INTRODUCTION

Spirometry is the most widely employed objective measure of lung function. It is central to the diagnosis and management of lung ailments like asthma, chronic obstructive pulmonary disease, and cystic fibrosis. Spirometry is generally performed in medical clinics using clinical spirometers—devices that measure the instantaneous exhaled flow (liters/sec.). High-end clinical spirometers can cost upwards of $5,000 USD. Portable spirometers generally cost between $1,000-$4,000 USD. Apart from being costly, these devices are not readily available in developing countries. Most developing regions have low cost peak flow meters in prevalence. These devices ($10-$50 USD) only sense a subset of lung function measures and are generally considered inadequate for managing and diagnosing lung ailments [2]. SpiroSmart [1] is a smartphone-based approach that measures many common lung function measures using the phone's built-in microphone. It does not require any additional hardware or adapter to be attached to the phone. The low cost of smartphones as compared to spirometers allows lowering of access barriers to full-fledged lung function measurement in the developing world.

SpiroSmart has a median error of 8.01% for the most common lung function measures and has been proven to the effective for diagnosing presence of lung ailments. However, the original design required a smartphone. In order to bring this technology within reach of a global population, we are working on a call-in service based system (coined SpiroCall), which is agnostic to the phone type. Users will be able to simply call in to a server with their personal phone and record their exhalation data. Our preliminary results show that the loss of bandwidth and resolution due to data transmission through voice channel does not have significant adverse effect on the performance, vastly reducing the access barriers for a technology such as SpiroSmart.

2. TECHNOLOGY

SpiroSmart requires users to hold the phone at approximate arm's length, inhale their full lung capacity, and then forcefully exhale at the screen of the phone until the entire lung volume is expelled. The microphone records the exhalation and sends the audio data to a server, which calculates the flow rate by estimating physiological model of user's vocal tract and the reverberation of sound around the user's head. The microphone acts as an uncalibrated pressure sensor. SpiroSmart converts this pressure into a flow rate by compensating for pressure losses between phone and mouth, and keying in on acoustical properties of the lips that relate pressure to flow. Then, a number of features are extracted from this signal through: (1) envelope detection, (2) spectrogram processing, and (3) linear predictive coding (LPC). These features give an estimate of the uncalibrated flow rate. We then use regression to obtain specific lung function measures from these approximations. Lung function typically consists of lung function measures like PEF, FEV1, FEV1% and FVC. Regression to these measures is implemented using bagged decision trees. Another set of important constituent of lung function are Flow-Volume curves. These require much more difficult and computationally intensive regression. We use a combination of conditional random field (CRF) and a bagged decision tree for this regression. The process is similar for SpiroCall except we use a subset of the features, namely those chosen from linear prediction. The cellphone channel uses linear prediction in its encoding, which has the effect of preserving LPC audio features better than envelopes and spectrogram processing.

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3. EVALUATION

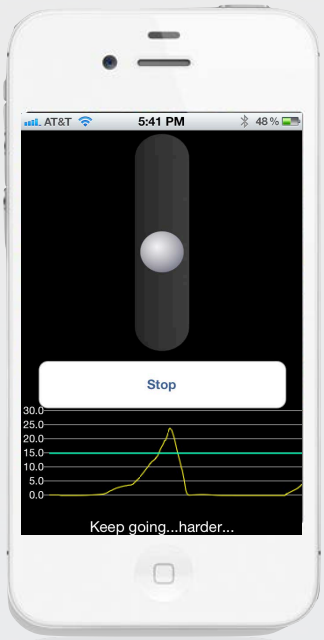
We evaluated SpiroSmart and SpiroCall by comparing the results of regressing the measures of PEF, FEV1, FEV1%, and FVC for 52 different subjects. For SpiroSmart the raw recordings were used to train different models in a tenfold cross validation across subjects (i.e., recordings collected from a particular subject were not used in training that subject's model). This resulted in an average error of 11.74% (median 8.01%, IQR 3.2-14.9%) for the different lung function measures. For SpiroCall, the original recordings were played back through a speaker while a cell phone transmitted the audio across the voice channel to a server. Thus the new recordings were lower sampling rate; contain artifacts from the voice channel and compression artifacts from being saved on the server. In this condition the results only slightly worsened to an average error of 11.9% (median 8.23%, IQR 3.6-15.0%). Based on these results we believe the SpiroCall service will be a viable option in the developing world. Results of the measures regression can be easily texted back to the participants. In the future, we plan to further validate the technology using more varied channel characteristics and different styles of phone.

4. REFERENCES

1. Larson, E.C., Goel, M., Boriello, G., Heltshe, S., Rosenfeld, M., and Patel, S.N. SpiroSmart : Using a Microphone to Measure Lung Function on a Mobile Phone. *Proceedings of the 14th International Conference on Ubiquitous Computing*, (2012).
2. Pesola, G., O'Donnell, P., and Jr, G.P. Peak expiratory flow in normals: comparison of the Mini Wright versus spirometric predicted peak flows. *Journal of Asthma*, 4 (2009), 845–848.

SpiroSmart

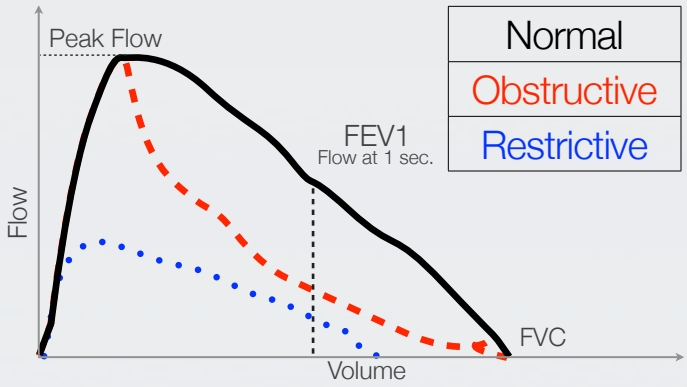
A Smartphone Based Spirometer that helps you keep track of your lung function.



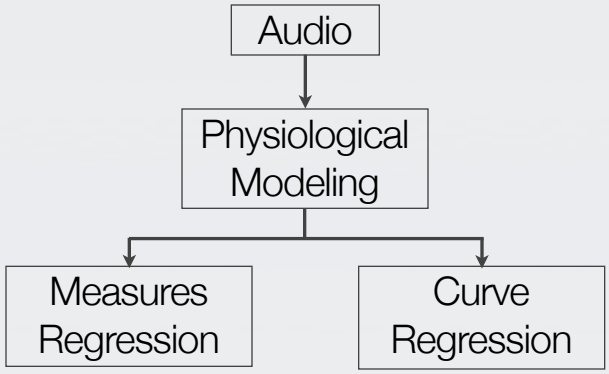
Lung Function

Consists of measure and curves, used to evaluate severity of pulmonary impairments like:
Asthma
COPD
Cystic Fybrosis
Chronic Bronchitis

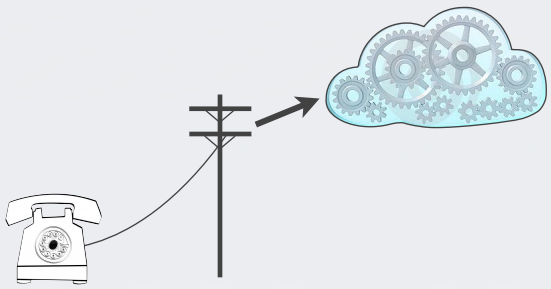
Measures and Curves



Technology

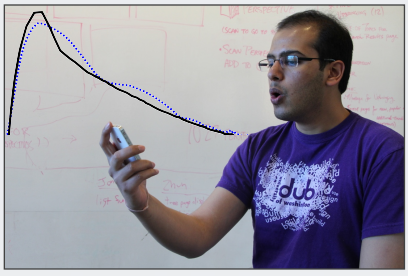


Call-In Service



Results

	Error
ATS Criteria	5-7%
SpiroSmart	8.01%
Call-In Service (SpiroLite)	8.23%



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