MMLung: Moving Closer to Practical Lung Health Estimation using Smartphones

Mohammed Mosuily
University of Southampton
mtm1g19@soton.ac.uk

Lindsay Welch
University of Southampton
lindsay.welch@wessexahsn.net

Jagmohan Chuahan
University of Southampton
j.chauhan@soton.ac.uk

Pulmonary diseases, such as Chronic Pbstructive Pulmonary Disease (COPD) and Asthma, are considered to be the third leading cause of mortality in the world [1]. According to the report by the Global Initiative for Chronic Obstructive Lung Disease (GOLD) [2], spirometry test is the gold standard when it comes to measuring lung function and identifying respiratory diseases such as COPD. However, it requires medical-grade equipment and trained medical professionals to operate the equipment. Hence, such methods are challenging to scale, expensive, and lack accessibility. Moreover, blowing into a spirometer can be quite hard for people suffering from pulmonary illnesses. Therefore, the need to explore the potential of using ubiquitous technologies to predict lung function estimation is becoming important.

Multiple studies have proposed using smartphones for lung health assessment, such as SpiroSmart[3] and Ubilung[4]. Thus, demonstrating that it is possible to estimate lung function using multiple audio modalities (cough, speech, vowel, spirometry) collected from a smartphone. However, two major limitations have come to light in the existing works: (a) the performance obtained is in the range of 5%–10% Mean absolute percentage error (MAPE), which is slightly higher than the recommended MAPE (less than 5%) for clinical use, and (b) they have not compared the performance of different modalities using the same methods to evaluate their utility for lung health assessment.

In this work, our aim is to enhance the performance of lung health estimation to make it practical for real-life use and clinical practice. To achieve this, we gathered data from 40 participants via smartphone and created a machine-learning pipeline, as shown in Figure 1. The pipeline utilizes and combines audio signals from different modalities that were acquired through various tasks performed by the participants. The tasks performed are as follows: (a) force cough up to 10 times; (b) pronounce the vowels (A, E, I, O, U) in one breath, like "AAAA..." for two to three iterations; (c) perform a spirometry task on their phone by taking a deep breath and blowing into the microphone until they have expelled all of their air; (d) read the Rainbow Passage; (e) describe a picture to record spontaneous speech for two minutes; (f) read a short sentence within one breath; (g) read a long sentence within one breath; (h) describe the room in which they are recording; (i) read a text full of action words; and (j) read a text that does not contain action words. We collected ground truth data using a medical-grade spirometer.

Many existing studies suggest that smartphone spirometry cannot yet replace current clinical spirometry devices. However, this study demonstrates that personal lung monitoring is a possibility, at this stage as a screening tool, to enable public awareness of changes or early detection in the deterioration of their lung health. An example of this is the KardiaMobile Cardiac Screening [5]. The best-case scenario would be continuous monitoring and reporting to medical experts, which could be effective for earlier treatment if necessary. To this end, this paper proposes the MultiModal Lung (MMLung) approach, which merges audio signal information from multiple modalities through multiple tasks to achieve impressive performance in lung function estimation.

We obtained the optimum result with a MAPE of 1.13% by combining all of the tasks mentioned above. However, since performing all tasks simultaneously may not be feasible for a user, our results also demonstrate that a combination of three to five small tasks can yield a MAPE of (<3%), without involving mobile spirometry. Our work is the first to compare all modalities - cough, speech, vowels, and mobile spirometry - using a single benchmark setting. We show that speech is the best modality for testing lung functionality with smartphones. Overall, MMLung takes one step further to make smartphone-based lung health assessment more accurate and practical.

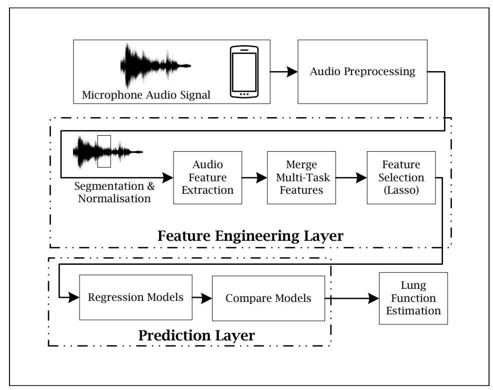

Fig. 1: Flowchart representing Audio signal analysis and processing pipeline. Consenting of the pre-processing stage, feature engineering layers, and prediction layer and ending with the lung function estimation.

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