

Edge Intelligence: Multi-Modality Sensing to Revolutionize Chronic Diseases Management

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The Crisis of Chronic Disease

Chronic Disease Stats

China (2023) [1]:

480M patients

30.5% of population

《国家计划十三五期间居民慢性病监测的报告》

Chronic Disease Deaths

91% in China^[1] vs. **81%** in HK^[2]

Top Killers:

- Hypertension
- Heart Diseases
- COPD

[1] 《中国卫生健康统计年鉴 2022》（国家卫健委）

[2] 香港卫生防护中心《2020 年香港死因统计》

Heavy Social Burden

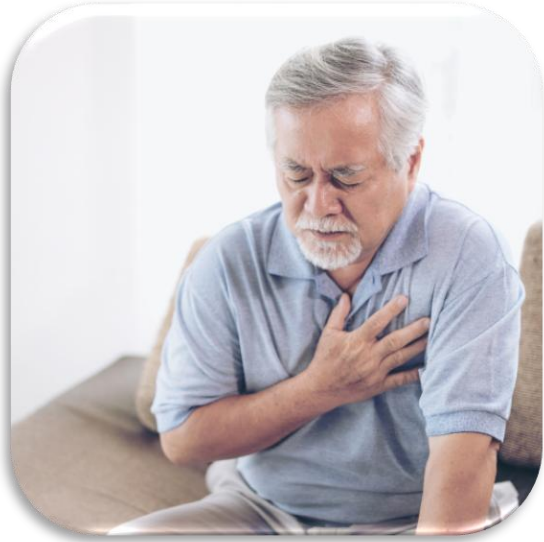
Need **Long-term** Management

China (2023) [1]:

68% of medical insurance fund expenditure (**¥1.9T**)

[1] 《国家医保局统计公报 2023 》

Pain Points for the Existing Chronic Disease Management



Late Diagnosis

How can a myocardial infarction patient be warned of an acute attack a few days in advance?



Fragmentation

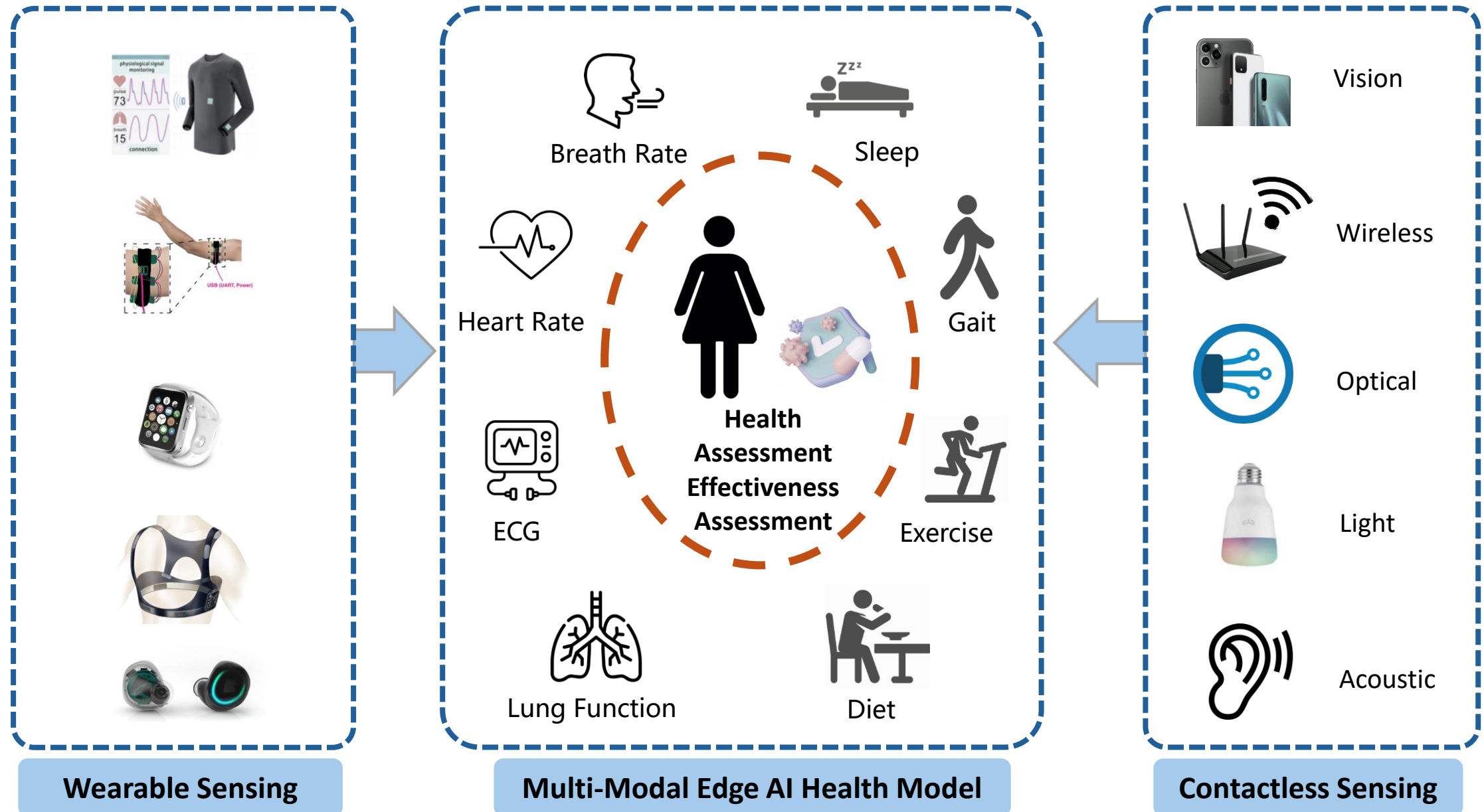
Lack of continuous monitoring capabilities to track patients' health status over time and adapt treatment plans accordingly



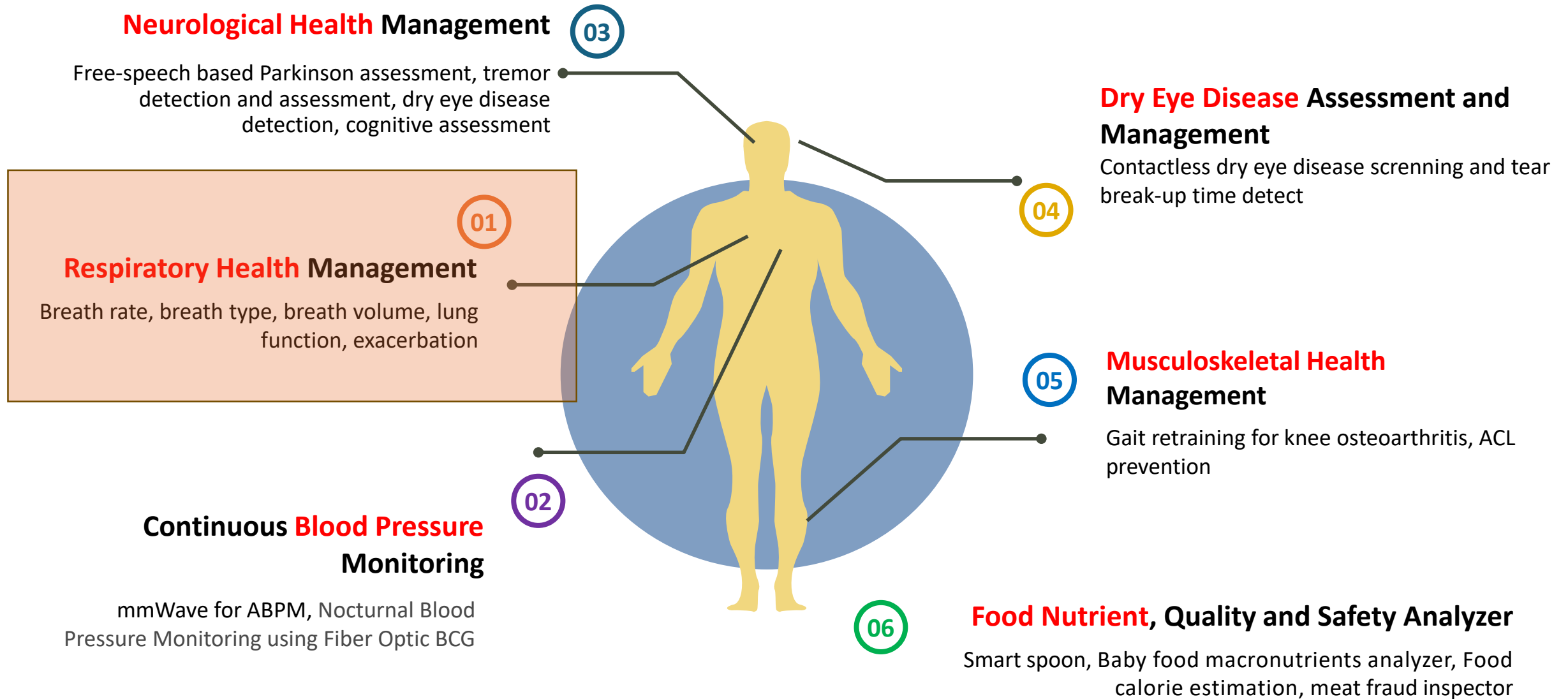
Passive Engagement

Poor adherence to treatment regimens and challenging to offer timely guidance and support

Multi-Modality Sensing: Pushing the Limits of Ubiquitous Intelligence

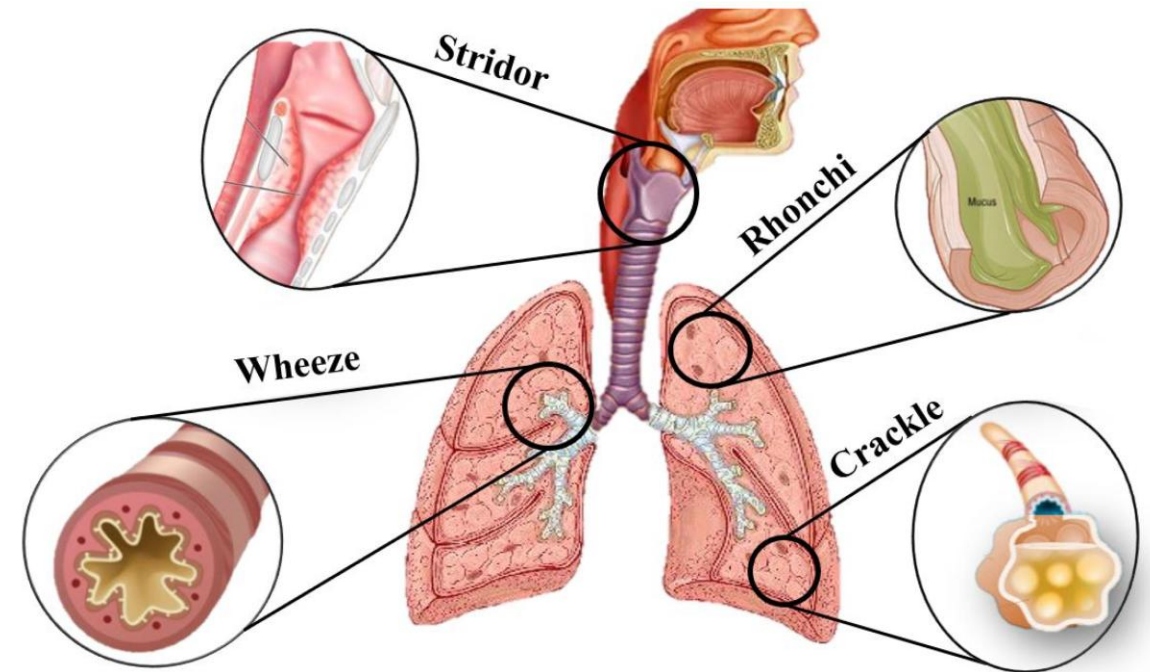


Current Focused Research Directions



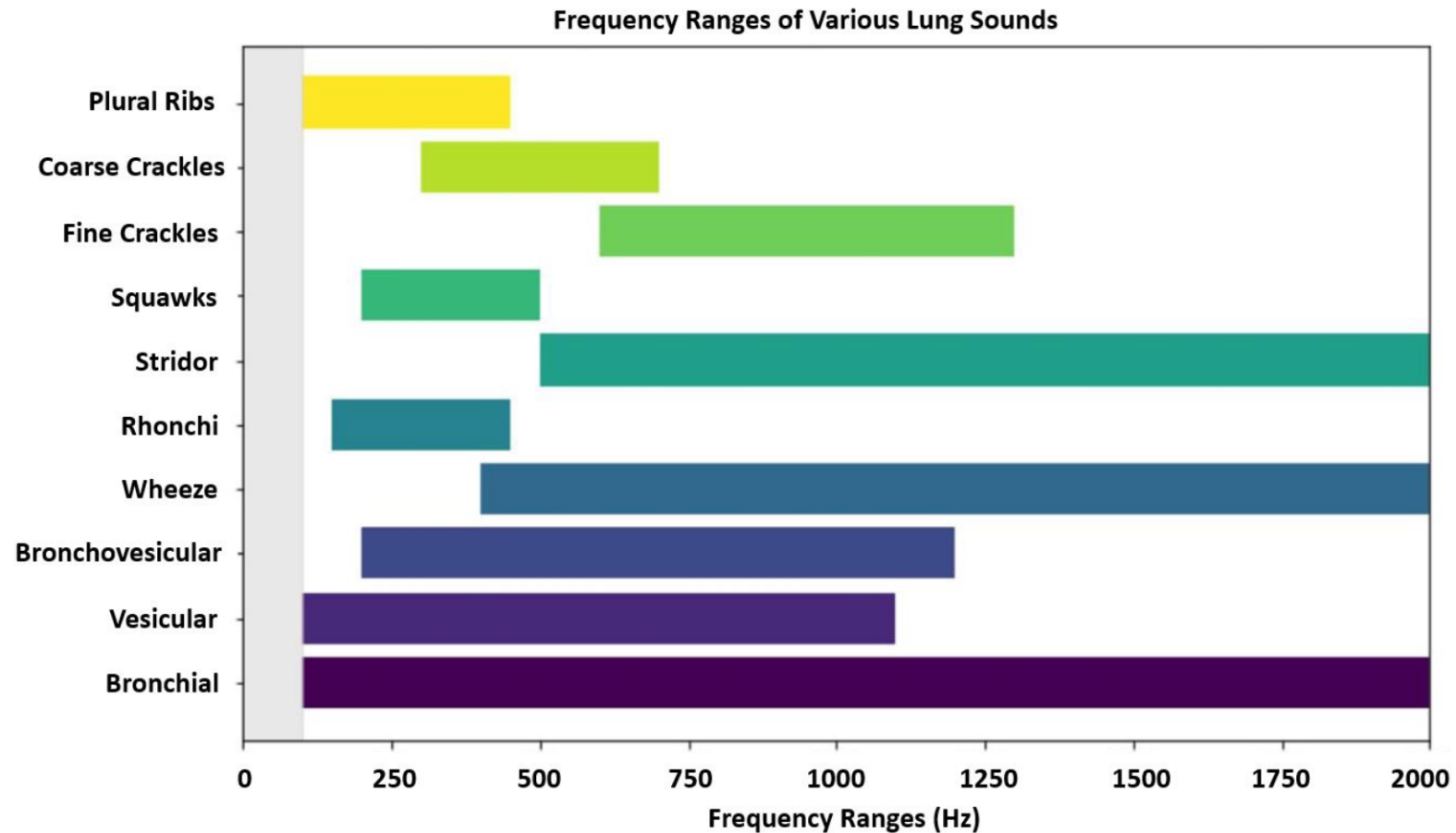
Breathing Sound

- Breathing sounds provide valuable insights about the condition of the respiratory airways, pulmonary structures, and can be analyzed to assess respiratory health
- Breathing sounds are classified into normal and abnormal sounds
 - Normal breathing sounds are divided into several categories based on their pitch and location of auscultation
 - Abnormal breath sounds, categorized as crackles, wheezes, rhonchi, stridor, and pleural rubs, are one of the key indicators of respiratory diseases



<https://www.mdpi.com/2079-9292/14/10/1994>

Breathing Sound



Subtle differences among respiratory sounds can be differentiated more accurately using AI

<https://www.mdpi.com/2079-9292/14/10/1994>

Learn from Breathing Sound



Lung Function Assessment

Wentao Xie, Qingyong Hu, Jin Zhang, and Qian Zhang, *EarSpiro: Earphone-based Spirometry for Lung Function Assessment*.
In ACM IMWUT/UbiComp 2023

C. Xu*, W. Xie*, B. Yang, Y. Zhang, J. Zhang, W. Li, S. Yang, and Q. Zhang, “EasySpiro: Assessing Lung Function via
Arbitrary Exhalations on Commodity Earphones,” in ACM MobiCom 2025



Chronic obstructive pulmonary disease
(COPD)



Asthma

Chronic, no cure for these diseases

Regular pulmonary function tests (PFTs)

Data sources:

[https://www.who.int/news-room/fact-sheets/detail/chronic-obstructive-pulmonary-disease-\(copd\)](https://www.who.int/news-room/fact-sheets/detail/chronic-obstructive-pulmonary-disease-(copd))

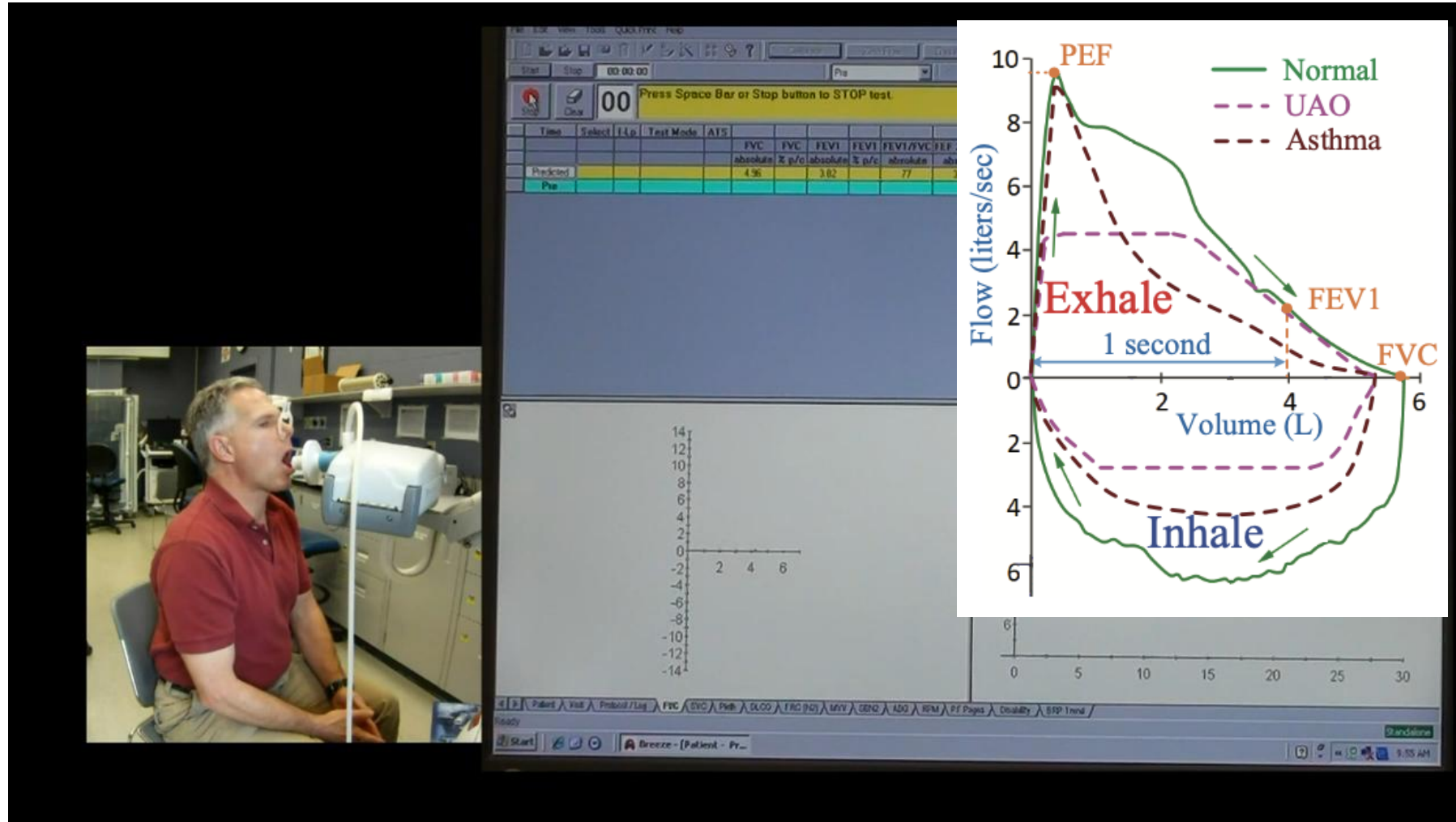
<https://www.who.int/news-room/fact-sheets/detail/asthma>

Image sources:

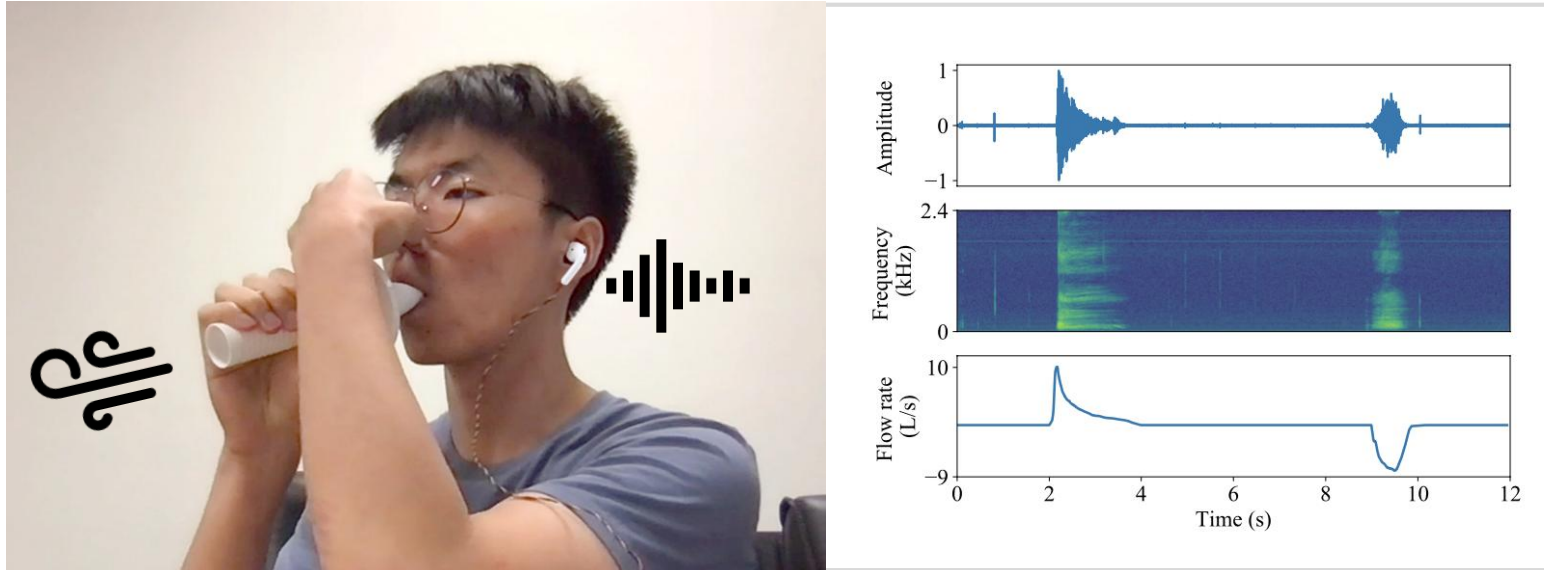
<https://frontierhealthcare.com.sg/chronic-obstructive-pulmonary-disease/>

<https://www.choa.org/medical-services/asthma>

Pulmonary Function Test (PFT) - Spirometry



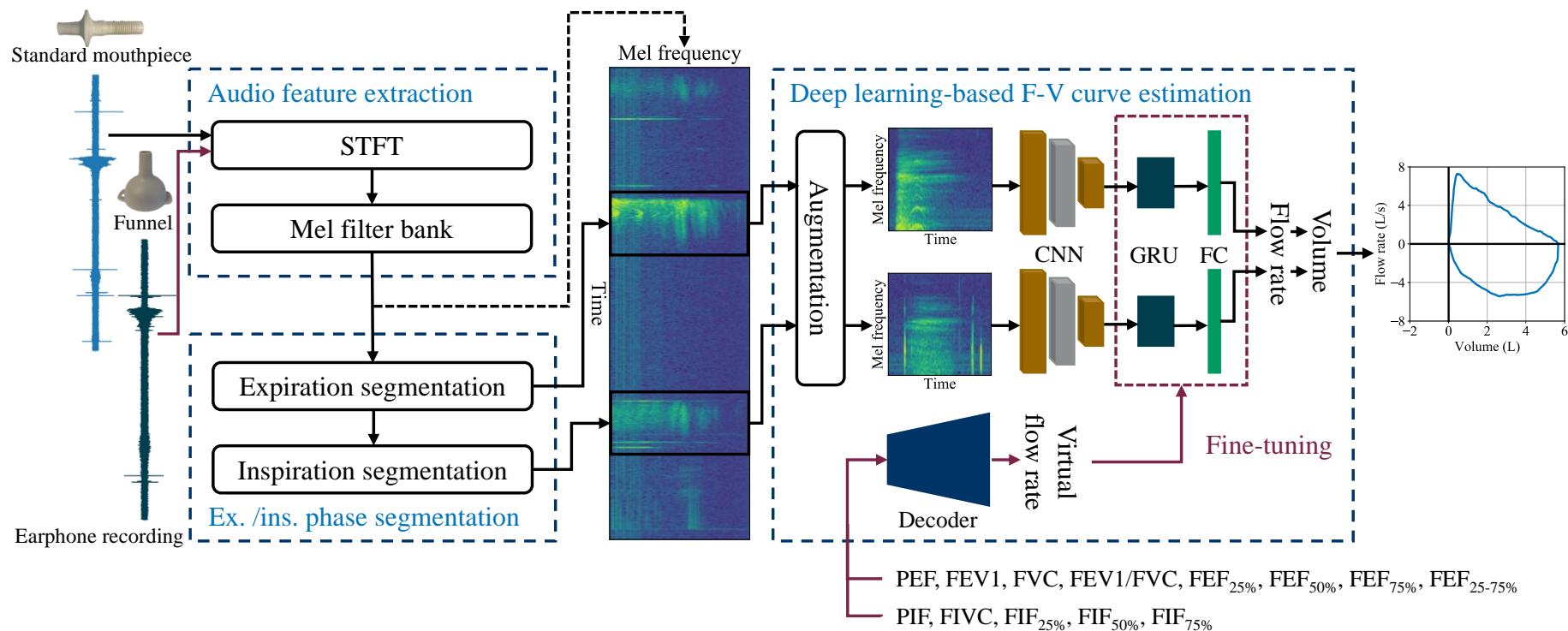
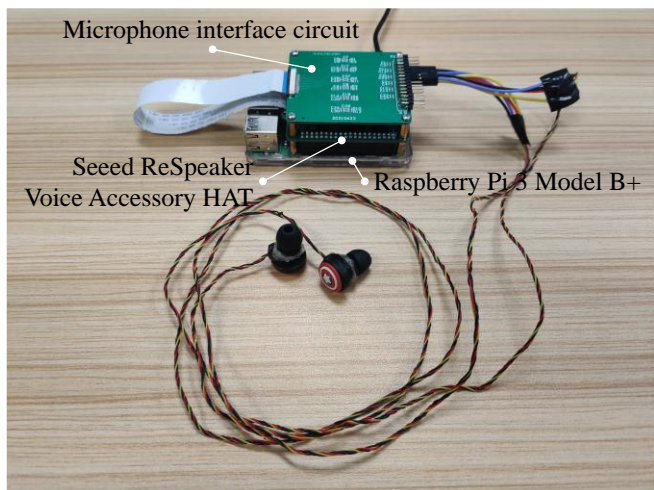
How to Conduct PFT Cost-Efficiently?



Audio ↔ Flow rate → F-V curve

Breathing sound is associated with airflow rate

EarSpiro Overview



Wentao Xie, Qingyong Hu, Jin Zhang, and Qian Zhang, *EarSpiro: Earphone-based Spirometry for Lung Function Assessment*. In ACM IMWUT/UbiComp 2023

EarSpiro: Earphone-based Spirometry for Lung Function Assessment

Wentao Xie, Qingyong Hu, Jin Zhang and Qian Zhang

The Hong Kong University of Science and Technology

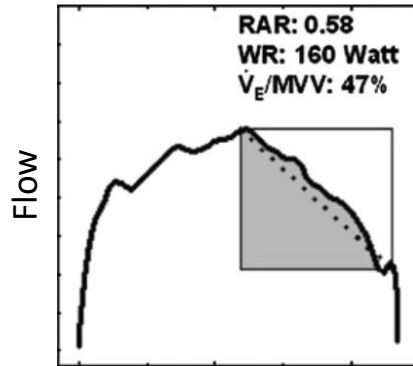
Southern University of Science and Technology

UbiComp 2023

Can We Make Home PFT Effortless?

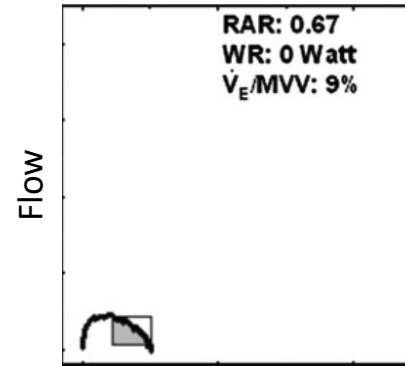
Healthy control

Maximal exhalation



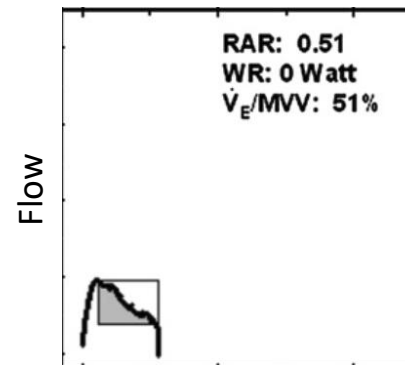
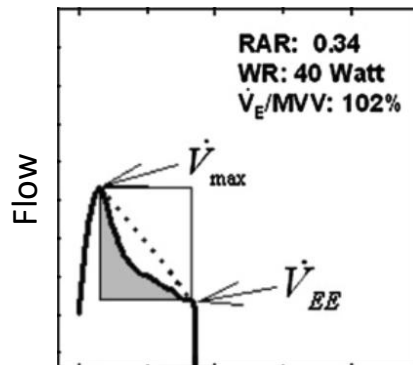
Volume

Casual breathing



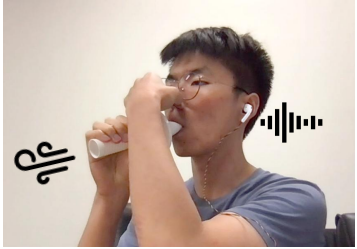
Volume

COPD patients



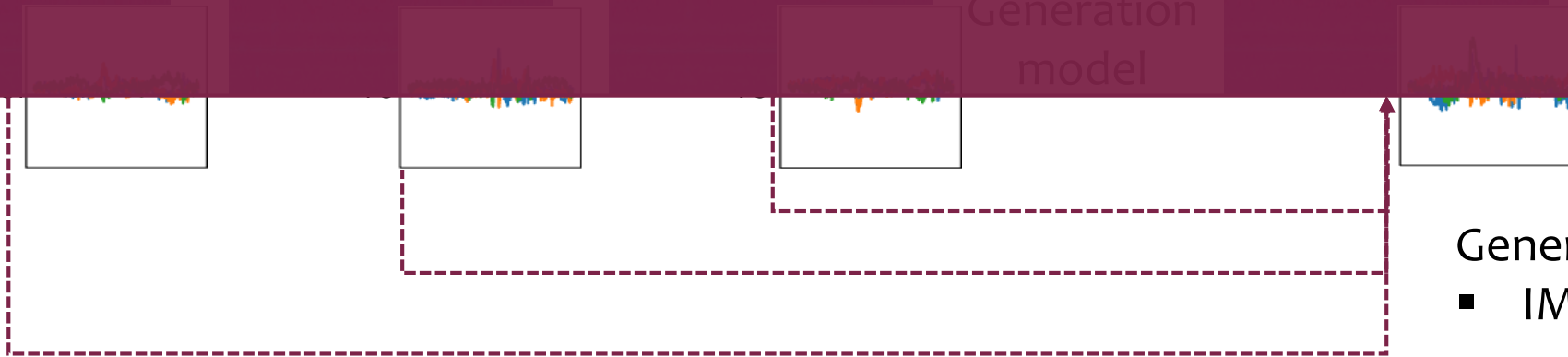
convex and concave discrepancy

Casual breathing patterns can also imply lung impairments.



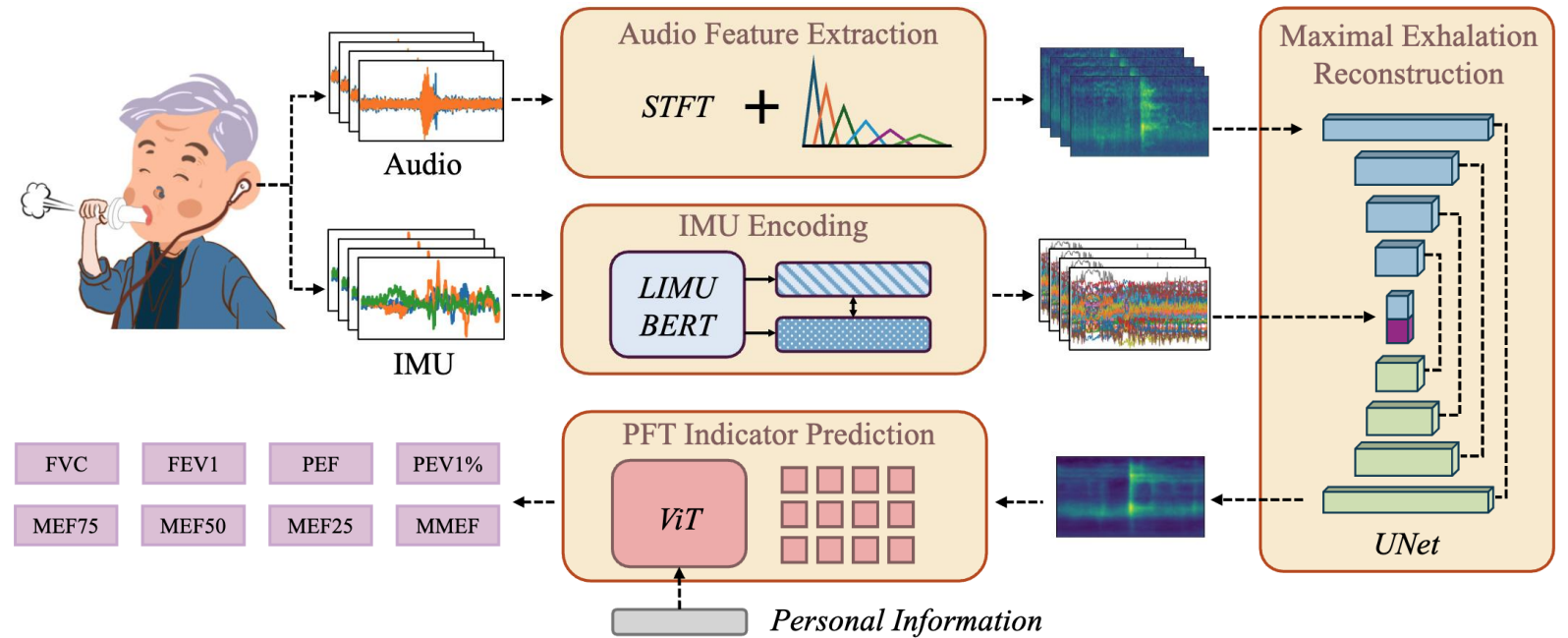
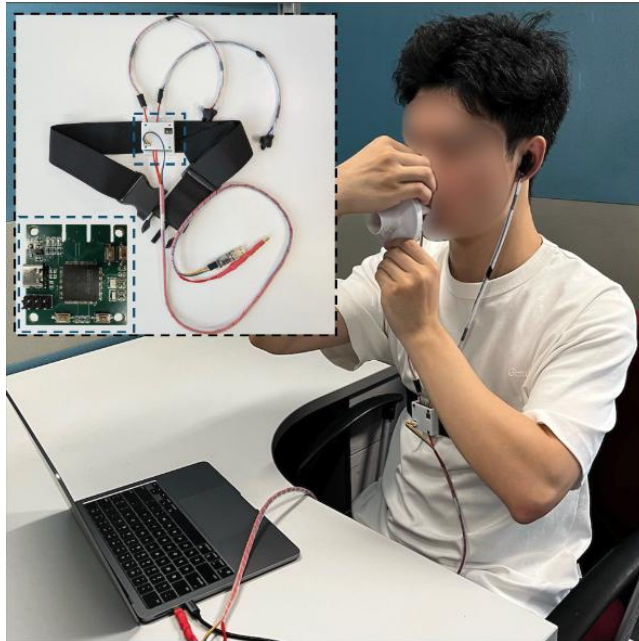
EarSpiro

How to describe the discrepancy in exhalation effort with IMU?



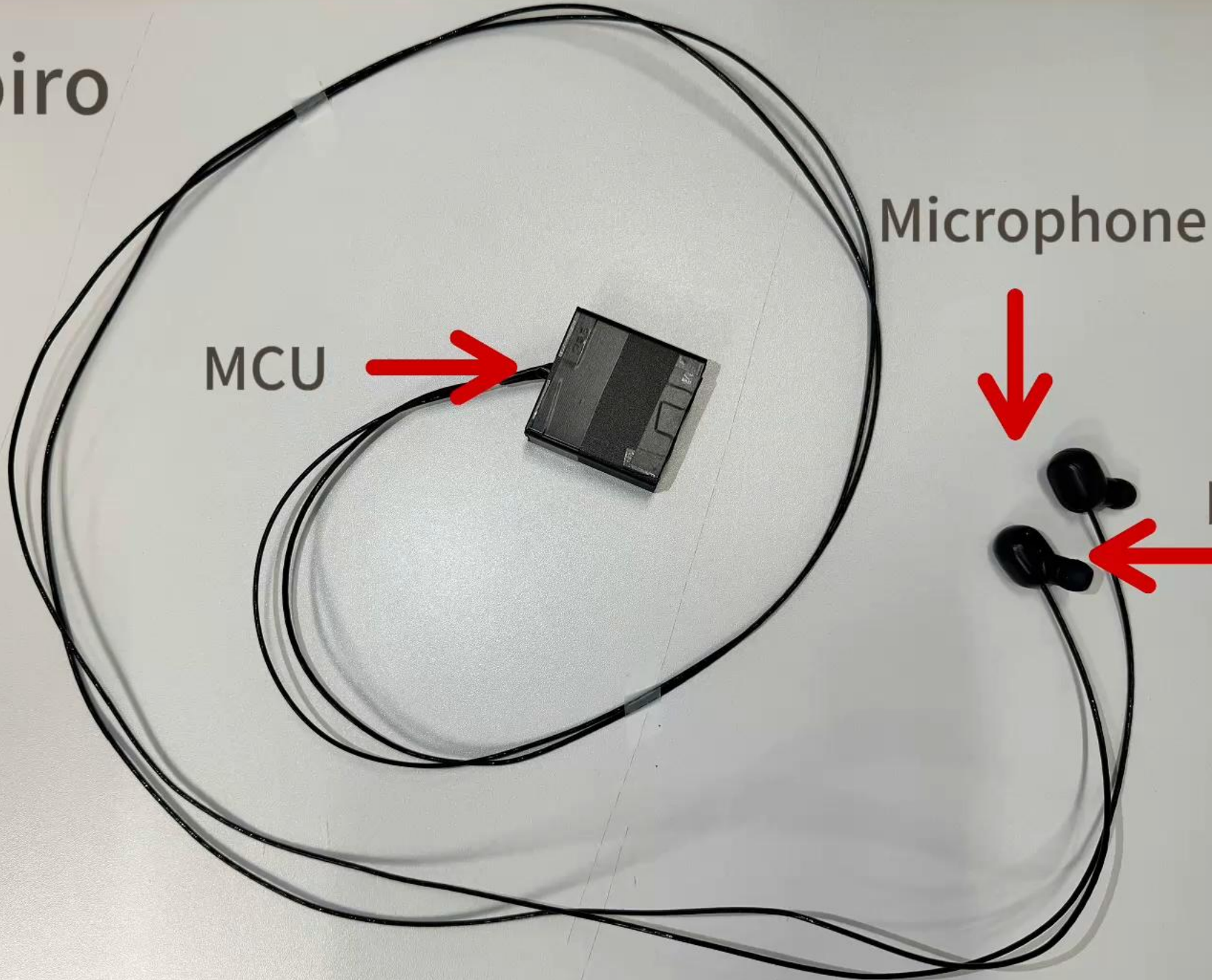
- Generation gap?
- IMU encoding

EasySpiro Overview



C. Xu*, W. Xie*, B. Yang, Y. Zhang, J. Zhang, W. Li, S. Yang, and Q. Zhang, "EasySpiro: Assessing Lung Function via Arbitrary Exhalations on Commodity Earphones," in ACM MobiCom 2025

EasySpiro



MCU



Microphone



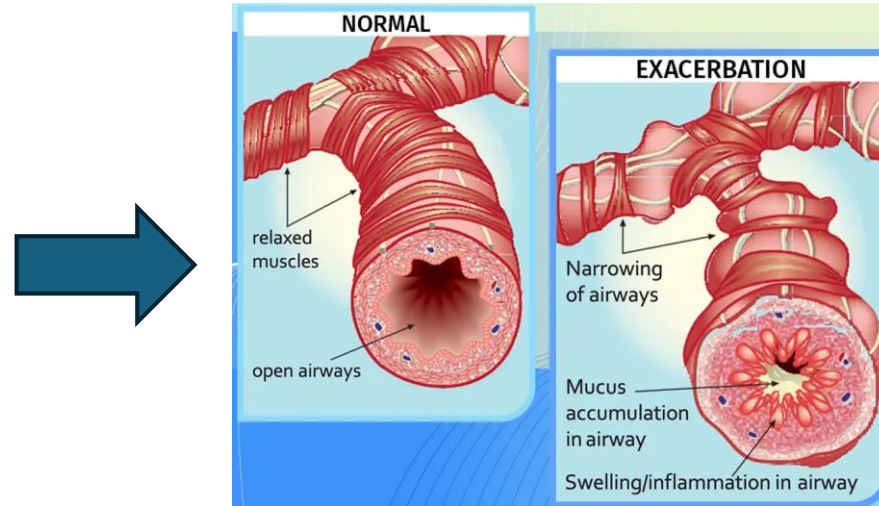
Embedded IMU



Learn from Breathing Sound



Lung Function
Assessment



The Acute Exacerbation Detection

Y. Gong, C. Xu, C. Mo, J. Wu, H. Lin, H. Su, Q. Zhang, and S. Yang, "AI-Driven Smartphone Screening for Acute COPD Exacerbations: A Non-Self-Report Approach to Improve Health Equity in Developing Regions", npj Digital Medicine, 2025.

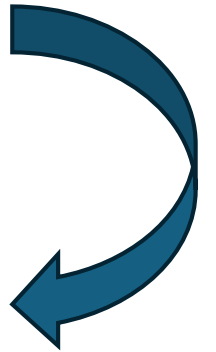
The Acute Exacerbation of COPD (AECOPD)



- AECOPD is fatal
- Hospitalization is inevitable
- Early symptoms of AECOPD are too subtle to be detected
- Patients always wait until the development of severe symptoms before they go to a doctor, which is usually too late

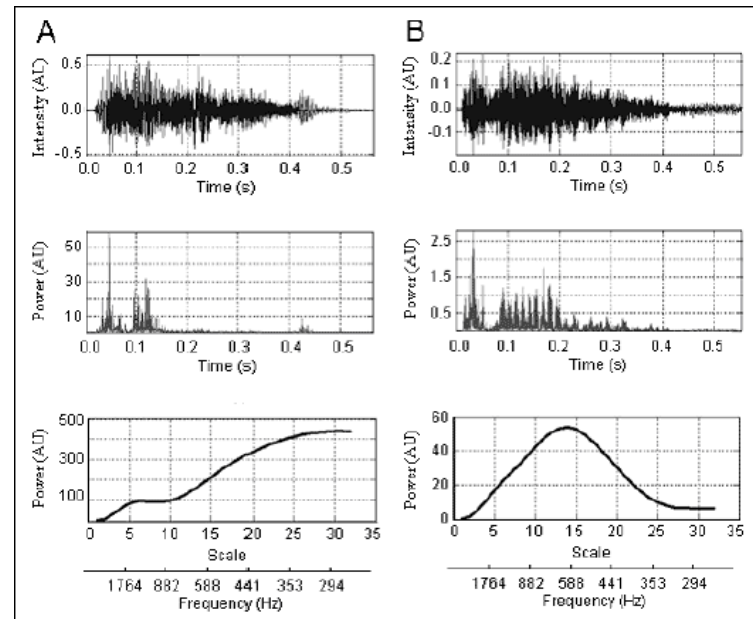


- Self-screening of AECOPD with a smartphone
- E.g., when cold weather is coming, alert the user to self-check the onset of AECOPD
- It is convenient to use. Place the phone on the chest.

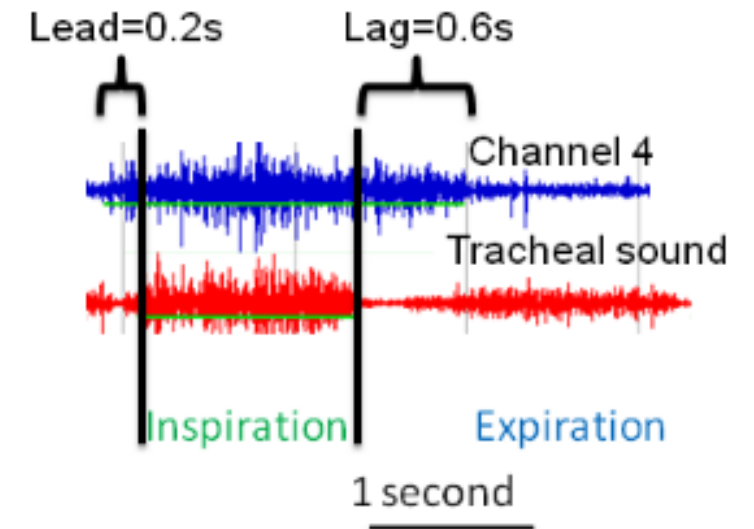


Motivation

- Cough sounds [1]
 - Increased duration and power
 - Energy envelope variations
 - Spectral characteristics
- Deep breath sounds [2]
 - Presence of adventitious sounds, i.e., wheezes and crackles
 - Altered breathing rhythm
 - Frequency spectrum shifts



Calculations of the lead and lag:



Lung sounds can tell more than imaged!: an objective biomarker

[1] Knocikova, Juliana, et al. "Wavelet analysis of voluntary cough sound in patients with respiratory diseases." *J Physiol Pharmacol* 59.Suppl 6 (2008): 331-340.

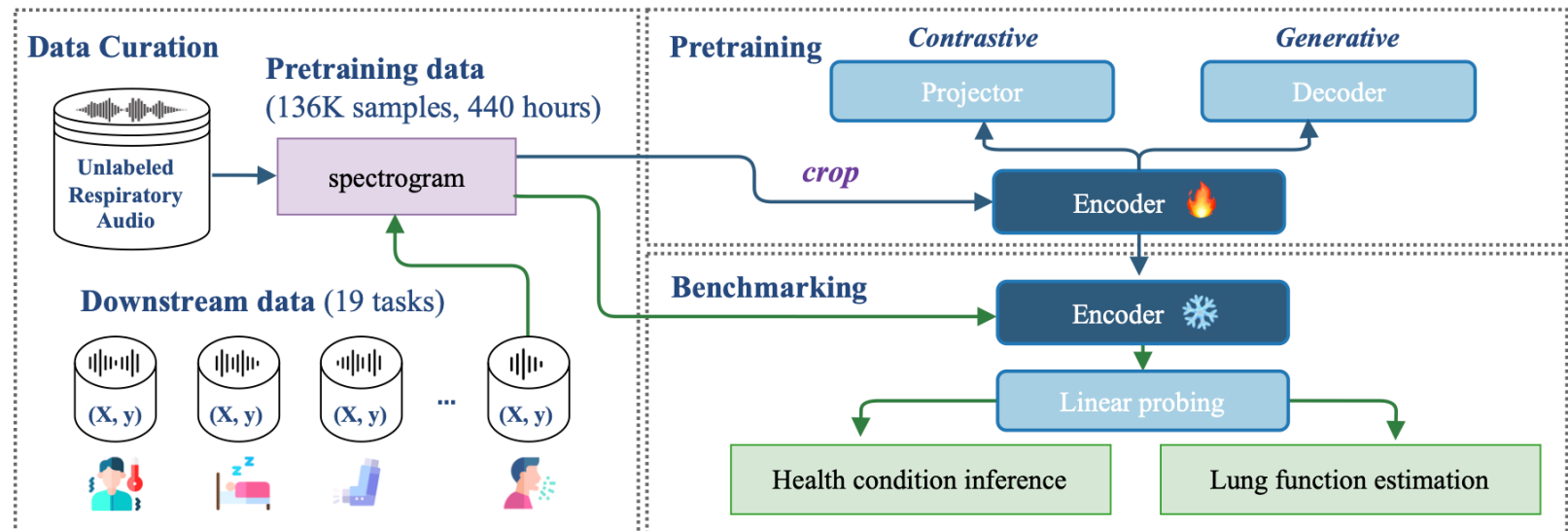
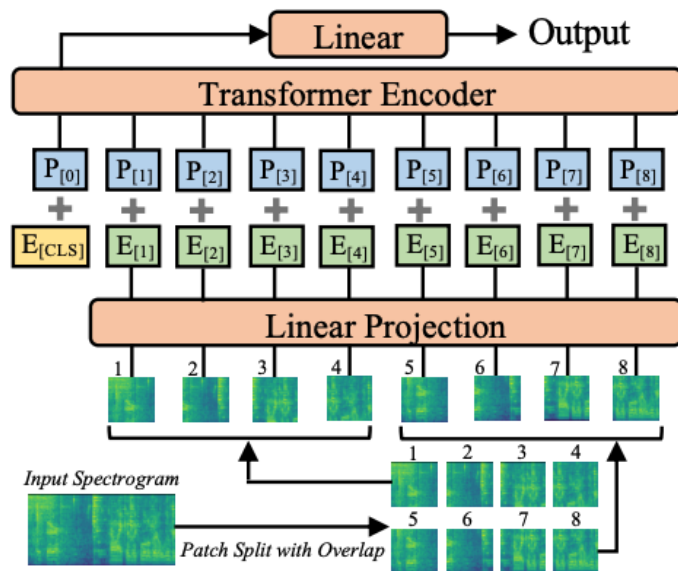
[2] Vyshedskiy, Andrey, and Raymond Murphy. "Acoustic biomarkers of chronic obstructive lung disease." *Research Ideas and Outcomes* 2 (2016): e9173.

Motivation

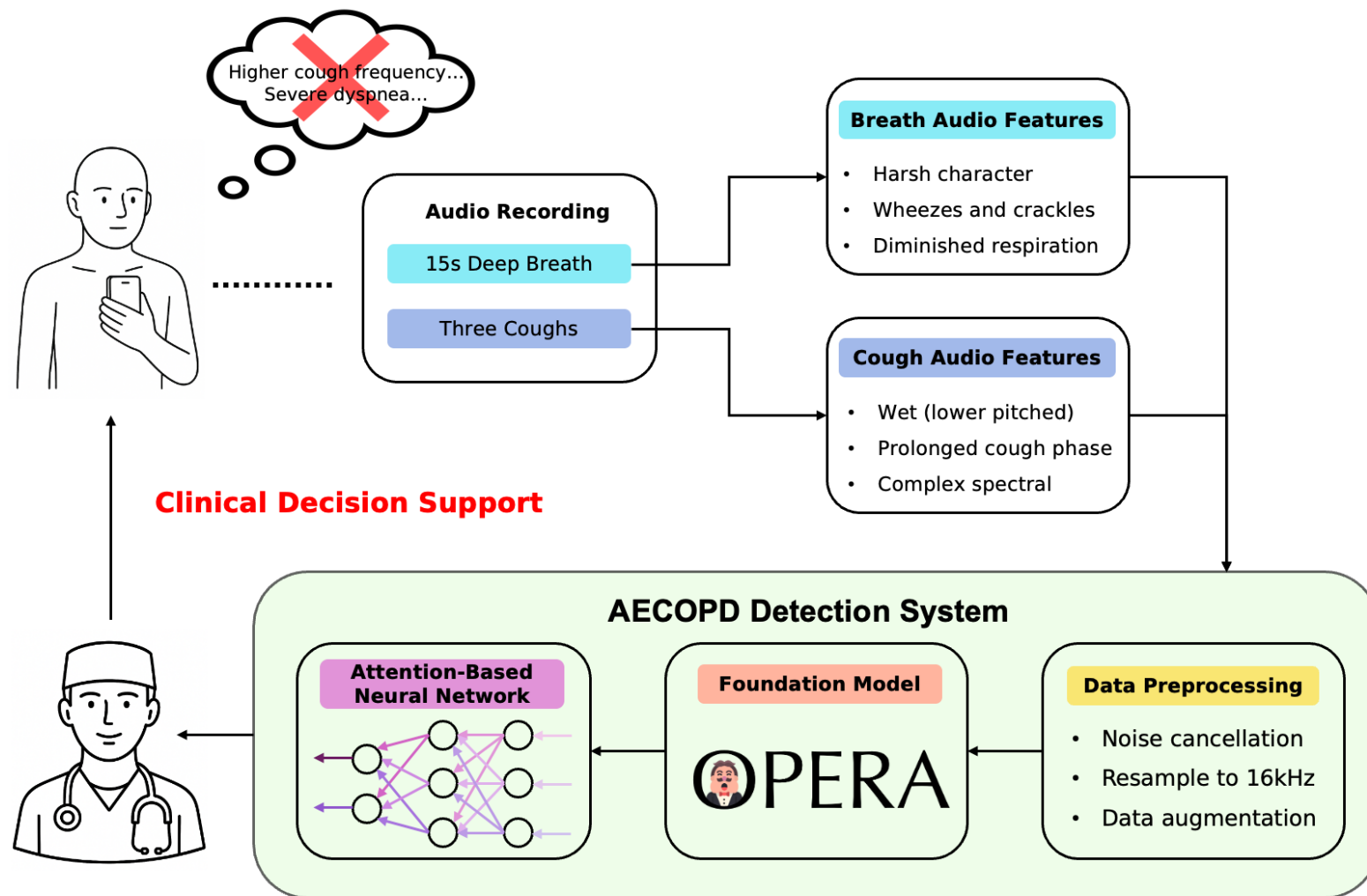
- Audio Foundation Models have raised
 - AST (Audio Spectrogram Transformer)
 - Foundation model trained on millions of audio data
 - OPERA (OPEn Respiratory Acoustic foundation model)
 - Foundation model trained on hundreds of thousands respiratory data
- Making it possible to extract useful patterns from limited data



efficiently extract highly relevant, deep features from our own limited clinical dataset



AECOPDetector

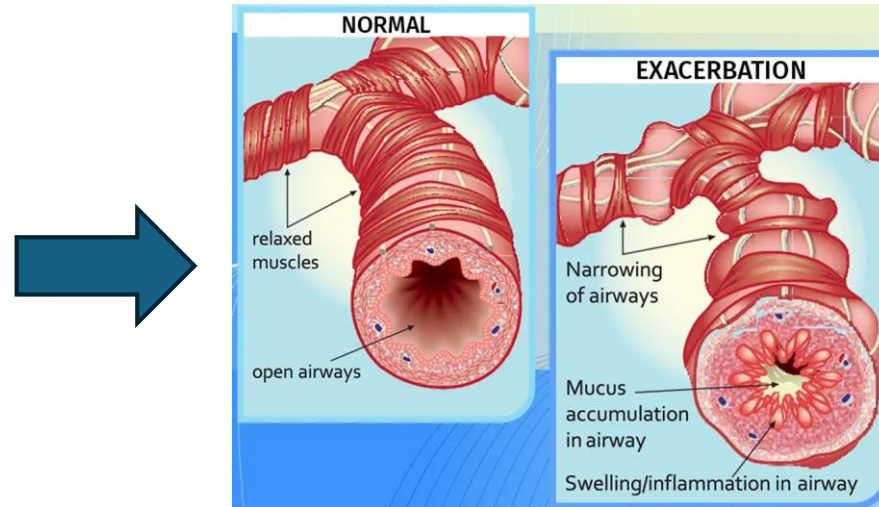


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Lung Function Assessment



The Acute Exacerbation Detection



Contactless Breathing Coaching

Wentao Xie, Chi Xu, Yanbin Gong, Yu Wang, Yuxin Liu, Jin Zhang, Qian Zhang, and Zeguang Zheng, DeepBreath: Breathing Exercise Assessment with a Depth Camera. in ACM IMMUT/Ubicomp 2024.

DeepBreath — Guiding with a Depth Camera

Current Solution



Contactless tracking for breathing mode & lung volume



High accuracy:

Rate error: 0.09 BMP

Mode classification: 92%

Volume error: 0.09 L



Hospital validation:

Conduct in **the First Affiliated Hospital of Guangzhou Medical University**



Easy setup:

A single depth camera, no clinician needed

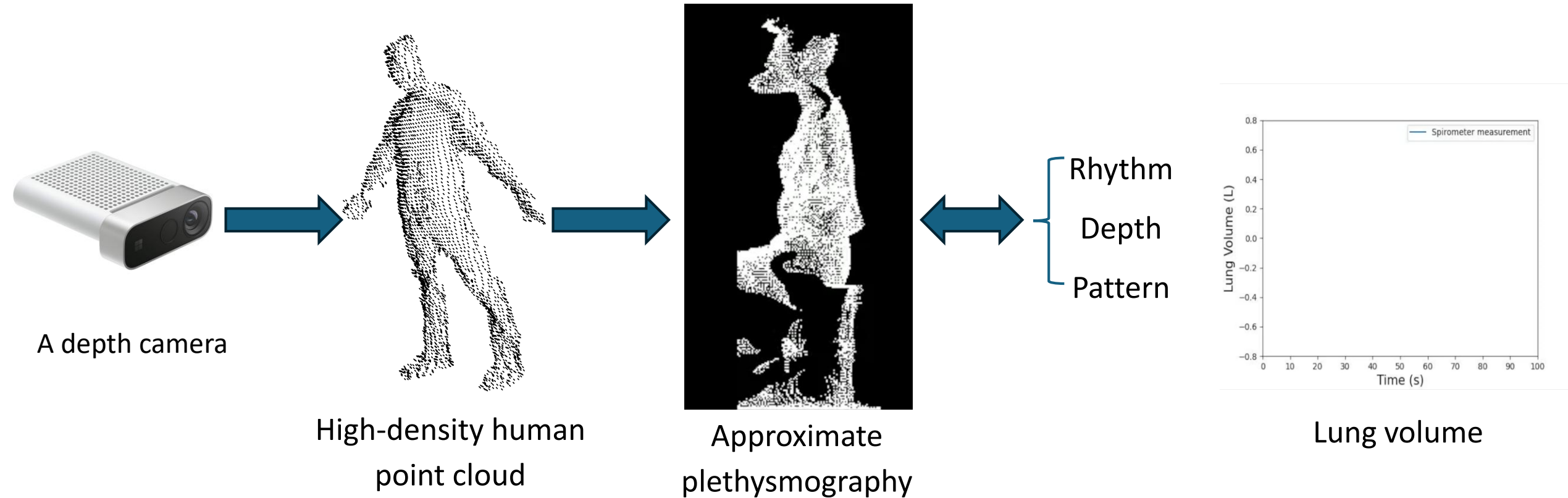


Clinically proven:

Validated with **36 real-world participants, including 14 COPD patients**

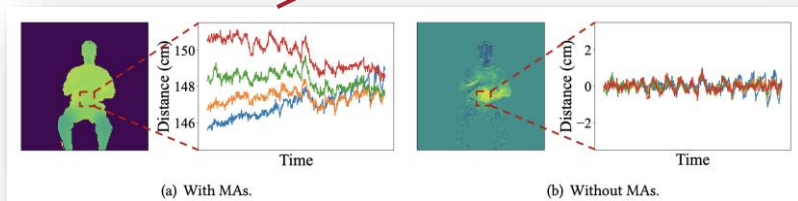
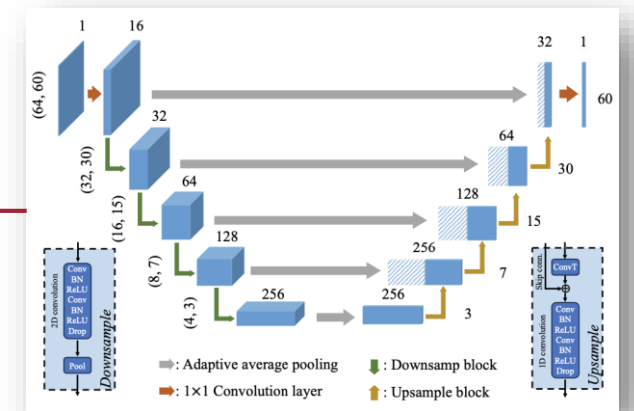
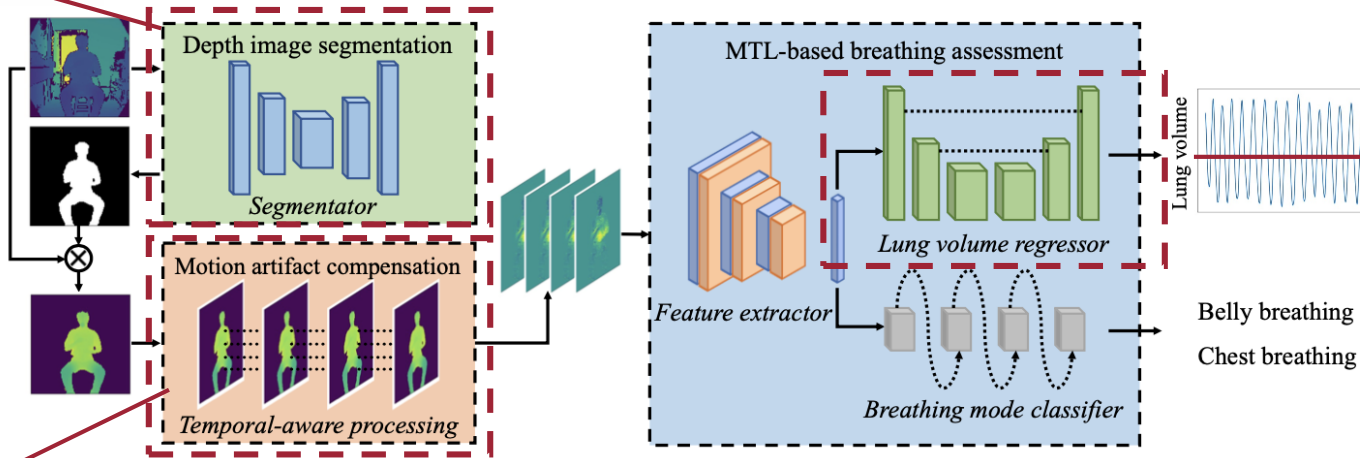
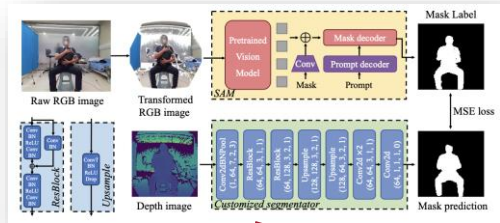
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DeepBreath – Comprehensive Breathing Coaching with Depth Cameras

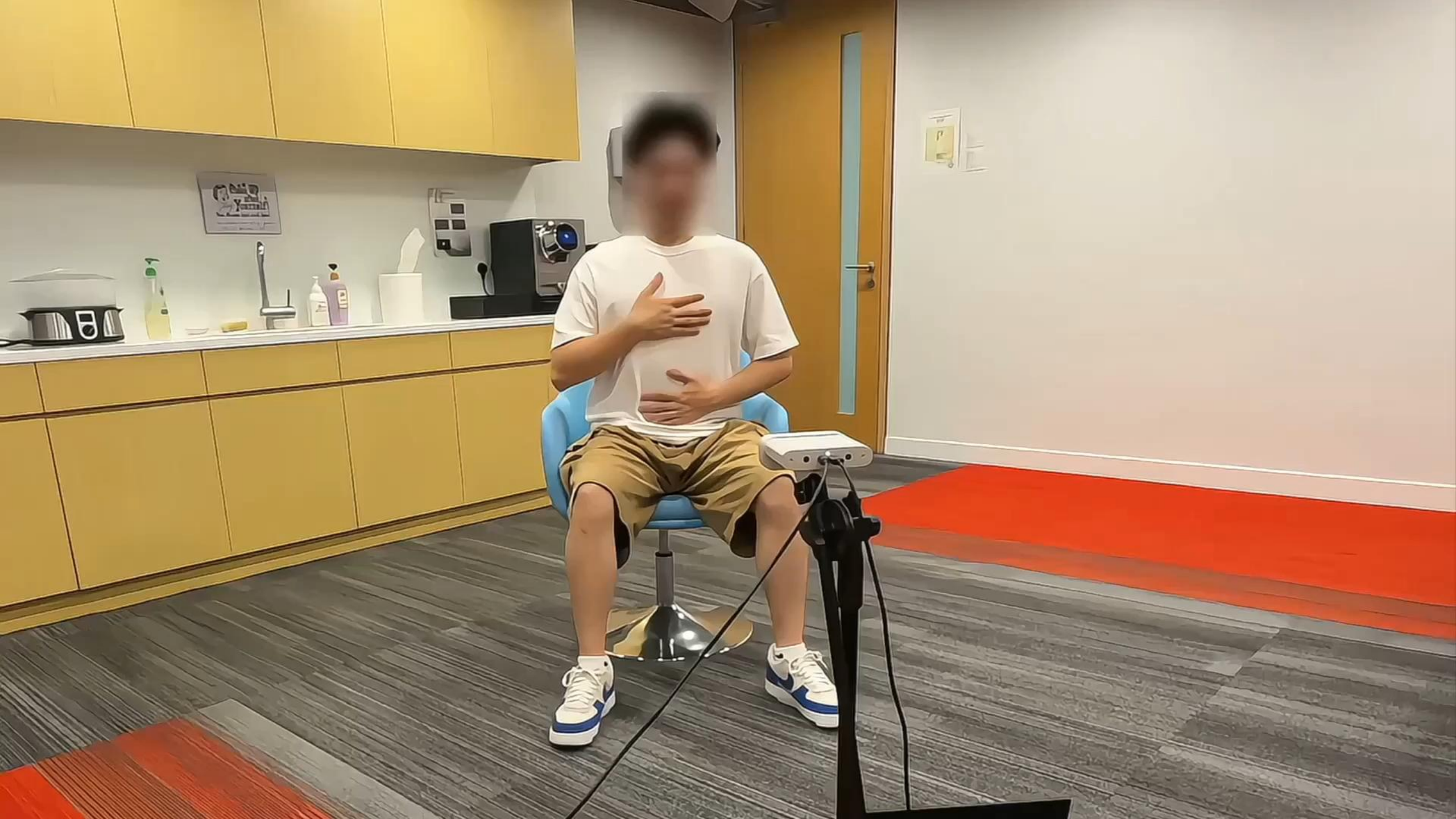


Using a depth camera and deep image processing algorithms, we can obtain measurements such as volume plethysmography and then deduce various parameters of human breathing

DeepBreath – Comprehensive Breathing Coaching with Depth Cameras



广东省医学科学院
GUANGDONG ACADEMY OF MEDICAL SCIENCES
广东省人民医院
GUANGDONG PROVINCIAL PEOPLE'S HOSPITAL



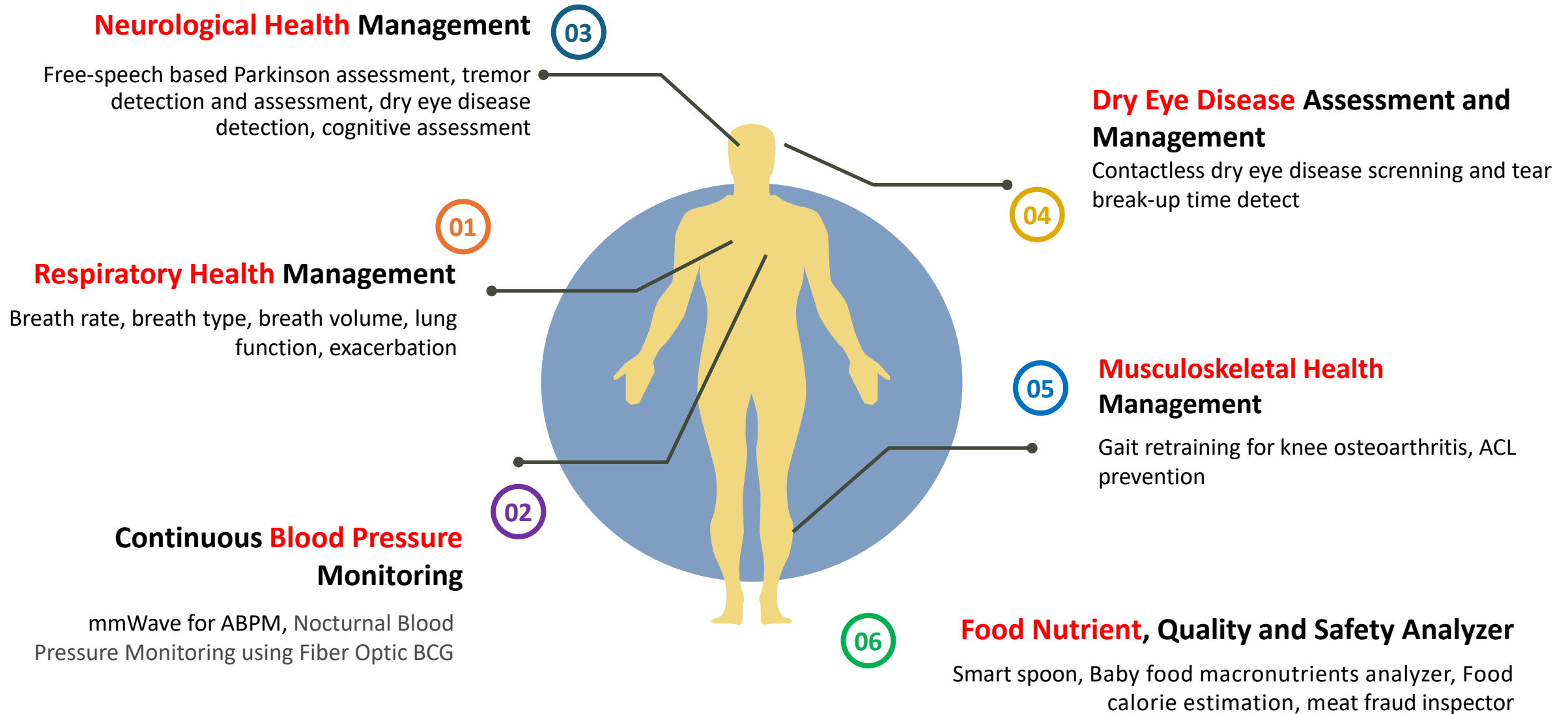
Proactive Health Management:

Hospital + Home Medical-Grade Multimodal Health Management Platform

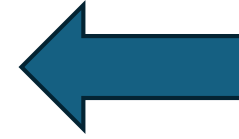
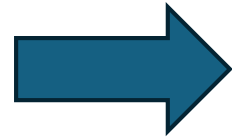


- ✓ Early and Convenient Diagnosis
- ✓ Continuous Monitoring and Assessment
- ✓ In-time and Personalized Intervention

Current Focused Research Directions



On-Going Directions



Enhanced Sensing Modalities

- New materials
- Flexible Circuits (Wearables)
- Reconfigurable Intelligent Surface (RIS)

Personalized Therapist

- Various health "prescriptions" (nutrition, exercise, psychology, rehabilitation, etc.)
- Digital Therapy improves health

Sustainable development of AI models

- Large Model AI → Edge AI → Tiny AI
- Resource constraint
- Data privacy, robustness of learning model

Edge Intelligence: Multi-Modality Sensing to Revolutionize Chronic Diseases Management

Thank you!

