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Wearable Heart Rate and Breath Rate Monitoring Using Hearing Protection Device (HPD)

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Abstract- This paper presents the integration of a non invasive heart rate and breath rate monitoring for workers using hearing protection devices by placing microphone in the ear canal under the HPD. To assess heart rate and breath rate digital signal algorithms are developed. In this paper, the sounds produced in the occluded ear canal are measured by placing an in-ear microphone in hearing protection devices. This concept enables the development of non invasive audio wearable heart rate and breath rate monitoring.

I. INTRODUCTION

Heavy industries and confined spaces such as mines are hazardous and extremely noisy work environments in which work accidents and sudden ailments are more likely to occur. The remote monitoring of workers' vital signs could enable efficient paramedic interventions and further reduce fatalities for these industrial workers but also for other workers, including armed forces, first responders, firefighters and the like. Non-invasive health monitoring methods already exist and are widely used in clinical applications to monitor physiological parameters such as heart rate or breathing rate. Systems such as electrocardiography, stethoscopy, plethysmography, and spirography are extremely accurate but often cumbersome and only used in controlled environments. Most wearables are not designed for the rough environments these workers are exposed to and are not designed to be compatible with the personal protection equipment (PPE) that these workers are likely to already wear. Interestingly, one of the most used PPE is the hearing protection device (HPD), which is used to protect workers from toxic noise and also sometimes, in its electronic version, to communicate over personal radio in very noisy environments. Therefore, a promising solution to monitor the vital signs of the workers mentioned would be to directly integrate such biosignal monitoring system within an electronic HPD, by taking advantage that these HPDs are often already equipped with external and internal microphones.

II. BLOCK DIAGRAM

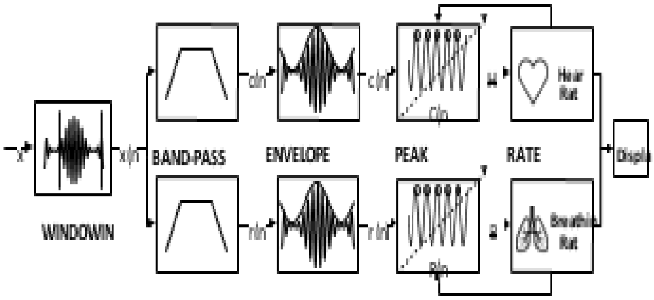

Fig 2.1 Block diagram of breath and heart rate extraction

III. DESCRIPTION

In this paper, sounds in the occluded earcanal are measured by an in-ear microphone (IEM) located in an instrumented earpiece. A database of in-ear audio recordings was created using a sample of individuals. During the experiment, subjects were asked to breathe at various rhythms and intensities through the mouth or nose to achieve realistic recordings. A total of sounds in the earcanal were recorded. The features of sounds correlated with heartbeats and respiration are investigated as recorded at this specific location to develop signal processing algorithms to assess the user's heart and breathing rates. Results from the algorithms are then compared to the numerical values obtained by a commercial reference device used during the measurement. Finally, noise is added numerically to the IEM signal to assess the robustness of the algorithms against ambient noise for further applications, such as monitoring workers' health.

A. Algorithms for Extracting Heart and Breathing Rates

First, recorded audio signals were downsampled to 4800 Hz to reduce processing time, by applying a low-pass filter and removing samples to reduce the sampling rate. A block diagram of the algorithms is presented in Figure 5. The first stage framed the input data *x* into windows of 10 seconds *x(n)*, where *n* ranges from 0 to M-1 (M= 48000). Then, the signal was sent to two similar processes: one for heart rate extraction, one for breathing rate extraction. For heart rate extraction, *x(n)* was downsampled to 160 Hz, then band-pass filtered from 15 Hz to 45 Hz, to obtain *c(n)*. For breathing rate extraction, *x(n)* was downsampled to 1600 Hz, then band-pass filtered from 150 Hz to 400 Hz to obtain *r(n)*. Envelope extraction was done by applying the Hilbert Transform with a moving average. Each envelope was downsampled to 16 Hz to obtain *c'(n)* and *r'(n)*. Then, the peak extraction process included several steps, one of which was a band-pass filter with cut-off frequencies computed from the spectra of *c'(n)* and *r'(n)* to obtain *C(n)* and *R(n)*. Then, moving thresholds were applied to *C(n)* and *R(n)* to determine whether a beat or a respiration phase (inspiration or expiration) was detected. Heart and breathing rates were computed based on the number of heartbeats (HB) and breathing cycles (BC) detected. A minimum sample number between two detections was computed using previous values of the heart and breathing rates to avoid erroneous detection, assuming that these biosignals are somewhat stable over a couple of seconds.

To evaluate the performance of the algorithms, the absolute error (also called least absolute deviation) for one subject and one sequence of 18 minutes was computed with the following formula: $\varepsilon = 1N\ \Sigma\ |\mathrm{Ref}i - Ai|\ Ni{=}1$, where Ref$i$ is the value of the reference rhythm (BPM or CPM), Ai is the value of the rhythm computed by the algorithms (BPM or CPM) and N is the number of observations. Heart and breathing rates were computed during 5 seconds each using the current detections of HB and BC and two previous values of the heart and breathing rates. Also, the relative error was defined by the difference in percentage between the reference values and the algorithm output values.

B. Denoising of Biosignals from Ambient Noise

To simulate a noisy work environment such as a mine or a factory plant, realistic industrial noise recordings were added numerically (off-line) to the IEM signal and the performance of the developed algorithms were assessed in the presence of these disturbances.

White noise and industrial noise from NASA's steam plant database were used [5]. First, the excitation consisted of multiplying the noise signal (white or industrial noise) *no(n)* by a gain G, which is computed to obtain a calibrated noise level ranging from 50 to 110 dB SPL (in steps of 5 dB). Then, the normalized noisy signal *OEMs(n)* goes through $H(z)$ to obtain the residual noise inside the ear *nr(n)*. (z) is the true transfer function of the subject's earplug computed from measurements made during the experimental protocol. Then, *nr(n)* was added to the biosignals*b(n)* measured by the IEM, which contains sounds resulting from cardiovascular and breathing activities, to obtain the noisy biosignals. Second, the denoising portion consisted of removing the residual noise from the noisy *IEMs(n)* signal originating from the ambient industrial noises and disturbances. Denoising was performed using a normalized least mean squared (nLMS) adaptive filter, originally developed by BouSerhal*et al.* for denoising speech signals captured in an occluded earcanal with an IEM[4]. The structure of the adaptive filter is based on the structure described by [6] except that the signal of interest is the error signal *e(n)* [5]. $H\ \tilde{}(z)$ is the estimated transfer function of the earpiece (primary transfer function) and $nr\ \tilde{}(n)$ is the estimated residual noise. Finally, the denoisedbiosignals were fed to the extraction algorithms previously developed.

IV. RESULT

The developed algorithms show an absolute mean error of 4.3 beats per minute (BPM) and 2.7 cycles per minute (CPM). The mean difference estimate are -0.44 BPM with a limit of agreement (LoA) interval of -14.3 to 13.4 BPM and 2.40 CPM with a LoA interval of -2.62 to 7.48 CPM. Excellent denoising is achieved with the adaptive filter, able to cope with ambient sound pressure levels of up to 110 dB SPL, resulting in a small error for heart rate detection, but a much larger error for breathing rate detection.

V. CONCLUSION

Extraction of the heart and breathing rates from an acoustical measurement in the occluded earcanal under an HPD is possible and can even be conducted in the presence of a high level of ambient noise. This proof of concept enables the development of a wide range of non-invasive health and safety monitoring audio *wearables* for industrial workplaces and life-critical applications where HPDs are used.

VI. REFERENCES

[1]. Alexis martin, student member, IEEE, jeremievoix, member, IEEE,2017, IN ear audio wearable vital sign monitoring.

[2]. J. Voix, "Did you say 'bionic' ear?," *Can. Acoust.*, vol. 42, no. 3, Aug. 2014.

[3]. J.-H. Park *et al.*, "Wearable Sensing of In-Ear Pressure for Heart Rate Monitoring with a Piezoelectric Sensor," *Sensors*, vol. 15, no. 9, pp. 23402–23417, Sep. 2015.

[4]. D. D. He *et al.*, "An Ear-Worn Vital Signs Monitor," *IEEE Trans. Biomed. Eng.*, vol. 62, no. 11, pp. 2547–2552, Nov. 2015.

[5]. S. Vogel *et al.*, "In-Ear Vital Signs Monitoring Using a Novel Microoptic Reflective Sensor," *IEEE Trans. Inf. Technol. Biomed.*, vol. 13, no. 6, pp. 882–889, Nov. 2009.

[6]. G. Chen *et al.*, “Algorithm for heart rate extraction in a novel wearable acoustic sensor,” *Healthc. Technol. Lett.*, vol. 2, no. 1, pp. 28–33, Feb. 2015.

[7]. P. Corbishley*et al.*, “Breathing Detection: Towards a Miniaturized, Wearable, Battery-Operated Monitoring System,” *IEEE Trans. Biomed. Eng.*, vol. 55, no. 1, pp. 196–204, Jan. 2008.

[8]. T. T. Zhang *et al.*, “Sound Based Heart Rate Monitoring for Wearable Systems,” in *2010 International Conference on Body Sensor Networks*, 2010, pp. 139–143.

[9]. A. Yadollahi*et al.*, “A robust method for estimating respiratory flow using tracheal sounds entropy,” *IEEE Trans. Biomed. Eng.*, vol. 53, no. 4, pp. 662–668, Apr. 2006.

[10]. R. Kusche*et al.*, “An in-ear pulse wave velocity measurement system using heart sounds as time reference,” *Curr. Dir. Biomed. Eng.*, vol. 1, no. 1, pp. 366–370, 2015.

[11]. G. A. Pressler*et al.*, “Detection of respiratory sounds at the external ear,” *IEEE Trans. Biomed. Eng.*, vol. 51, no. 12.