# Emerging Tools for Pneumonia Diagnosis in Resource Poor Regions

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# Where are we?

Brisbane, the third largest city in Australia.

**1-hour drive from Gold Coast.**

# Where are we?

The Faculty of Engineering, Architecture and Information Technology

Schools of Chemical, Civil and Mechanical Engineering

School of Architecture

School of Information Technology and Electrical Engineering

Biomedical Engineering Group

**Sleep and Respiratory Systems Engineering**

# Our Research

- Sleep apnea diagnosis and treatment
- Respiratory diseases
- Sleep and interaction with co-morbidities
- Medical Instrument design and diagnostic algorithms
- A large part of the work targeting remote area use.
- Mobile Health (mHealth), minimally invasive diagnostics, long-term monitoring.

Pneumonia Diagnostics project started from scratch

In 2009 with a GCE Phase I grant from the Gates Foundation

The first journal article appeared in 2013.

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## Clinical Collaborations

Universitas Gadjah Mada, Sardjito Hospital, Indonesia

Dr. R Triasih, Dr. A. Setyati

Royal Children's Hospital, Brisbane, Australia

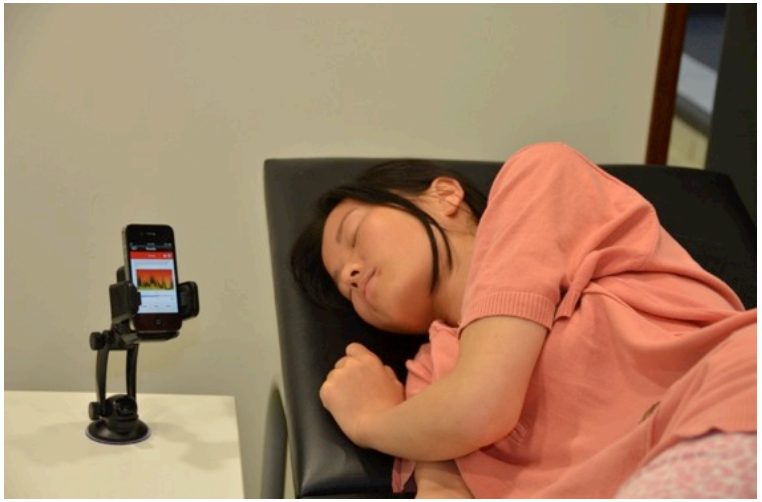
Prof. Anne Chang (Dry/wet analysis of cough)

Princess Alexandra Hospital, Brisbane, Australia

Assoc. Prof. C. Hukins (Adult Cough)

# Inspiration:
# Sound Analysis for Apnea Diagnosis

Standard PSG



Smart Phone

- About 17 years of research effort
- Peer-reviewed publications, IP protection
- Competitive funding
- Research translation (Appian Medical Pvt Ltd, 2014)
- Classification sensitivity and specificity above 90% compared to standard test.

# Cough Sounds Different in Different Diseases

Asthma Cough

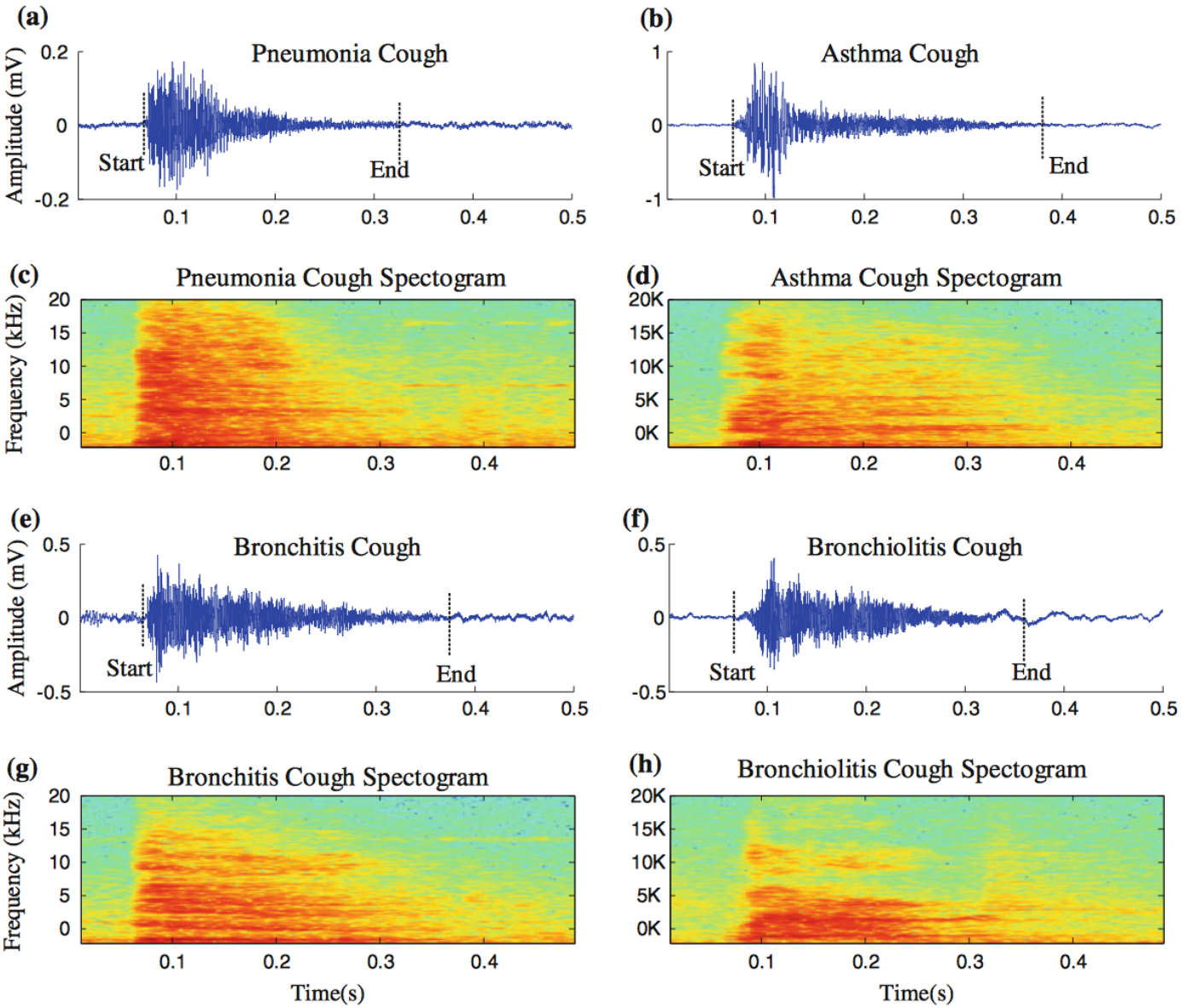
Bronchitis Cough

Heart Congestion

Bronchiolitis

Pneumonia

# Cough Spectra too is different

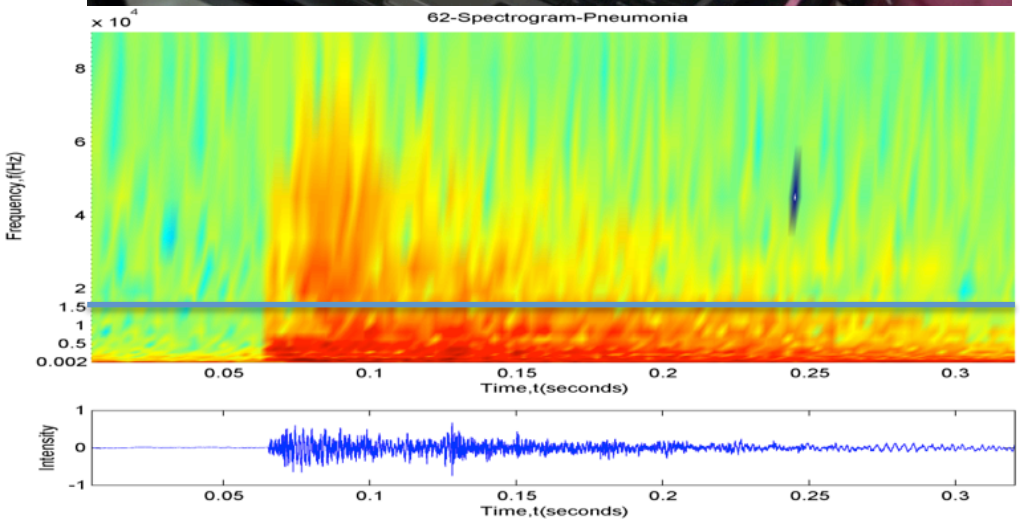



Annals of BME, USA, 2013

**FIGURE 3. Typical waveforms of cough sounds in (a) pneumonia, (b) asthma, (e) bronchitis and (f) bronchiolitis. Their frequency spectrograms are shown respectively in (c), (d), (g) and (h).**

# Data Acquisition

**Recording location:** Paediatric ward, Sardjito Hospital, Gadjah Mada University, Indonesia




## Setup-1:

### 20Hz-20kHz Bandwidth Recording

Microphone (Model NT3, RODE®, Sydney, Australia).
Frequency response 20 Hz – 20 kHz.
A/D converter (Mobile Pre-USB, M-Audio®, CA, USA).

## Setup-2:

### 4Hz-100kHz bandwidth Recording

Microphone (Model 40BE, GRAS®, Holte, Denmark)
Frequency Response 4 Hz – 100 kHz
A/D converter (Model Tracker Pre, E-MU®, CA, USA).

| Inclusion Criteria | Exclusion Criteria |
| --- | --- |
| ➢Patients with symptoms of chest infection, Cough, Sputum, Increased breathlessness<br>➢Temperature >37.5°<br>➢Consent | ➢Advanced disease where recovery is not expected eg terminal lung cancer<br>➢Droplet precautions<br>➢NIV required<br>➢No Consent |

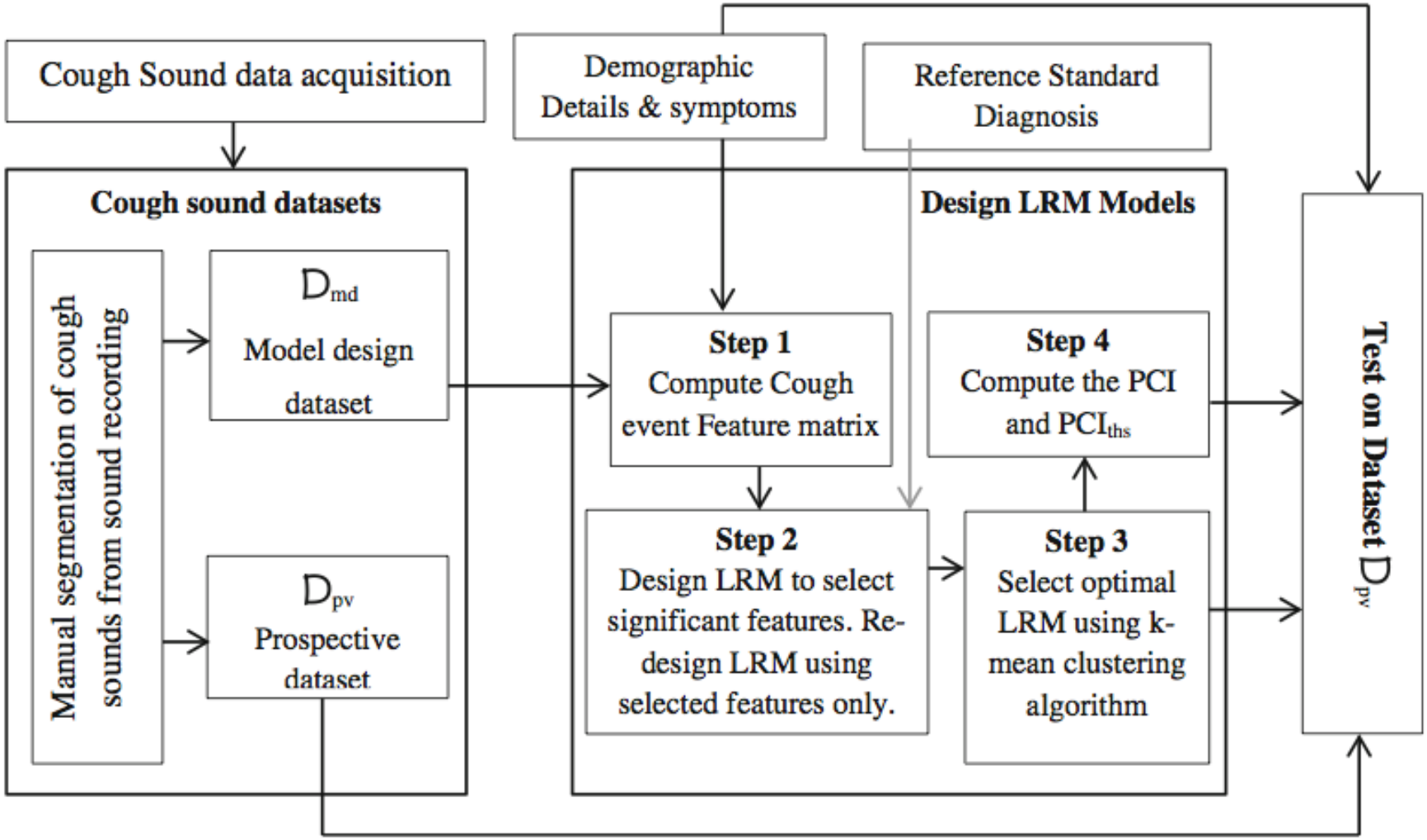
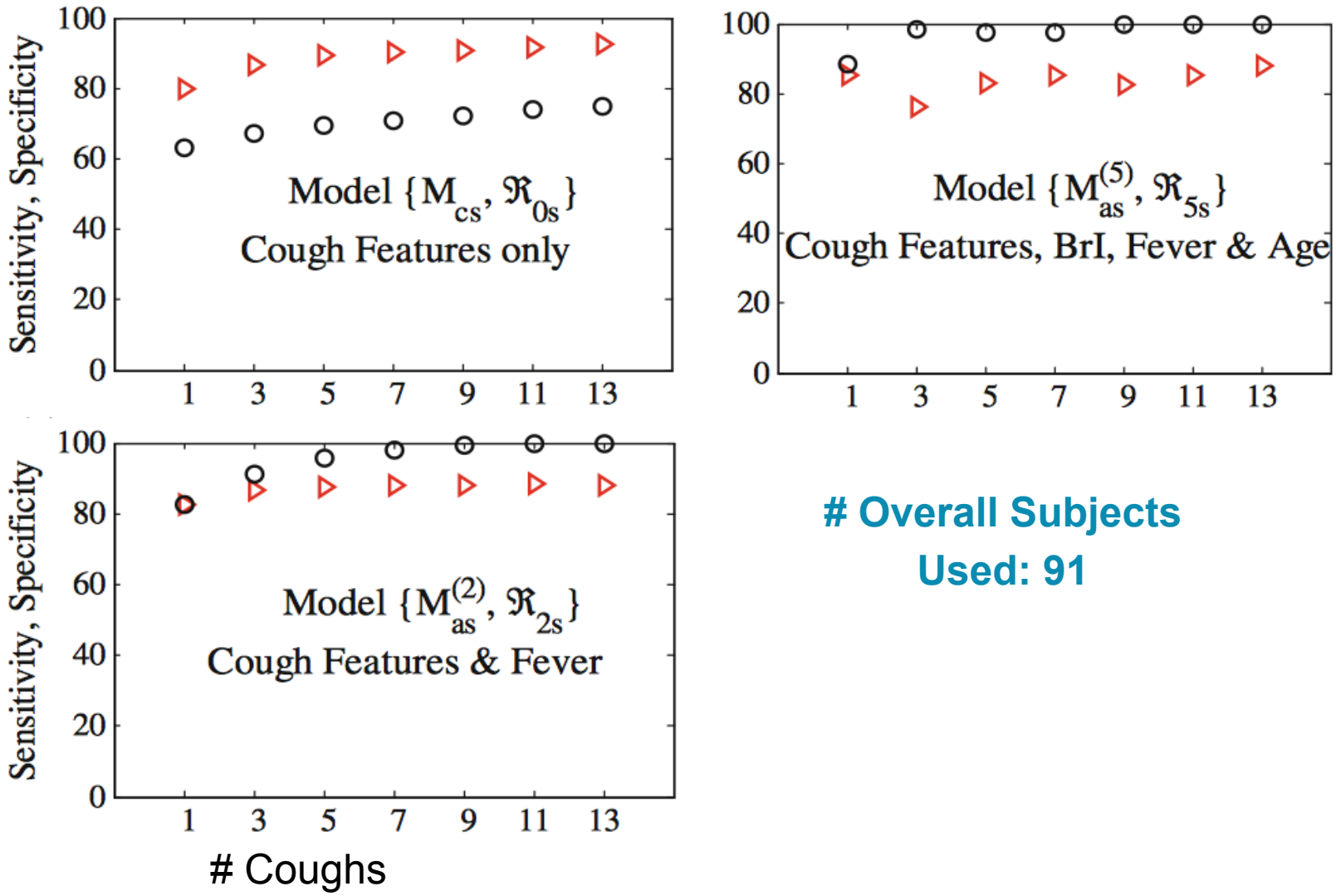



**FIGURE 1. Overall block diagram of the proposed method. The method consists of three main stages: (i) creating cough sound datasets, (ii) the development of features & the training of pattern classifiers, and, (iii) the prospective validation and performance evaluation of the technology.**

# Performance – Bedside microphone




**# Overall Subjects Used: 91**

# Performance on Prospective Data

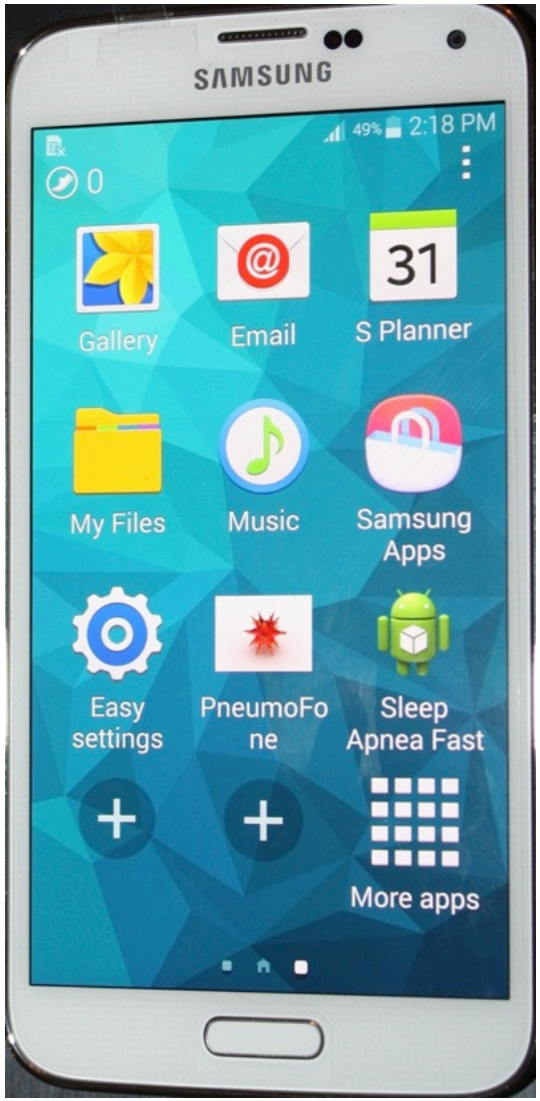
**TABLE 7. The performance of the selected (best) LRM models in diagnosing pneumonia at the patient level, based on the pneumonia cough index (PCI).**

| | Prospective dataset $D_{pv}$ | | | | | |
|---|---|---|---|---|---|---|
| Selected LRM model | Sens (%) | Spec (%) | Acc (%) | PPV (%) | NPV (%) | $\kappa$ |
| $\{\mathbf{M}_{cs}, \Re_{0s}\}$: only cough-features | 94 | 75 | 88 | 89 | 86 | 0.72 |
| $\{\mathbf{M}_{as}^{(1)}, \Re_{1s}\}$: cough and BrI | 88 | 62.5 | 80 | 83 | 71 | 0.52 |
| $\{\mathbf{M}_{as}^{(2)}, \Re_{2s}\}$: cough and fever | 94 | 100 | 96 | 100 | 89 | 0.91 |
| $\{\mathbf{M}_{as}^{(3)}, \Re_{3s}\}$: cough and Age | 88 | 75 | 84 | 88 | 75 | 0.63 |
| $\{\mathbf{M}_{as}^{(4)}, \Re_{4s}\}$: cough, BrI and fever | 82 | 87.5 | 84 | 93 | 70 | 0.66 |
| $\{\mathbf{M}_{as}^{(5)}, \Re_{5s}\}$: cough, BrI, fever and age | 88 | 100 | 92 | 100 | 80 | 0.83 |

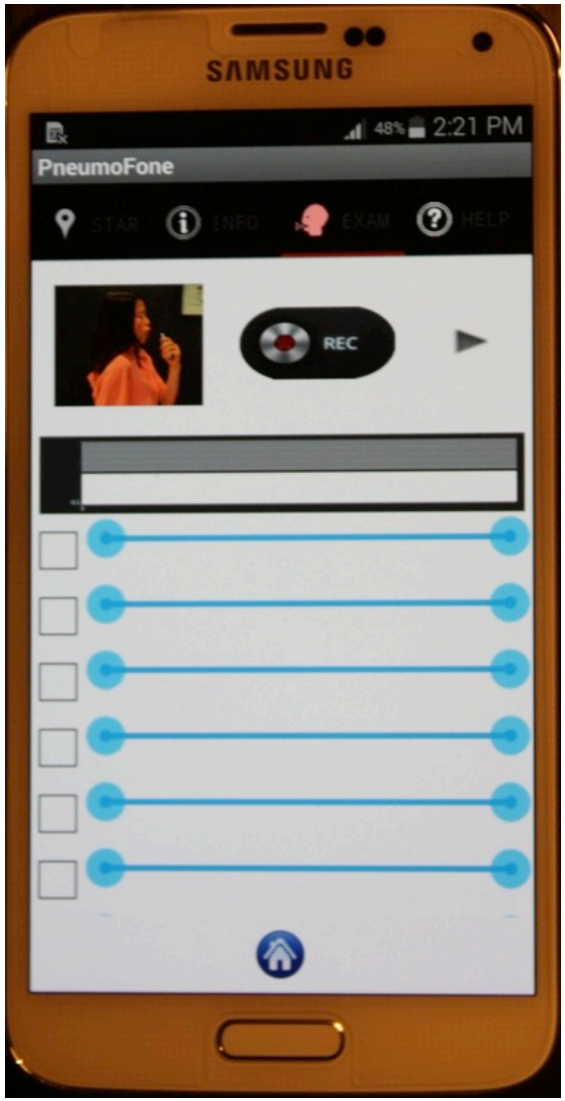
Results were obtained with the Prospective Data Set $D_{pv}$. $P = 11$ cough events were used for PCI calculation in Eq. (4). Note that Sens, Spec, Acc, PPV, NPV and $\kappa$ respectively denote sensitivity, specificity, accuracy, positive predictive value, negative predictive value and the Cohen's kappa statistic.

$$\mathrm{BrI} = \left\{ \begin{array}{ll} \mathrm{BR} - 20 & \text{if Age} \geq 60\,\text{months} \\ \mathrm{BR} - 40 & \text{otherwise} \end{array} \right\}$$

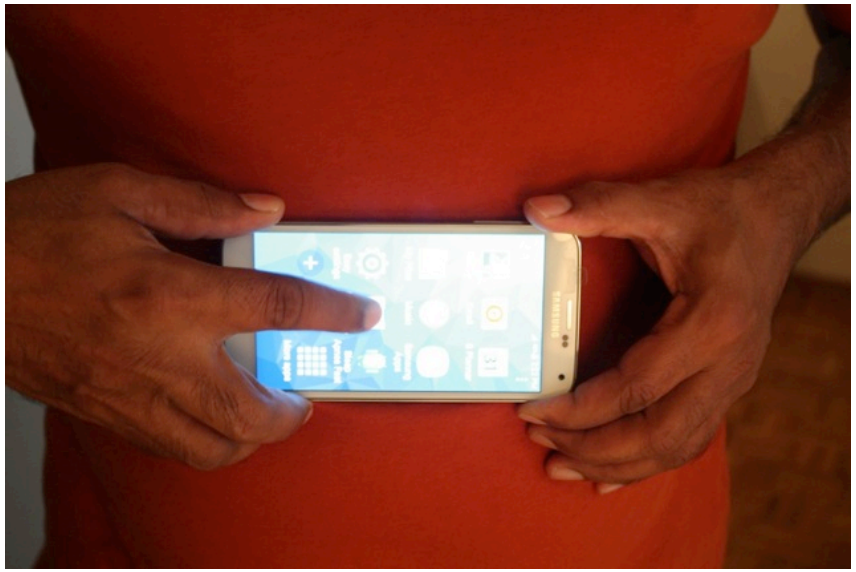
# Pneumonia Screening App







# Modes of Use



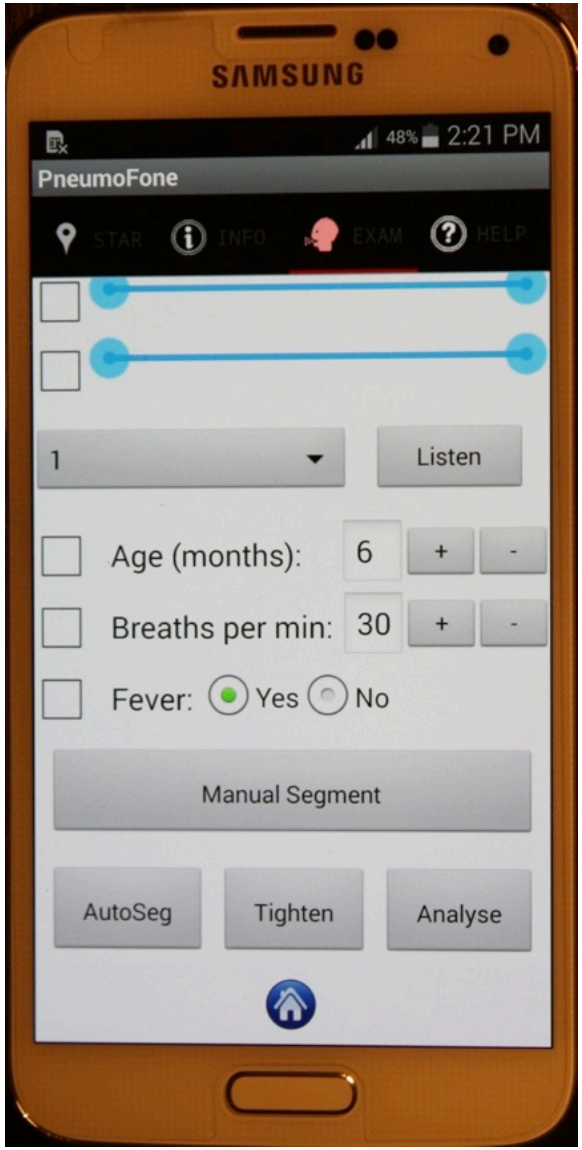
**On the abdomen**:

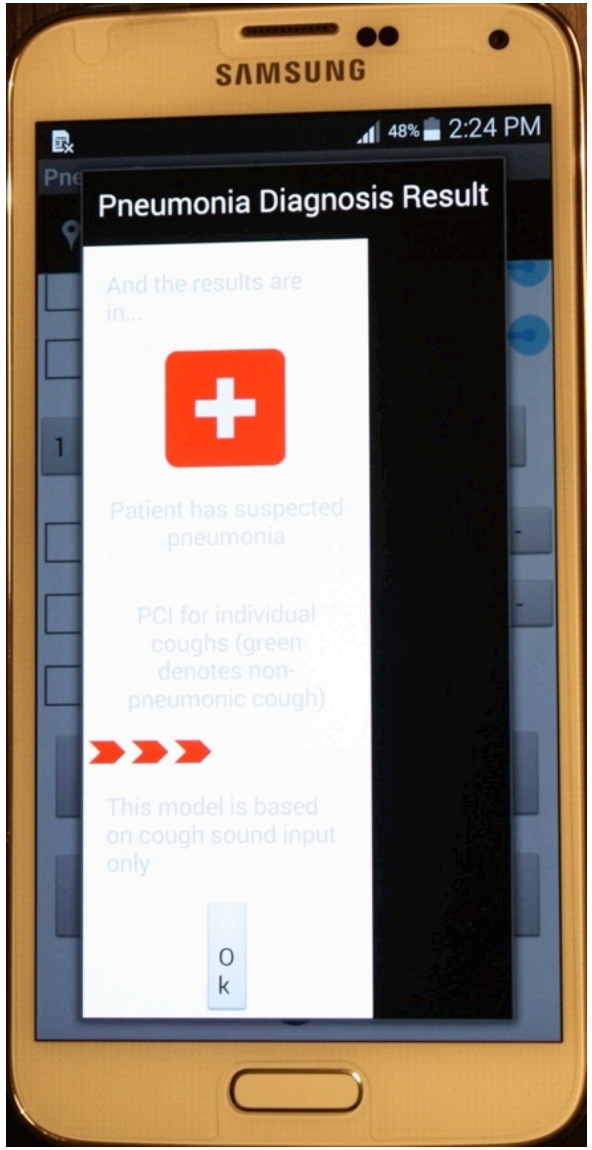
Cough detection can be aided by abdominal movements caused by cough.

**Non-contact**:

In-air sound measurement.

# Pneumonia Screening App



# PneumoFone Technology and the IMCI

Cough or Difficult Breathing?


**Pneumonia/No pneumonia?**
(Annals of BME, USA, 2013)

**Pneumonia/Asthma?**
**(Bronchodilator Test Substitute)**
IEEE Trans. of BME (under peer review, 2014)

# PneumoFone Technology and Potential Other uses


**Enhanced WHO Criteria?**

**Other parameters?**
**Fixed individual thresholds?**
**(paper in preparation, 2014)**

**Cough Statistics, Cough Counting**
**(paper under peer review, 2014)**

**Wet Cough/Dry Cough?**
**(Annals of BME, USA, 2013)**

# Enhanced WHO?

- Cough analysis coupled with other parameters (respiratory rate, existence of fever, age, **gender**,..) – requires manual entry of extra information.

- Diagnostic models that use breathing rate, age, oxygen saturation etc. and the existence of cough/breathing difficulty and fever etc.  (not available on the phone demonstrated but can be added quickly).

# What is next?

## PneumoFone:

•Optimizing coefficients of the algorithm for the Smart Phone.
•Severity classification
•Further validation using a larger prospective dataset.
•Limited Field Testing , FDA/TGA Approval, Field Testing

**Partnerships Needed!**

## Mobile Phone Augmentation options

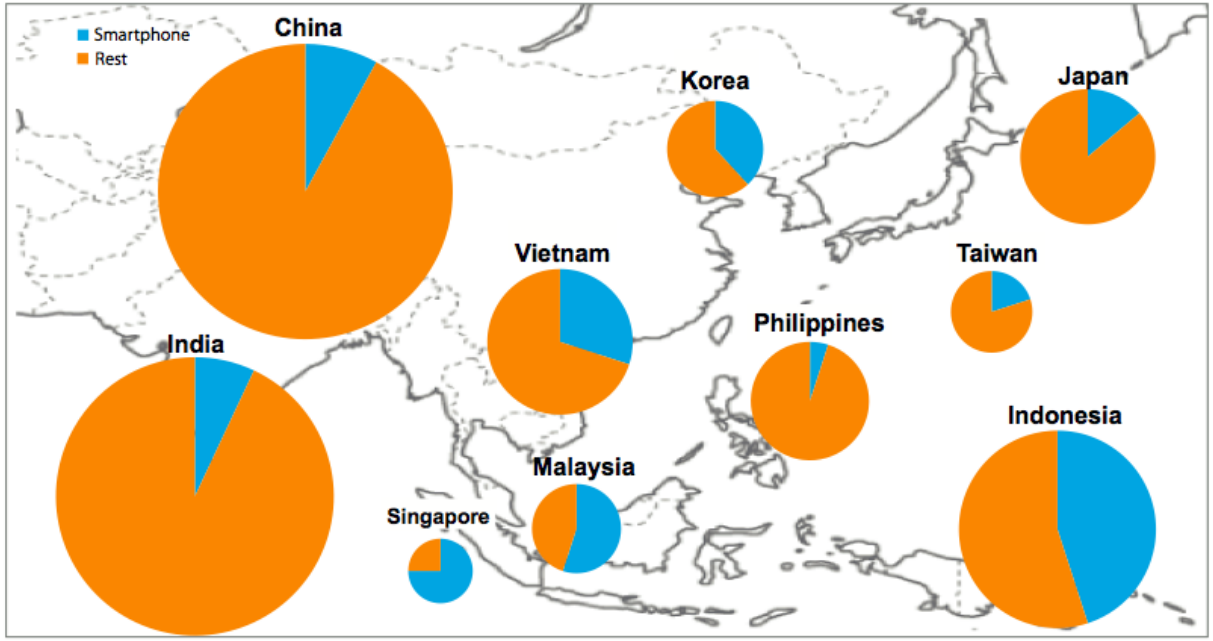
•Peripheral electronics/devices for the smart phone.
•Telemedicine approaches where useful
•Epidemiology

# Smart Phones

- Do we really need smart phones?
- Will they be affordable?
- Where in the management of pneumonia can we use the smart phones (or the alternative implementations)?
  - In-home monitoring?
  - Clinic, CHW home, during consultation?
  - Managing the queue?
  - Pneumonia confirmation (X-ray substitute)?
  - Bronchodilator substitute?

# Smart Phone penetration is accelerating substantially in the developing world

**[Figure 0-2] Asia Smartphone Penetration 2011**




Source: ROA Holdings Analysis

- Second quarter of 2013: more smartphones sold than feature phones.
- 2013: within a year, smart phone penetration doubled in India.
- Smart phones costing about $100 is available.
- Pessimistic estimate: 20% of the African population will have a smart phone by 2017.

# Project Status – June 2014

- GCE Phase I completed in 2011. No funding at present.
- 2 journals published, 3 journals under peer review, two journals in preparation. Several peer-reviewed archival conference proceedings published and publicly available.
- International PCT patent filed by UQ (subject to the terms of the BMG Foundation Global Access Initiatives).
- One postdoctoral fellow and 2 PhD students (both from Indonesia) trained; several undergraduate students did their theses on the project (e.g. TriCoder, PneumoFone app).
- Original GCE Phase I leveraged by funding contributions from UQ (two PhD scholarships, travel fellowships, postdoc partial support, UniQuest PathFinder Grant, researcher time in UQ and outside).
- Smart phone prototype proof-of-concept is available, but require further work before field testing.
- We have the ability to develop other implementations, from designing and prototyping electronic devices to implementing advanced algorithms.

# Further Information

Cough Sound Analysis Can Rapidly Diagnose Childhood Pneumonia, Annals of Biomedical Engineering, Vol. 41, No. 11, November 2013, pp. 2448–2462.

Automatic Identification of Wet and Dry Cough in Pediatric Patients with Respiratory Diseases, Annals of Biomedical Engineering, Vol. 41, No. 5, May 2013, pp. 1016–1028.

# Acknowledgements

## Pneumonia Diagnostics Project


| | |
|---|---|
| Bill & Melinda Gates Foundation | (GCE Phase I Grant, 2009) *Which started it all!* |
| The University of Queensland | (2X PhD Scholarships) |
| UniQuest Pvt Ltd. | (PathFinder Grant) |
| Universitas Gadjah Mada, Indonesia | (clinical collaboration, data site) |
| Royal Children's Hospital, Brisbane | (clinical collaboration, dry/wet) |
| Princess Alexandra Hospital, Brisbane | (clinical collaboration) |

### Postdocs and research students

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