SpiroMilli: Bringing Ad-hoc Spirometry to 5G Devices

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Bringing Spirometry to 5G Mobile Devices

Objective

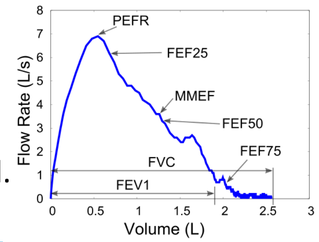
- Enable **ubiquitous millimeter-wave device** to perform at-home spirometry.

Motivation

- **Daily monitoring of lung function** is required for respiratory diseases, like Asthma, Covid-19.
- Daily in-clinic test is impracticable and existing portable systems are expensive, inaccurate, and **requires extra-hardware**.

Challenges

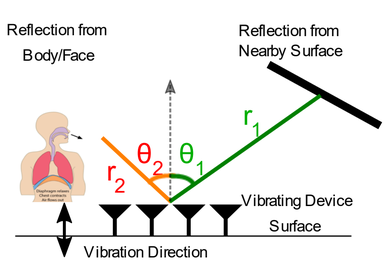
- When user exhales in-front of the 5G mobile device phase change should only be from airflow vibrations.
- Predicting lung function from vibration signal is complicated.

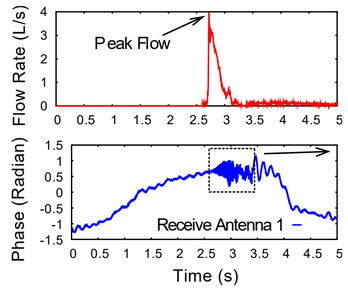


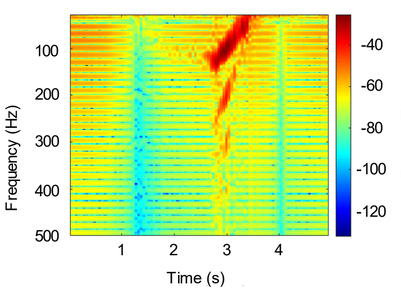
Estimating Vibration Signal from Airflow

How to accurately estimate vibration signal from airflow?

- **Distinct vibratory signature** on reflected signal when airflow strikes radar.





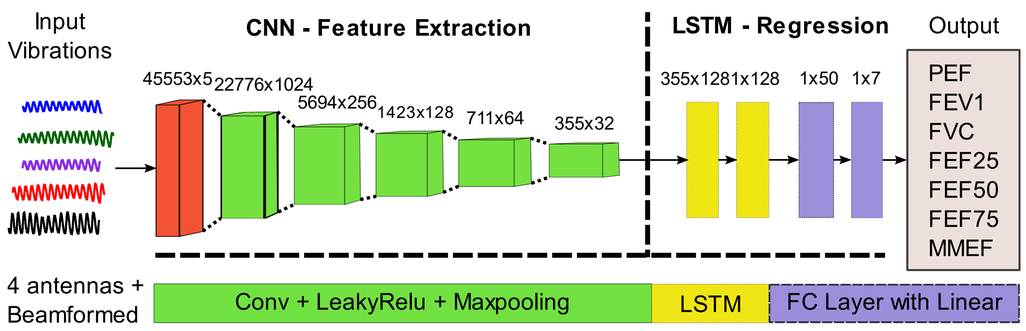


- **Beamforming** steers the signal towards an optimal location using **4 receive antennas**.
- **Reflector tracking algorithm** ensures phase tracking from the **strongest reflector**.

CNN-LSTM to Predict Lung Function Indicators

Predicting lung function indicators and flow-volume graph

- **CNN-LSTM** learns the **representative features** in the vibration signal by extracting **local features** between timesteps using *CNN.*
- *LSTM* captures the **temporal global features** and interdependencies between timesteps.

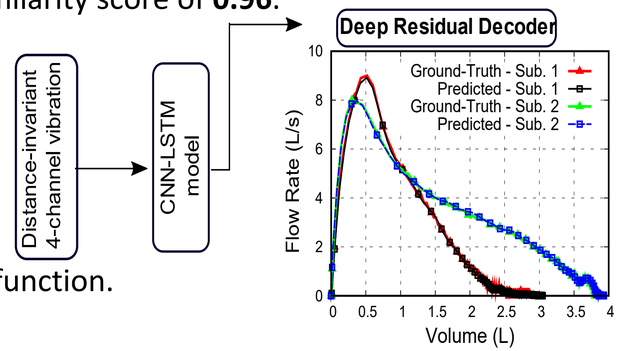


- Deep Residual Decoder is trained on CDC data to **predict flow volume graph** from the indicators.

Results and Conclusion

Prediction Performance

- CNN-LSTM predicts PEFR, FEV1 and FVC, with median errors of **0.40 L/s, 0.05 L and 0.03 L** and is comparable to the existing at-home spirometers.
- Decoder produces flow-graph with similarity score of **0.96**.



Conclusion:

- *SpiroMilli* can predict indicators and flow-volume graph.
- *SpiroMilli* can estimate vibration signal accurately to map it with lung function.

Future works:

- Mouth-to-Device Distance Calibration.
- Evaluate on different human and environment conditions and perform **clinical trials**.