Using in-mouth sensor measurement data to estimate breathing rate

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1 Background

Topic introduction

- Densor intraoral multi sensor data measurement collection device [1]
- Need for innovation: detection and analysis of biomarkers using sensors inside the body
- Breathing rate one of key vital signs with a wide range of applications [2, 3]

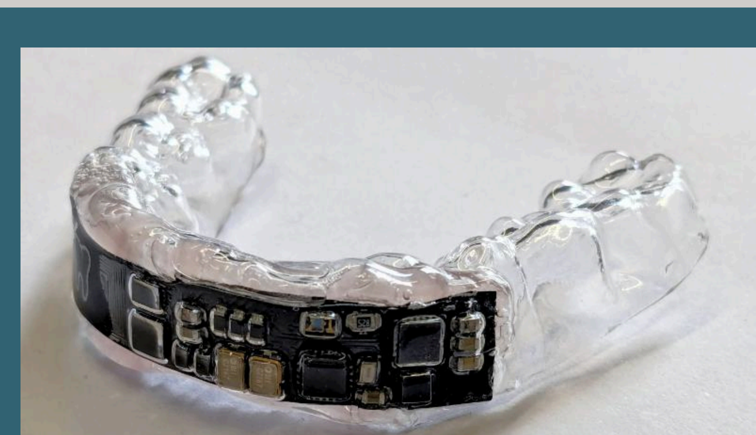

Figure 1: Densor [1] device

Data overview:
- three individuals performing various breathing experiments
- including measurements from an accelerometer, a barometric pressure meter and a light level sensor
- also includes metadata like sampling rates for sensors

Existing technologies

Biomarker measuring is an established field of research already. There exist devices such as wearables (earpiece, mask) or bed sensors that measure breathing rate.

- Bed pressure sensors located under mattress
- Smart masks with built-in temperature sensor
- ToF sensors, positioned opposite of subject (must stand still during experiment)
- Limited cases: *oral cavity pressure sensor*

2 Research Questions

Can intraoral sensor measurements be analyzed to reliably and accurately estimate breathing rates under varying physiological states?

Sub-Questions

1. Does pressure or acceleration data exhibit a stronger correlation with breathing cycles?
2. Are slow, normal or fast breathing rates most suitable for breathing rate estimation?
3. Are nasal or oral breathing patterns most suitable for detection?

3 Data Processing

Signal processing and analysis pipeline

1. Pre-processing: remove constant offset by mean-shifting
2. Signal filtering: "Butterworth" bandpass filter to isolate breathing frequencie
3. Multiple signal analysis: compare pressure and acceleration measurements, compare spatial axes
4. Using peaks to estimate breathing rate

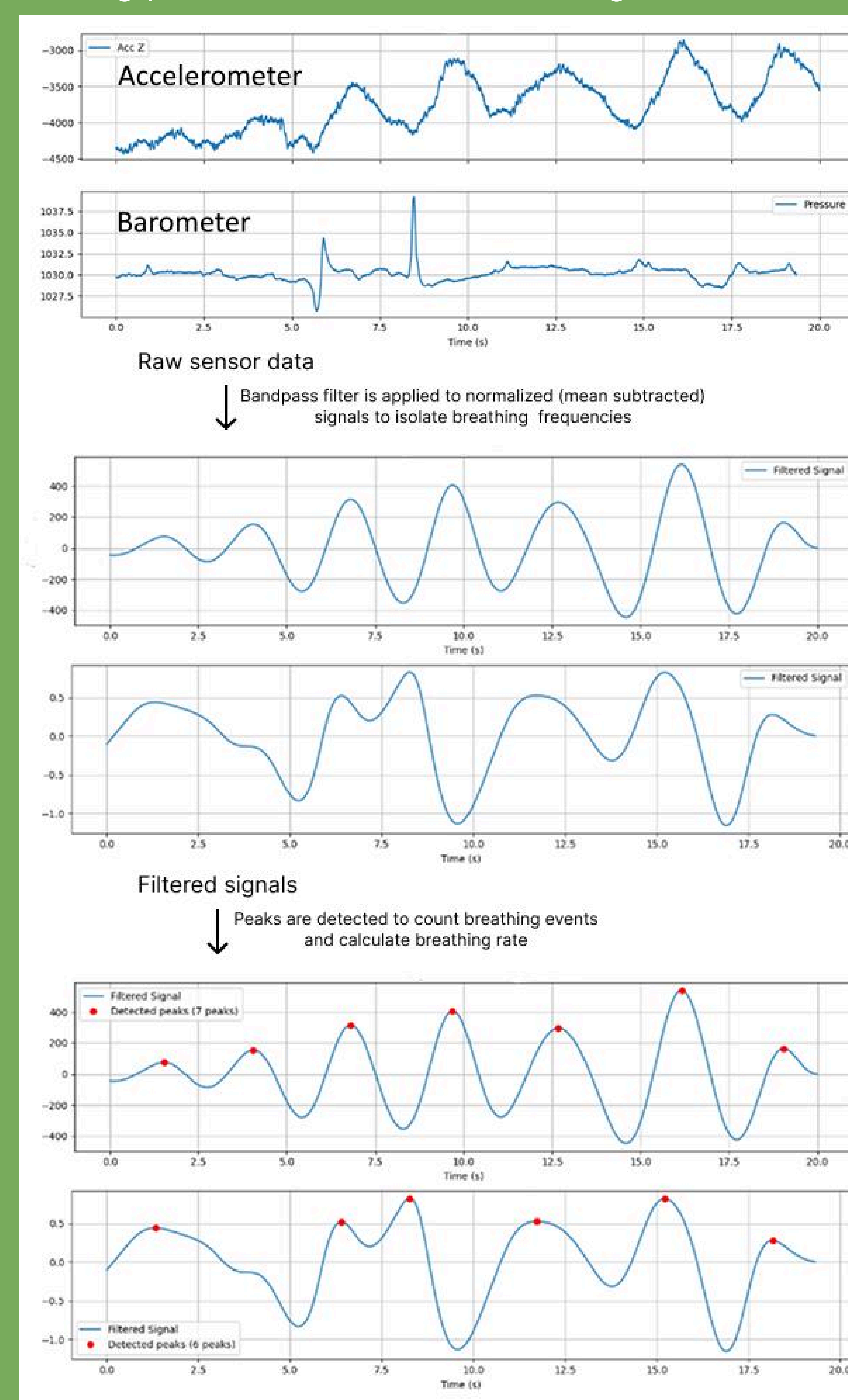

Figure 2: Signal processing pipeline visualization.

4 Results

RMSE: Root Mean Square Error
MAPE: Mean Absolute Percentage Error

Breathing type	RMSE (BPM)	MAPE (%)	n
Mouth (10BPM)	8.2128	78.12%	29
Mouth (10BPM)*	7.5895	72.06%	15
Mouth (14BPM)	3.1496	14.40%	23
Mouth (20BPM)	2.0544	7.99%	23
Nose (10 BPM)	8.2852	75.77%	9
Nose (14 BPM)	4.3581	27.14%	17
Nose (20 BPM)	**1.5481**	**6.65%**	23

Table 1: Overall breathing rate estimation performance, cutoffs 0.1 & 0.5 Hz, n = 139, *1:2 inhale exhale ratio

Breathing type	RMSE (BPM)	MAPE (%)	n
Mouth (10BPM)	8.0080	77.16%	14
Mouth (10BPM)*	5.7953	55.97%	4
Mouth (14BPM)	1.3930	6.61%	12
Mouth (20BPM)	2.4418	8.67%	11
Nose (10 BPM)	5.6796	55.26%	3
Nose (14 BPM)	3.4061	21.22%	6
Nose (20 BPM)	**1.4825**	**5.42%**	11

Table 2: Z-axis acceleration data estimation performance, cutoffs 0.1 & 0.5 Hz, n = 61, *1:2 inhale exhale ratio

5 Conclusions & Future works

- accelerometer overall: 5.42% MAPE for oral 20 BPM
- barometer overall: 7.77% MAPE for oral 20 BPM
- higher accuracy for nasal overall

Limitations:
- estimates combining multiple sensors
- record environmental conditions to increase experiment reproducibility

References:
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[2] Nicolò, A., Massaroni, C., Schena, E., & Sacchetti, M. (2020). The importance of respiratory rate monitoring: From healthcare to sport and exercise. Sensors, 20(21), 6396. https://doi.org/10.3390/s20216396
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