Low-Cost, Portable Pneumonia Diagnostic Device

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Need/Project Scope

- Need
  - Pneumonia is a major cause of death in developing countries
  - Early diagnosis is key for improved patient outcomes
- Project Scope
  - To develop a low-cost, non-invasive, portable device that can diagnose pneumonia

Specific Design Requirements

Accurate
- False Positive Rate < 10%
- False Negative Rate < 10%

Inexpensive
- Total cost < $150

High throughput
- Measurement time < 30 seconds
- Diagnostic time < 1 minute

Safe
- No pathogen exposure
- Non-invasive

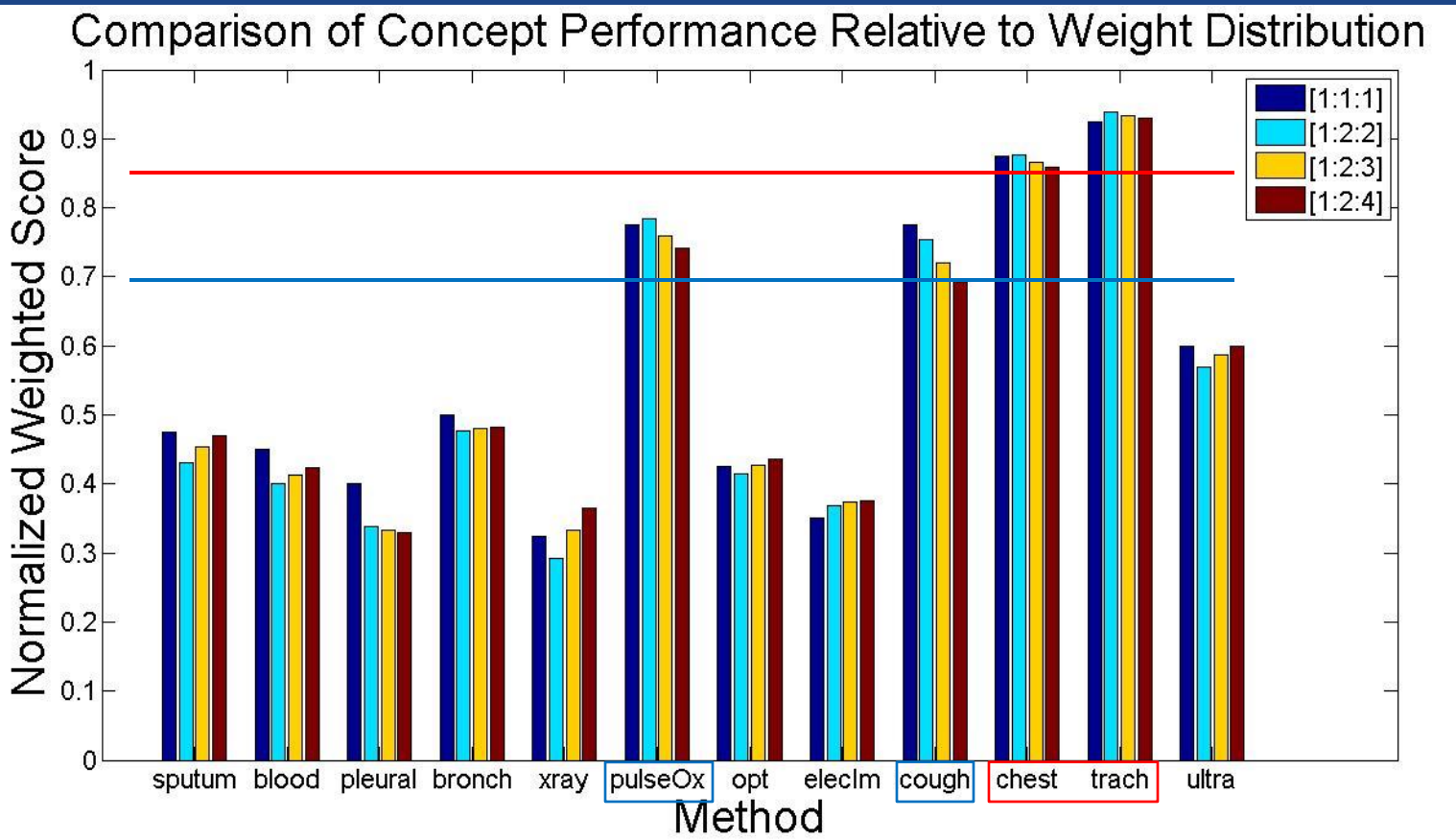
Portable
- Mass < 0.5 kg
- Volume < 1L

Easily Operated
- Does not require a trained technician

Overview of Design Alternatives

- The design alternatives were divided into 3 categories:
  - Chemical Methods
  - Electromagnetic Methods
  - Acoustic Methods
- 12 designs were generated and evaluated

Specification:	Weight:	Sputum Test:	Blood Test:	Pleural Fluid Analysis:	Bronch-oscopy:	Portable X-ray:	Pulse Oximetry:	Optical Coherence:	Electrical Impedance:	Cough Sound:	Chest Sound:	Tracheal Sound:	Ultrasound:
Portable	2	0	0	0	4	0	5	4	2	4	5	5	3
Substantial Operation Time	1	5	5	5	4	1	3	4	1	5	5	5	3
High Throughput	1	1	1	1	1	3	4	1	2	4	4	4	3
Reliable: Durable	1	4	4	4	4	3	4	2	1	4	4	4	5
Reliable: Accurate	3	1	2	1	1	5	1	1	1	4	3	4	3
Easily Operated	2	1	1	1	0	0	4	0	2	4	4	5	0
Safe	3	5	3	2	4	1	5	4	3	1	5	5	4
Inexpensive	2	2	2	2	2	0	5	1	2	5	5	5	3
Non weighted score		19	18	16	20	13	31	17	14	31	35	37	24
Weighted Score		**34**	**31**	**25**	**36**	**25**	**57**	**32**	**28**	**54**	**65**	**70**	**44**
Normalized Weighted Score		0.45	0.41	0.33	0.48	0.33	0.76	0.43	0.37	0.72	0.87	0.93	0.59


Comparison of Concept Performance Relative to Weight Distribution
Normalized Weighted Score
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
[1:1:1]
[1:2:2]
[1:2:3]
[1:2:4]
sputum
blood
pleural
bronch
xray
pulseOx
opt
elecIm
cough
chest
trach
ultra
Method

Electromagnetic Method: Pulse Oximetry

- Measures SpO_2 based on absorption differences of red and infrared light in blood
- Pros:
- Low-cost and easily operated
- Can distinguish between pneumonia and non-respiratory illnesses
- Cons: Accuracy
- Cannot easily distinguish pneumonia and other acute respiratory illnesses (ARI's)
- Healthy SpO_2: 98.73% ± 1.51%
- Other ARI SpO_2: 94.97% ± 2.70%
- Pneumonia SpO_2: 92.32% ± 3.83%

www.staples.com

Madico et al.

Acoustic Method: Cough Sound Analysis

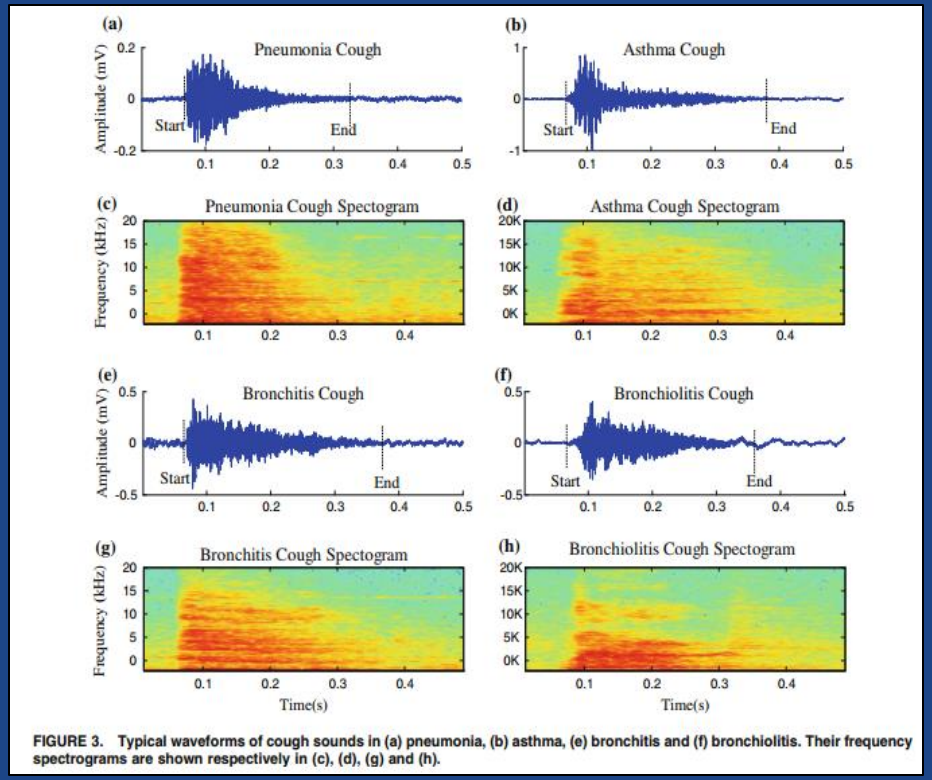
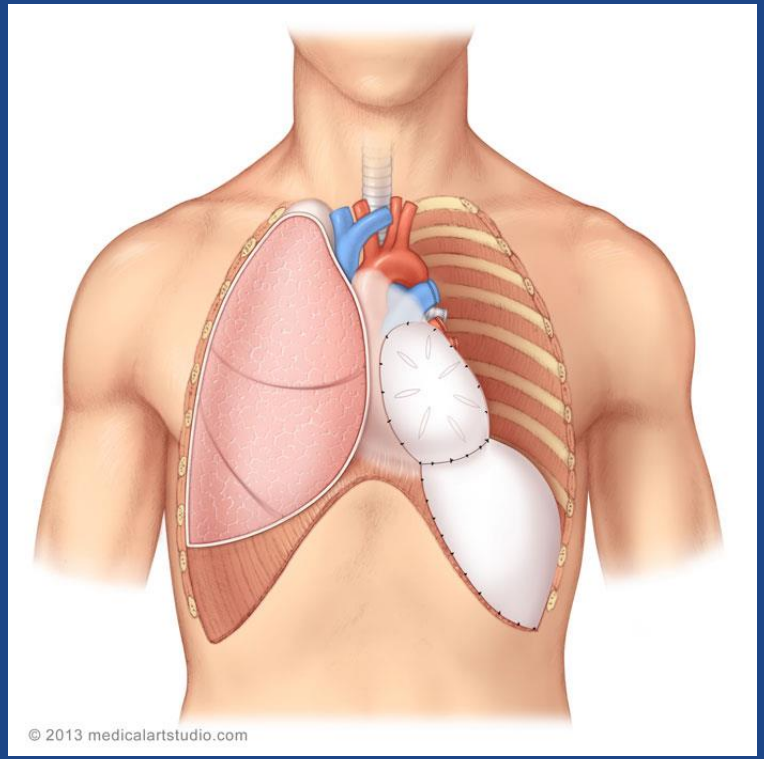


FIGURE 3. Typical waveforms of cough sounds in (a) pneumonia, (b) asthma, (e) bronchitis and (f) bronchiolitis. Their frequency spectrograms are shown respectively in (c), (d), (g) and (h).

Abeyratne, et al.

- Patient coughs would be recorded in a microphone
- Key features from amplitude plot and spectogram would be extracted and used for diagnosis
- Pros:
- Low-cost, easy method to extract key features
- 94% sensitivity and 75% specificity
- Cons: Safety
- Device and user directly exposed to pathogens

Acoustic Method: Chest Sound Analysis

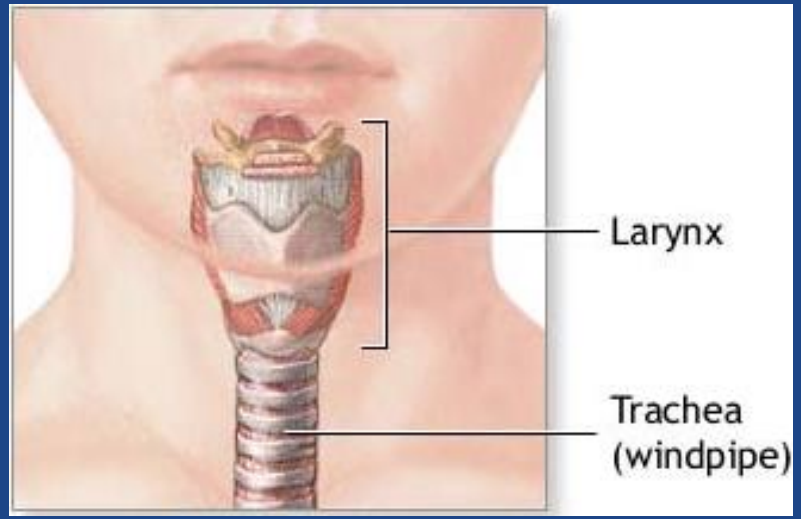


- Conductive diaphragm would be enclosed in “puck” shaped housing and placed on chest
- Key features would be extracted and used for diagnosis
- Pros:
- Low-cost, easy method to extract key features
- 78% sensitivity and 88% specificity
- Cons: Accuracy
- Lung tissues in the chest act as low-pass filter (attenuates key features)

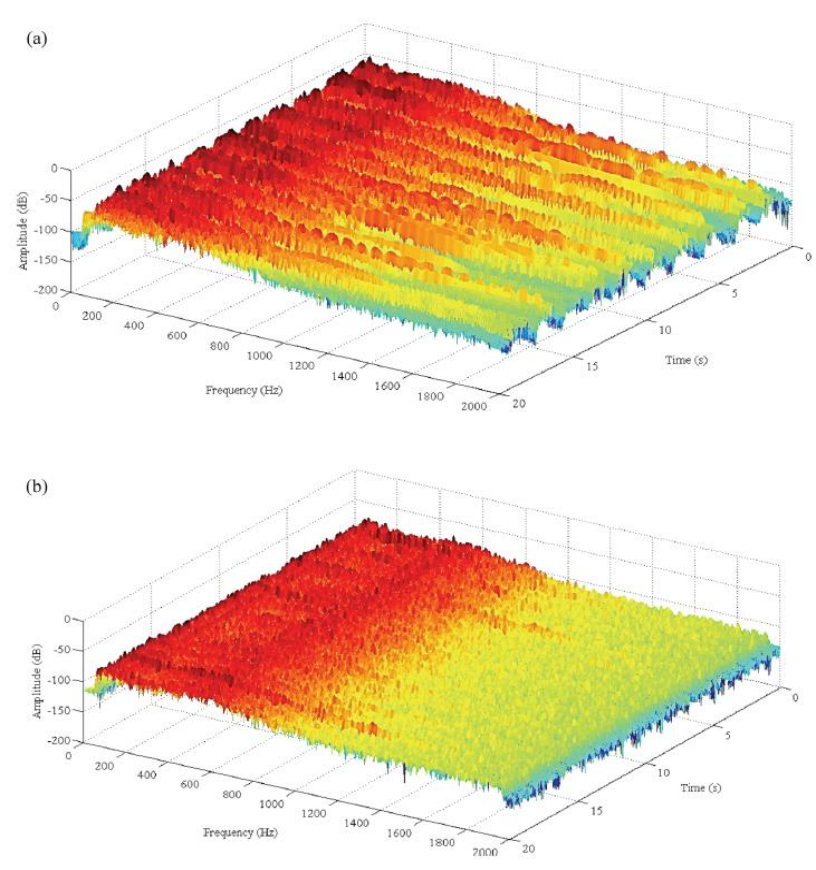
http://thoracicsurgery.stanford.edu/

Murphy

Chosen Design: Tracheal Sound Analysis



Acoustic Method: Tracheal Sound Analysis

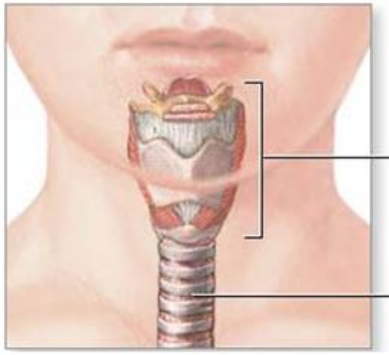


- Sensor would consist of diaphragm, air-coupled chamber, and microphone
- Key features would be extracted and used for diagnosis
- Pros:
  - Low-cost, easy method to extract key features
  - 72% sensitivity and 82% specificity
  - Low variability between subjects
- Cons:
  - Paper did not analyze differences between healthy patients and patients with pneumonia

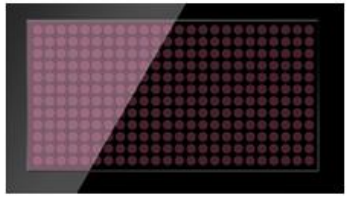
Morillo et al.

Improvements to Morillo Paper

- Make a portable, classification device that does not require a computer or mains power
- Analyze differences in key features between patients with and without pneumonia
- Improve sensitivity and specificity to over 90%

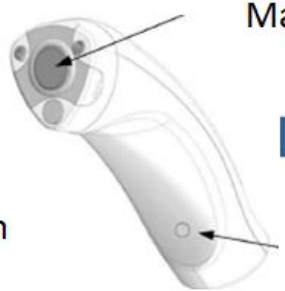


Displays diagnosis



Records acoustic signals from trachea

Main mic



Secondary mic (to filter background)

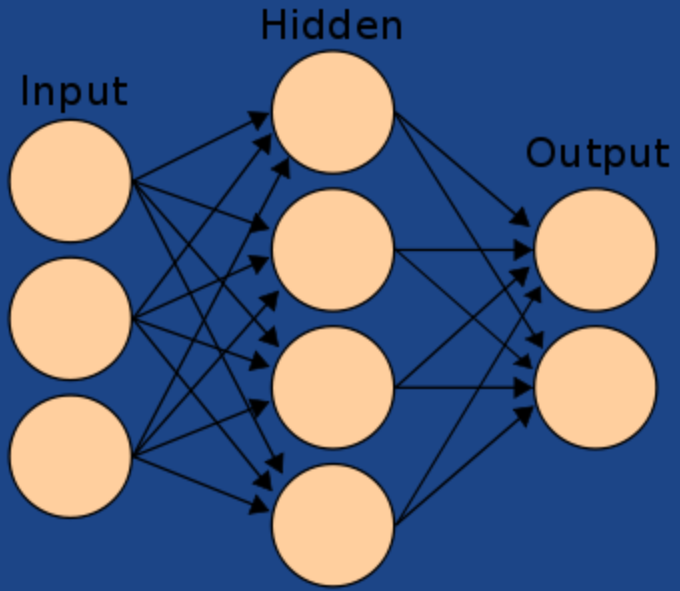
Convert analog signals to digital signals

Process digital signals to determine likelihood of pneumonia

Tracheal Sound Analysis: Feature Extraction

- Mean frequency
- RP in the 50-200 Hz band
- Vesicular sounds: normal breath sound
- RP in the 200-400 Hz band
- Wheezing sounds
- RP in the 400-800 Hz band
- Fine crackles
- RP in the 800-2000 Hz band
- High turbulence through trachea

Tracheal Sound Analysis: Classification



- Pneumonia will be diagnosed using an artificial neural network
- Key parameters will be inputs, and the neurons will update weights as learning occurs

Acknowledgements

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- Rebecca Gilson
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References

- www.staples.com
- Madico, Guillermo, et al. "The role of pulse oximetry: its use as an indicator of severe respiratory disease in Peruvian children living at sea level." *Archives of pediatrics & adolescent medicine* 149.11 (1995): 1259-1263.
- Abeyratne, Udantha R., Vinayak Swarnkar, Amalia Setyati, and Rina Triasih. "Cough Sound
- Analysis Can Rapidly Diagnose Childhood Pneumonia." Annals of Biomedical Engineering 41.11 (2013): 2448-462. Web.
- Murphy, Raymond. "Respiratory Care." *Automated Lung Sound Analysis in Patients With Pneumonia*. Washington University School of Medicine. Web. 23 Oct. 2014.
- American Accreditation HealthCare Commission
- Morillo, D. Sanchez, A. Leon Jimenez, and S. A. Moreno. "Computer-aided Diagnosis of Pneumonia in Patients with Chronic Obstructive Pulmonary Disease." *Journal of the American Medical Informatics Association* 20.E1 (2013): E111-117. Web.

Questions?