Pulmonary Acoustic Sensor Telemetry Array

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OSF HealthCare

OSF INNOVATION

MOTIVATIONS

- Heightened demand for *remote* and *contactless* methods of clinical care
- Continuous non-invasive pulmonary monitoring is not commonly available
- Respiratory conditions remaining the number one cause of hospitalization in children nationwide [1], [2]

Figure 1: Example Digital Stethoscope, Eko CORE 500

OBJECTIVES

- A novel hardware prototype capable of recording data from an array of acoustic pulmonary sensors simultaneously
- Simultaneously recording **8 channels** of audio at a frequency of **48 kHz** and depth of **24 bits**
- Low-cost, modular, and open-platform

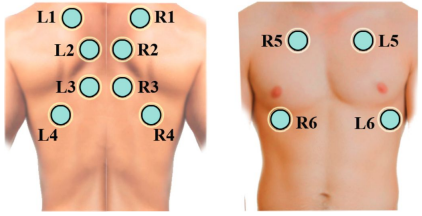

Figure 2: Target monitoring locations include L1, R1, L4-L6 and R4-R6

PROTOTYPE HARDWARE

We chose off-the-shelf components with small form factor and wide availability to assemble the prototype

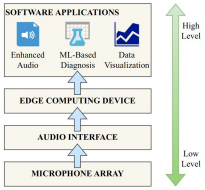

Figure 3: Data flow in PASTA prototype

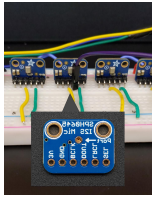

Figure 4: MEMS microphone breakout

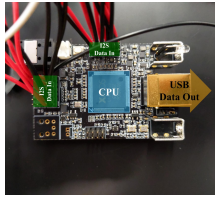

Figure 5: MCHStreamer Lite for audio interface

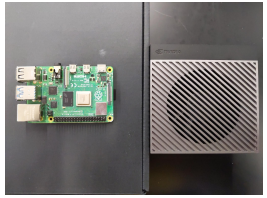

Figure 6: Edge computing devices Raspberry Pi 4 (left) and NVIDIA Jetson Orin (right)

ON-SITE DATA COLLECTION

- Laerdal SimMan 3G mannequin patient model generates nine lung diagnostic sounds
  - Normal breathing
  - Coarse crackle
  - Fine crackles
  - Pleural rub
  - Neumonia
  - Gurgling rhonchi
  - Rhonchi
  - Stridor
  - Wheezes
- Record lung acoustics with PASTA prototype and two competitor digital stethoscopes
  - ThinkLabs One
  - Eko CORE 500

Figure 7: On-site data collection

OFF-SITE DATA ANALYSIS

- Normalize data between -1 and 1
- Spectral analysis with discrete Fourier transform [3]

$$X(k) = \frac{1}{N}\sum_{n=0}^{N-1} x(n) e^{-j\pi kn/N}$$

- Compare frequency spectrum with cosine similarity

$$sim(A,B) = \cos(\theta) = \frac{A \cdot B}{\|A\|\|B\|}$$

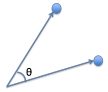

Figure 8: Frequency spectrum of gurgling rhonchi collected from PASTA with NVIDIA Jetson Orin, PASTA with Raspberry Pi 4, ThinkLabs One and EKO CORE 500 (left to right)

TABLE I: Cosine similarity between configurations (mean value across sound profiles)

	Jetson Orin	RaspberryPi	ThinkLabs	EkoCore 500
Jetson Orin	1.0000	0.9451	0.8032	0.3873
RaspberryPi	0.9451	1.0000	0.7590	0.3751
ThinkLabs	0.8032	0.7590	1.0000	0.0843
EkoCore 500	0.3873	0.3751	0.0843	1.0000

Note: number closer to 1 shows higher similarity

MULTI-CHANNEL CAPABILITY

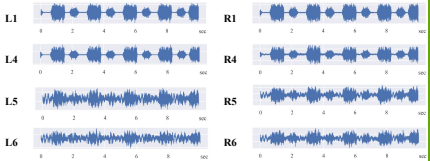

Figure 9: Lung acoustics over time recorded on 8 channels simultaneously

SPEC COMPARISON

PASTA prototype outperforms competitors in key metrics

TABLE II: Comparison of PASTA versus two commercial digital stethoscope

Device	PASTA	ThinkLabs One	EkoCore 500
Price (USD)	$300 - 400	$500	$450
Number of Channels	8 (mono)	1 (stereo)	1 (mono)
Bit Depth	24	16	16
Sampling Rate	48 [kHz]	44.1 [kHz]	4 [Hz]
Auscultation Interface	USB Audio Class 2.0	3.5 mm AUX	Proprietary ear piece and mobile app

CONCLUSIONS

- PASTA prototype returns comparable audio to on the market digital auscultation devices
- Eight channel recording allows for simultaneous auscultation at key locations on patients body
- Next steps:
  - Enclose hardware in a package complaint to medical standards
  - Develop software applications for pre-processing

REFERENCES

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3. W. H. Press, S. A. Teukolsky, W. T. Vetterling, and B. P. Flannery, Numerical Recipes 3rd Edition: The Art of Scientific Computing, 3rd ed. Cambridge University Press, 2007.

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