Non-Contact Respiratory Analysis using Thermal and CO_2 Imaging

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Problem

- Respiratory analysis involves the evaluation of various pulmonary and breathing conditions.
- Most existing clinical respiratory analysis methods drastically interfere with natural breathing behaviors due to restricted air-flow, constant attention on the monitoring device, or discomfort during long-term studies.

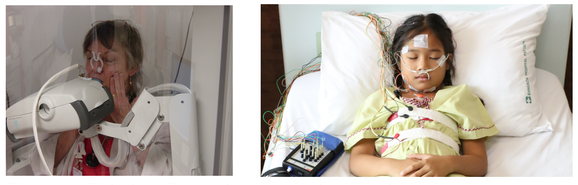

Figure: Existing Breathing Analysis techniques a)Plethysmography(left) b)Polysomnography

Objective

- Medical professionals prefer respiratory analysis methods that are accurate as well as comfortable.
- The goal of this project is to conduct non-contact respiratory analysis using computer vision and image analysis technologies.

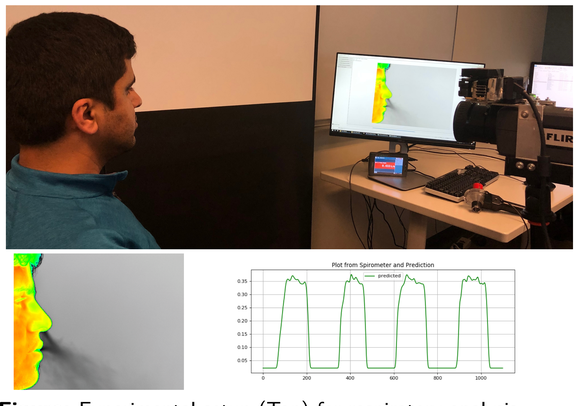

Figure: Experimental setup (Top) for respiratory analysis using CO2 imaging (Bottom Left) and tidal volume estimation (Bottom Right)

Introduction

A thermal infrared camera embedded with special filters for CO2 is used to collect carbon dioxide density videos of a patient while they exhale. The technique provides advantages in terms of -

- Remotely deployable technique
- Non contact method of breathing analysis
- Give comfort during breathing
- Enables natural breathing

Methods

- Exhale Segmentation and Pre-processing
  - The orientation of the patients face is detected and using this information we apply different image processing techniques to extract only the exhale area from the videos.

Figure: Process of Exhale Segmentation

- Airflow simulation from 1 Litre Calibration Pump

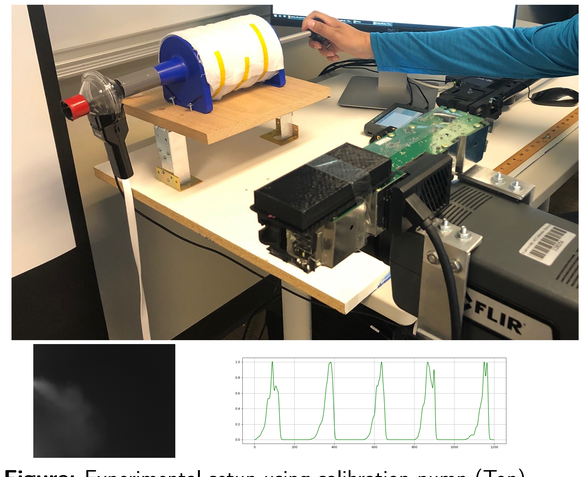

Figure: Experimental setup using calibration pump (Top). Thermal flow imaging of pumped air (Bottom Left). Thermal flow rate estimation (Bottom Right)

Methods (continue)

- Airflow simulation from 1 Litre Calibration Pump (continue)
  - A 1 Litre calibration pump is filled with human exhale. The exhale is then pushed out of the syringe with a spirometer attached to its opening.
  - The thermal imaging device captures the CO2 images of the exhale as it is being pumped out. Spirometer data is also recorded simultaneously.
  - Spirometer data provides ground truth value for estimating the breathing behaviors using Machine Learning methodologies.
- Flow Rate Formulation
  - Flow rate is formulated from each frame by calculating a weighted sum of the pixels from the segmented exhale area.
  - The computed flow rate is then interpolated to provide a direct correlation between the image flow rate and the spirometer waveform.
  - An LSTM(Long short-term memory) network is utilized to find a relationship between the image flow rate and the spirometer waveform.

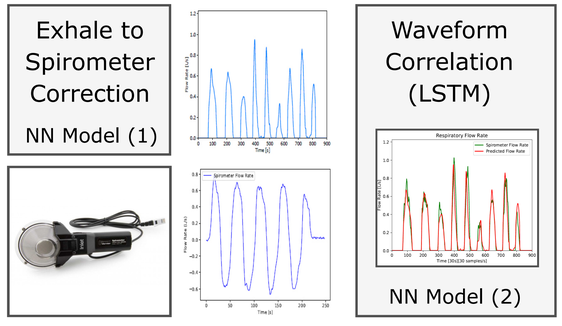

Figure: Process of predicting tidal volume using LSTM(Long short-term memory) network

Results

1. Tidal Volume Estimation The predicted image flow rates from the LSTM network are aggregated to estimate the tidal volume.

Results (continue...)

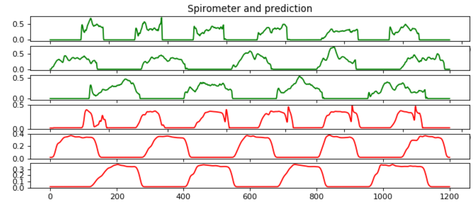

Figure: Predicted results of test dataset

2. Breathing Rate The number of cycles in predicted data is being used for calculating the breathing rate.

Future Work

- The results from the proof of concept show promising results in correlating flow rate calculated from thermal images with the ground truth data generated through the spirometer.
- Based on these results, a model can be implemented to analyze human respiratory behaviors directly through thermal imaging, without the use of a spirometer.

References

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[2] Prochazka, A., Charvatova, H., Vysata, O., Kopal, J. and Chambers, J., 2017. Breathing analysis using thermal and depth imaging camera video records. Sensors, 17(6), p.1408.

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