Breathing Detection from Tracheal Sounds in Both Temporal and Frequency Domains in The Context of Phrenic Nerve Stimulation

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Introduction

Central respiratory paralysis induces a dependence on artificial ventilation If patient's phrenic nerves and diaphragm remain functional, **diaphragm pacing (DP)** through **electrical stimulation** can provide a more natural respiration instead of **mechanical ventilation** [1]. Different **DP technic** are illustrated in Fig.1. However, commercialized systems do not embed any **respiratory monitoring** function and cannot adapt to patients' electro-ventilation needs. To increase the performance and safety of these systems, in this study, a **real-time acoustic respiratory monitoring method** based on a **microphone** is investigated. This method is tested on recordings from 18 healthy individuals.

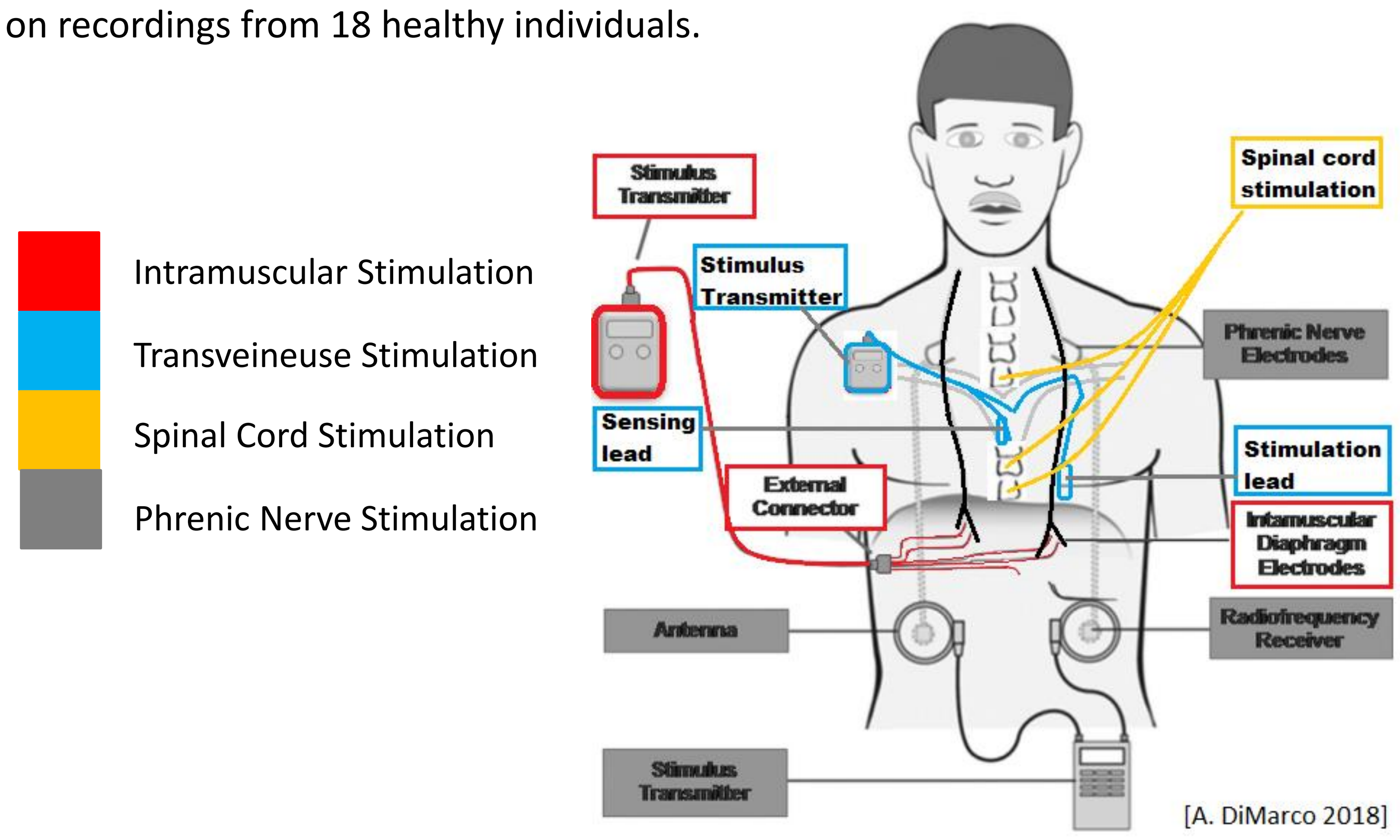

Figure 1 – Diaphragm pacing technics

Methods

Equipment:

- An **omni-directional** microphone was inserted into a 3D-printed support, which was positioned on the neck (at supsternal notch). (Fig.2.)
- Tracheal sounds were first filtered (**100Hz - 1200Hz**) and amplified (230 times), then sampled at **4600Hz**.

Figure 2 – Position of microphone

Protocol:

Eighteen healthy subjects participated in this observational study. One recording of **30 seconds** was performed on each subject. The procedure consisted in 3 succeeding phases : (1) 10s normal respiration → (2) 10s apnea (holding respiration) → (3) 10s normal respiration.

Detection algorithm:

Tracheal sounds recordings are processed in **real-time** with a **delay of 0.22s**, corresponding to a moving segment of 3×1024 samples. As shown in the detection flow diagram (Fig.3), the segment of recording is first **high-pass filtered at 300 Hz** to **remove cardiac noises**, then processed both in **temporal** and **frequency** domains. At the end, the detection results of these two domains are **combined** to get the **final result**.

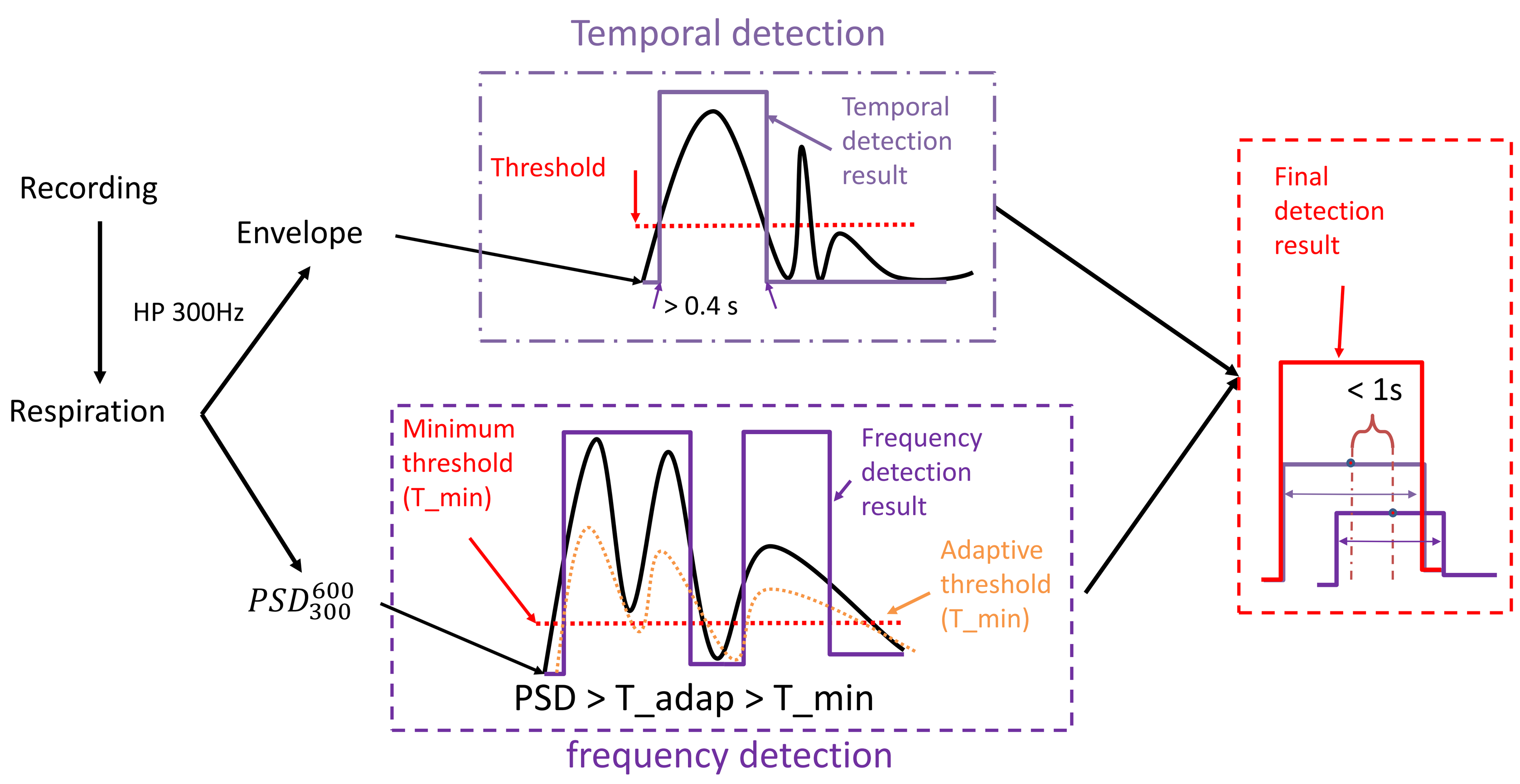

Figure 3 – Detection flow diagram

Results and discussion

The algorithm is evaluated on its **specificity, sensitivity and accuracy**, which in this study reached **99.31%, 96.84% and 98.02%**, respectively. This result is much higher than the **lowest acceptable limit** (missing maximum 10s respiration per minute), which corresponds to 82.86% and 90.48% of specificity and accuracy, respectively.

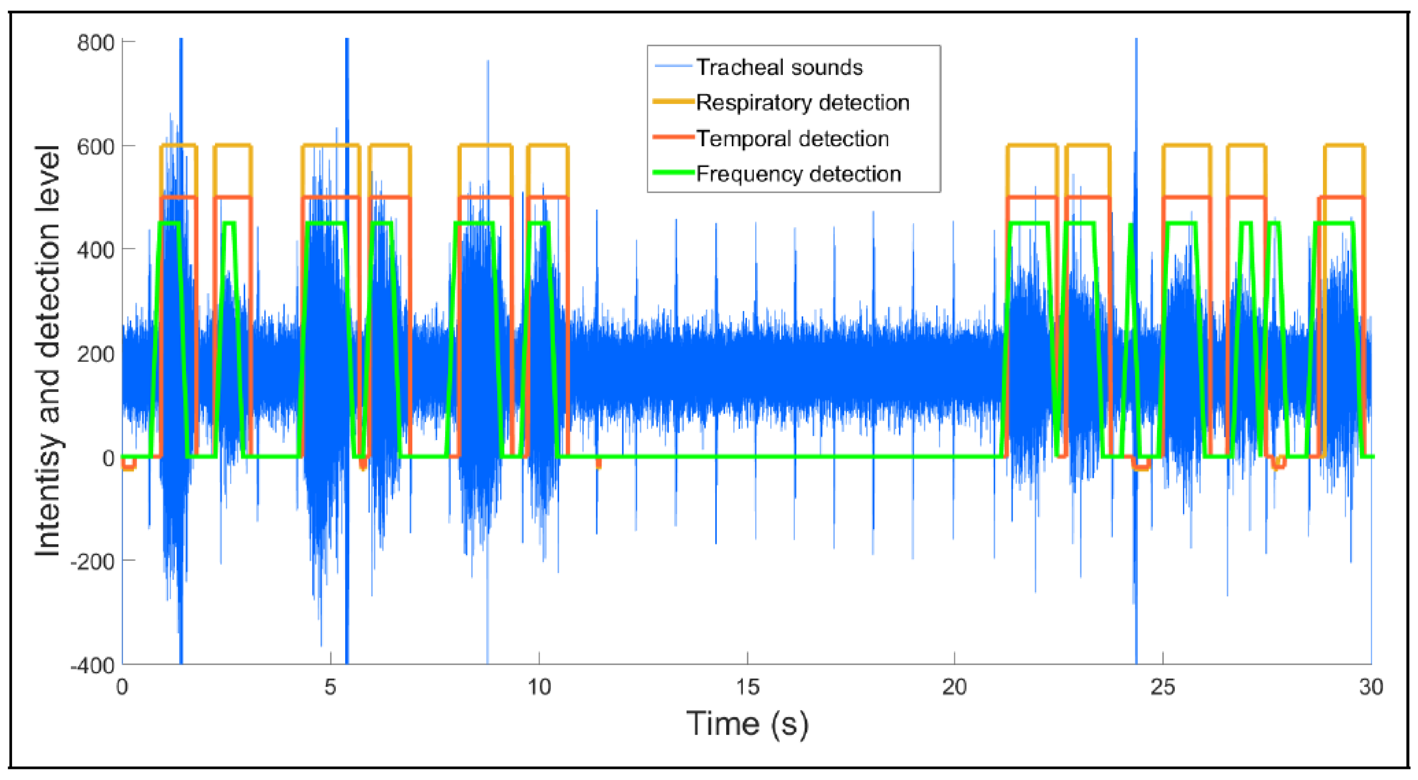

Figure 4 – One example of detection result : short noise is eliminated thanks to temporal detection

Combination of analysis in two domains can increase detection accuracy because some **short noises** may be detected as respiration **in frequency domain**, but could **be eliminated in temporal domain** like shown in Fig.4. On the contrary, **long noises** are detected in **temporal domain**, but **eliminated in frequency domain** (Fig.5).

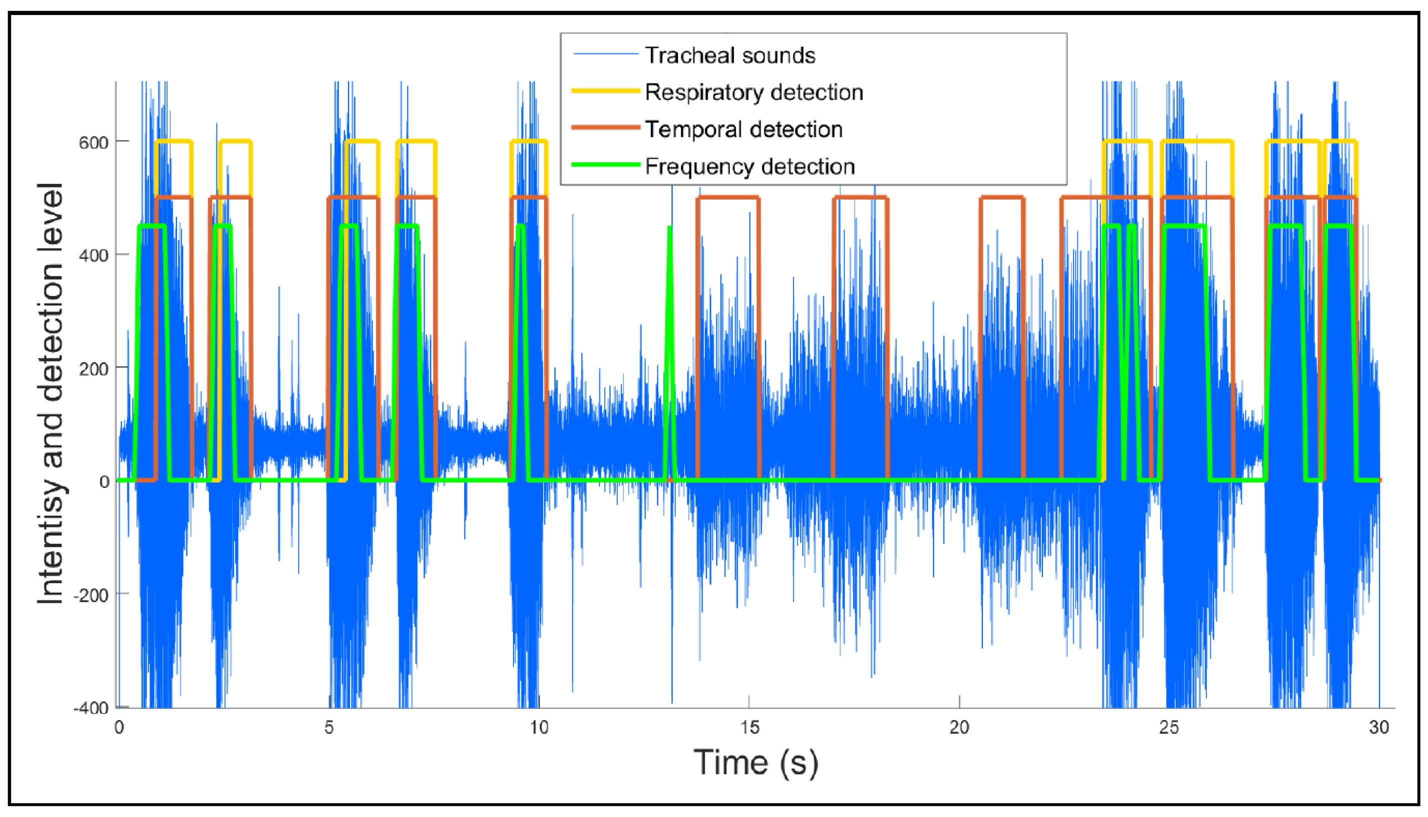

Figure 5 – One example of detection result : long noises are eliminated thanks to frequency detection

Even in the presence of speech and strong background noise (playing video), the detection reached a sensitivity of 92.8% and a specificity of 99.7% (Fig.6).

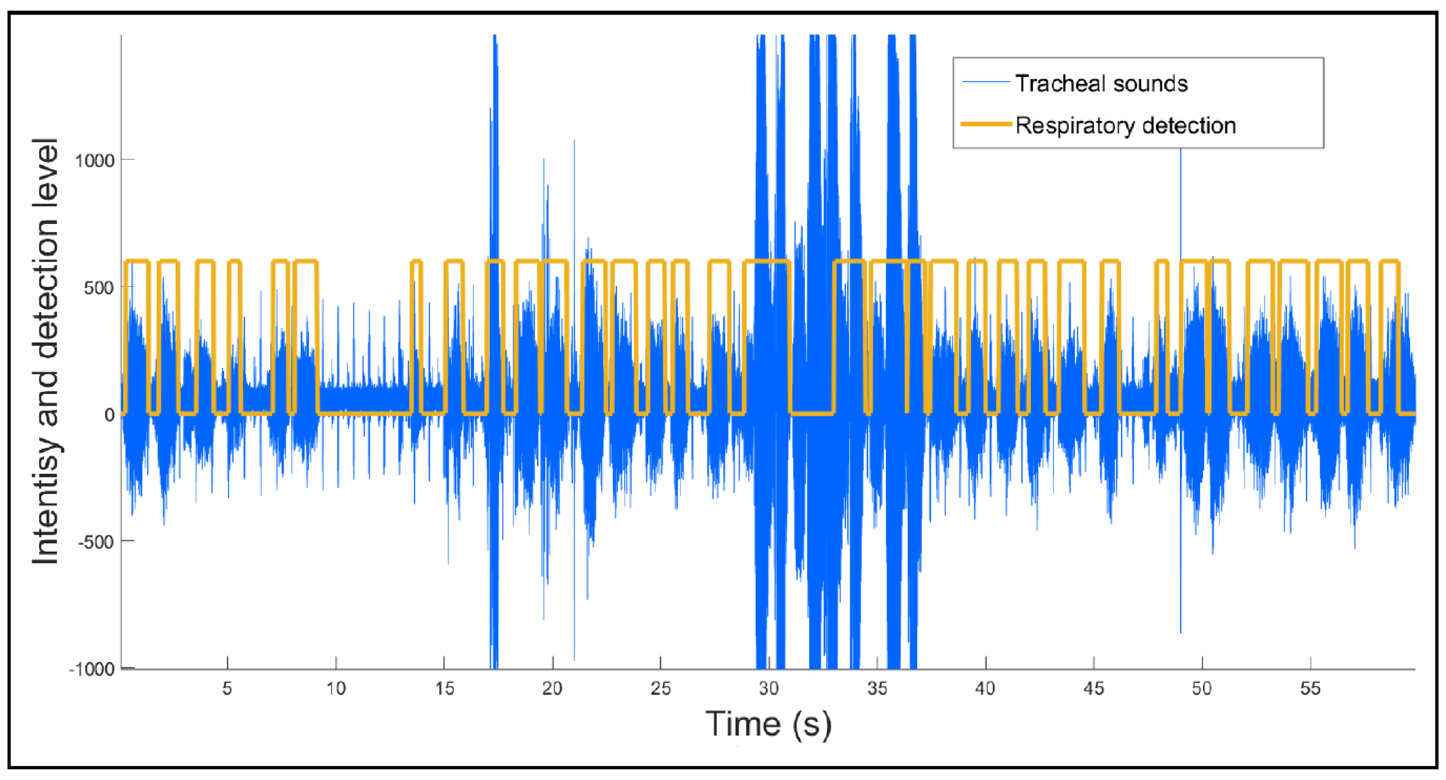

Figure 6 – Detection result on recording with speech and strong background noises

- Detection results are accurate enough, but the algorithm needs to be applied on more recordings, especially recordings from target patients.
- One reference signal (pneumotachograph, plethysmograph …) will be added to compare the result.
- More vitals information could be extracted from cardiac recordings.

References:

1. *F. Le Pimpec-Barthes et al., "Diaphragm pacing: The state of the art," J. Thorac. Dis., vol. 8, no. Suppl 4, pp. S376–S386, 2016.The first obtained result is very promising;*

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