Acoustic Detection of Breathing Patterns For Opioid Overdoses

Jon Eby, Eric Fraser, Misha Hasan, Liam Lightbody

PROJECT SCOPE

- Starfish Medical is a Canadian company that performs case studies on various medical devices.
  - Approached by a physician to fabricate a medical device that could detect a patient's breathing rate acoustically
- Opioid epidemic affects thousands of Canadians each year [1]
- Breathing rate drops significantly when experiencing an overdose
- No affordable or portable device that can determine whether a Naloxone injection is required exists in the market

PROJECT GOALS

To design a device for non-medical professionals that monitors a patient's breathing rate and indicates whether a Naloxone injection is needed if their breathing rate drops below a threshold value.

DESIGN OBJECTIVES

- Transduce and amplify an acoustic signal generated from patient.
- Sample the audio signal with a sufficient sampling rate, following the Nyquist criteria.
- Filter the signal above 5 Hz (to isolate the sound generated by breathing).
- Calculate the patient's breathing rate by counting the number of peaks in the filtered signal, within 80% of the actual breathing rate [2]
- If the breathing rate is below the threshold of 4 breaths/minute, the software should produce an alert to inject Naloxone.

CONCLUSIONS

- Laryngophone prototype serves as a successful proof-of-concept to demonstrate that isolated audio detection of breathing patterns is possible with a limited budget.
- Future work to improve the prototype includes:
  - implementing a wireless module
  - multithreading to process the acoustic data as it comes in

REFERENCES

[1] *Opioid and Stimulant –related Harms in* Canada. Gov. Can. Jul. 2021, Accessed: Jul. 2021. [Online]. Available: https://health-infobase.canada.ca/substance-related-harms/opioids-stimulants/.

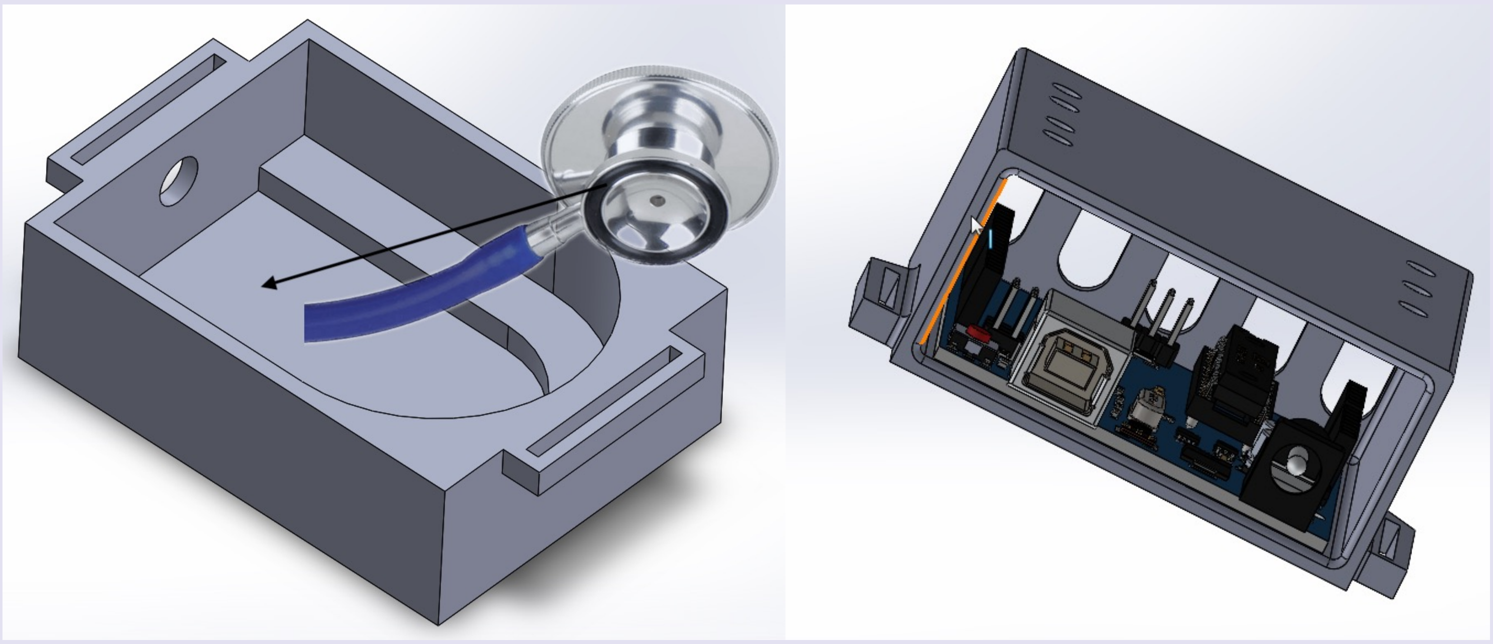
[2] K. Yatani and K. N. Truong, "BodyScope," *Proceedings of the 2012 ACM Conference on Ubiquitous Computing - UbiComp '12*, 2012.

STETHOSCOPE DESIGN

A dual-headed stethoscope was modified to record an acoustic signal in real time using an Arduino. It was designed to fit around the patient's neck.

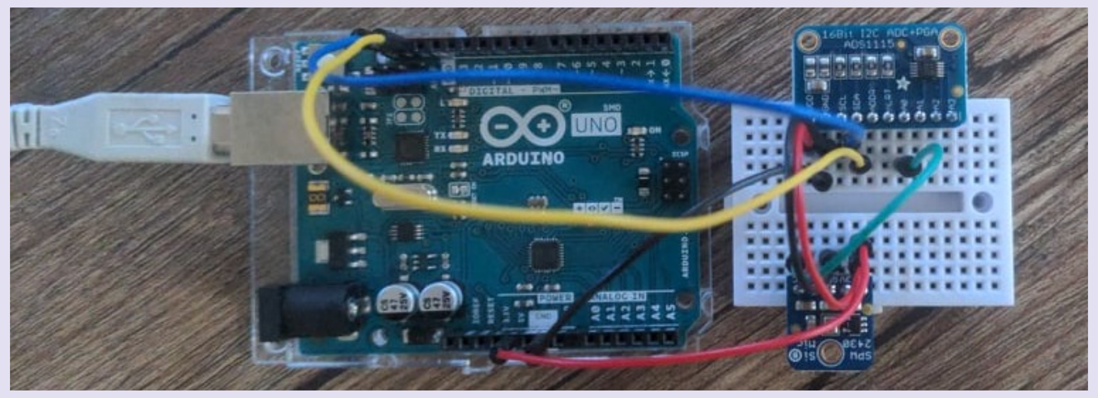
Mechanical Design:

- Modified the chest piece and sound isolating PVC tubing of a stethoscope and implemented them into the prototype.
- A throat attachment holds the stethoscope chest on the patient's throat.
- Enclosure was designed to protect the electronics of the system.
- The attachments were connected by a Velcro strap.



Electrical Design:

- MEMS microphone used to convert an acoustic signal into an analog electrical signal.
- ADC used to convert the analog signal into a digital signal then passes that output to the Arduino.
- Arduino UNO R3 takes output from ADC and sends it to MATLAB through USB.
- Final design utilizes a contact microphone that plugs directly into the PC. The PC's internal integrated sound card handles the conversion and amplification.



Results and Recommendations:

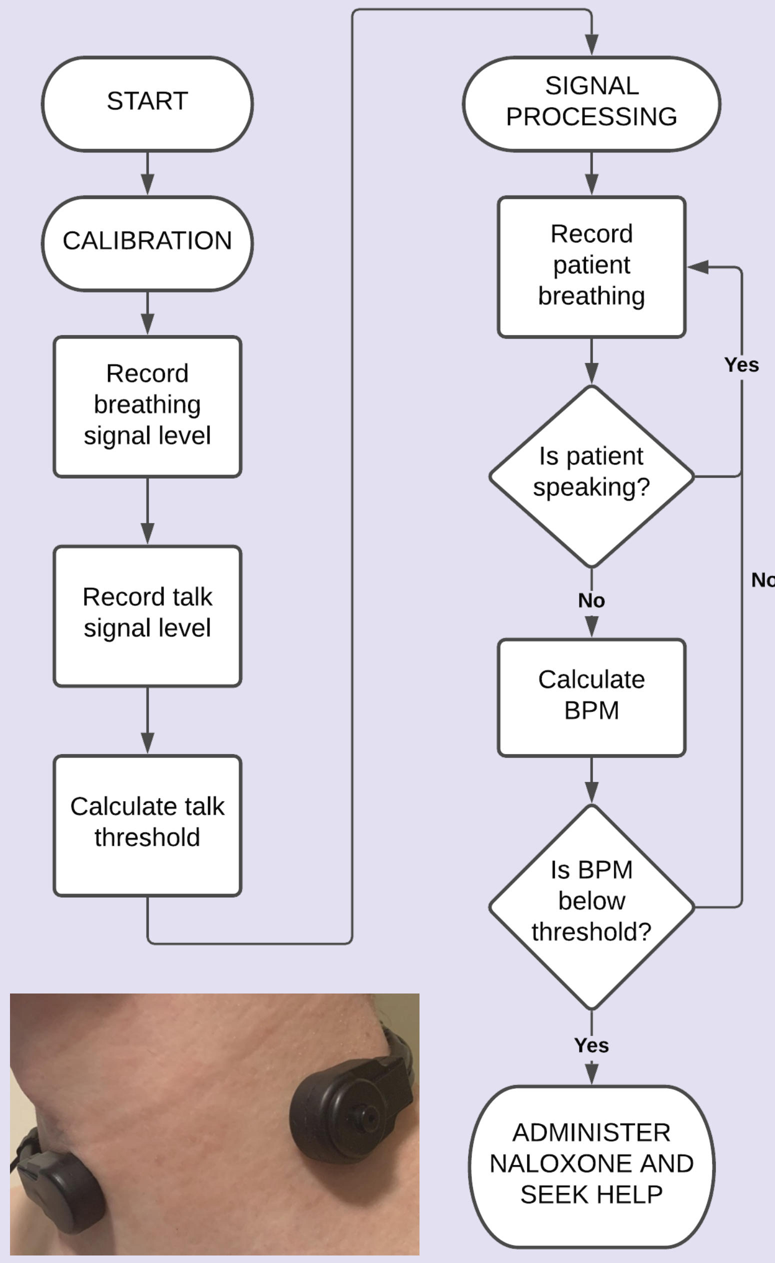
- Microphone lacked the sensitivity needed to adequately record the breathing rate.
  - Primarily due to the microphone's DC offset (Low S/N ratio)
- Could implement a high-pass filter to eliminate the DC bias, followed by an amplifier stage to maximize the range of the converted signal.

LARYNGOPHONE DESIGN

A pre-built laryngophone was purchased and connected to a PC via an AUX port. The breathing rate detection program designed on MATLAB.

Software Design:

- Breathing and speech recorded to define threshold
- Fourier transform used to generate a band pass filter to remove high frequency noise and DC creep
- Average peak height calculated and abnormally high breathing signal peaks were smoothed
- Breathing rate is generated as the total # of peaks over the time between the first and last peak divided by two and multiplied by 60
- If breathing rate < 4 or < 0.25X the previous recorded rate, the program breaks for potential naloxone injection



Results:

- Distinct breathing patterns identified
- Minimal background noise picked up by contact microphone - accurate breathing rate detected with 60-70 dB of background noise.
- Signal strength dependent on microphone position
- Signal strength from mouth breathing and nose breathing was approximately the same
- Iterative peak detection algorithm allowed smoothing of extreme peaks

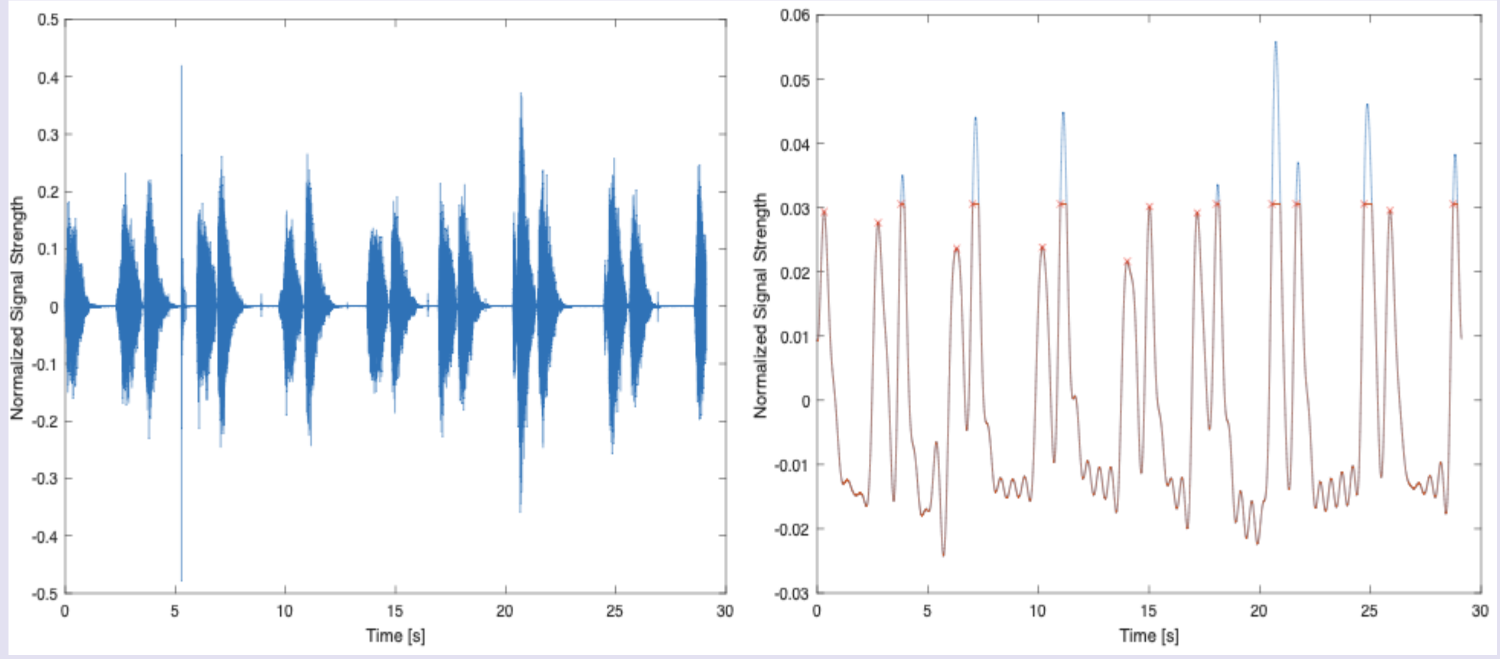


Figure 1: Base signal read by laryngophone and the filtered output with peak detection algorithm.