Pediatric Respiratory Rate Estimation through Deep Neural Networks

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We present results for respiratory rate determination using deep learning and classic machine learning and based on analysis of respiratory sounds recorded on 48 children less than 60 months old and presenting an acute lower respiratory infection (ALRI). The method has an overall rms error for determining respiratory rate of 0.02 (±0.86) breaths per 10 seconds.

In low-resource settings, ALRI is diagnosed using children's respiratory rate [1]. Breaths are counted manually by care givers with one-minute timers. Following our previous publication [2], this study intends to illustrate determination of respiratory rate through respiratory sound analysis. More precisely, in this abstract, we do present the data acquisition and annotation protocol—a methodology combining deep learning and classic machine learning techniques as well as results regarding automatic respiratory rate counting.

Material

Using the Littmann 3200® electronic stethoscope, chest sounds were recorded from 48 children at the pediatric emergency department of the University Hospital of Geneva. All children were aged under 60 months and had clinical diagnosis of chest infection (fever ≥38°C, dyspnea, polypnea, tachypnea, respiratory distress, cough, or relevant auscultation), and had a parent or a legal representative signing an informed consent. Eight auscultation sites (anterior-posterior, right-left, superior-inferior) were recorded, on each patient, with an average of 10.76 (±3.42) seconds per site. Recorded sounds were downloaded on a computer using Stethassist® software and annotated using Audacity® software. A board-certified pediatrician annotated inspirations and expirations contiguously.

Methods

Chest sound waveforms were transformed into Mel-spectrograms. An overlapping sliding window technique was used to create 2-second spectrogram patches with 0.0125 s displacement between windows. Each patch was assigned a label, either inspiration or expiration.

A pipeline containing a convolution neural network and hidden Markov model was used for spectrogram segmentation. The network was composed of 12 deep-learning layers, Convolution, Activation and Max Pooling, and 1 Dense layer. Dropout was used as a regularization technique. Automatic respiratory rate was determined by counting the number of inspiration-expiration predicted events.

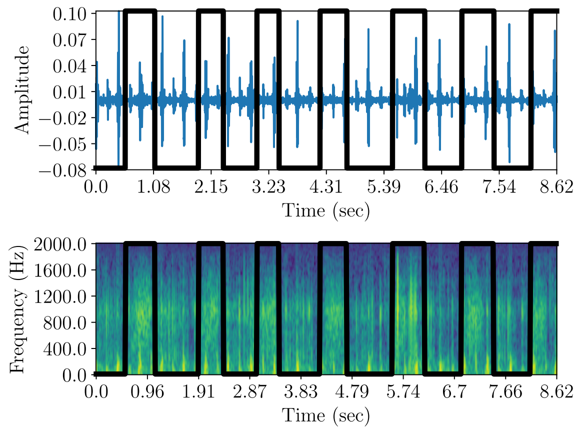

Figure 1: Contiguous inspiration and expiration annotation. Waveform on the top and Mel-spectrogram on the bottom. The black line represents segmentation of inspirations and expirations. When the black line is on the top of the plot, it represents inspiration. When the black line is at the bottom of the plot, it represents expiration.

Results

Automatic respiratory rate determination was performed using leave-one-out cross-validation, meaning that for each patient that is tested, 47 other patients are used for algorithm training from scratch.

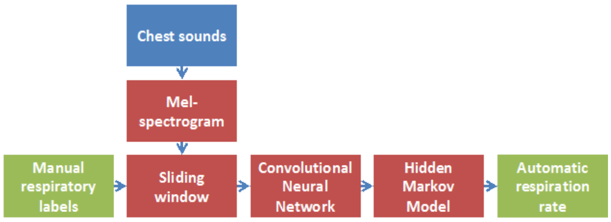

Figure 2: Automatic respiratory rate estimation methodology.

The system predicts chest sound spectrogram sliding window labels with a sensitivity of 85%, a specificity of 87.9% and an accuracy of 86.9%.

Due to limitations in duration of recorded auscultations, respiratory rate was calculated as the number of breaths per 10 seconds. Even though segmentation, through sliding window technique, does not perfectly match manually labeled respiratory events, respiratory rate determination is precise, with an overall root-mean-square error of only 0.02 (±0.86) breaths per 10 seconds.

• HUG, Hôpitaux Universitaires de Genève

[1] WHO, "Integrated management of childhood illness by outpatient health workers: technical basis and overview. The WHO Working Group on Guidelines for Integrated Management of the Sick Child", Bulletin of the World Health Organization, p. 20, 1997.

[2] J. Solà, *et al.*, "Towards an unsupervised device for the diagnosis of childhood pneumonia in low resource settings: Automatic segmentation of respiratory sounds", Conf Proc IEEE Eng Med Biol Soc., Aug. 2016.