Single-Signal Noninvasive Blood Pressure Estimation

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Introduction

Arterial blood pressure is of great significance in cardiovascular health, yet few devices allow for its unobtrusive, continuous monitoring. Such devices could be a middle-ground option for patients where invasive catheterization is not recommendable, and sphygmomanometry is not sufficient. We present results from novel signal processing on unimodal plethysmographic signals, which were acquired with various sensing technologies.

Methods

Photoplethysmography, impedance plethysmography and pulse applanation tonometry are used to measure the pulse wave, which is modulated by the underlying blood pressure. These changes are parametrized and fed into regression models, estimating the original blood pressure. The feature extraction for the models is performed by two different methods, spectral decomposition, and progressive dynamic time warping. Both require no fiducial point detection, implicitly parametrizing all morphological changes, and thus work with pulse waves of any Dawber class. The algorithms' performance is validated in a feature selection and regression framework against a cuff sphygmomanometer or a Finapres NOVA monitor, regarding systolic, mean and diastolic pressures during a light physical strain test protocol.

Results

Spectral decomposition yields a baseline error of 0.62 mmHg, an absolute error of 4.6 mmHg and a standard deviation of 5.3 mmHg. Phase information mostly outperforms amplitude information. For progressive dynamic time warping, the obtained baseline error is 2.13 mmHg, the absolute error is 5.4 mmHg and the standard deviation is 5.6 mmHg. Features at the beginning of the warp path are selected more often and with bigger coefficients. Optically, electrically and electro-mechanically derived signals perform similarly, but best compliance and quality is achieved for impedance plethysmography.

Conclusion

Spectral parametrization and progressive dynamic time warping show promising results, suggesting that, at the cost of somewhat lower accuracy compared to more complex systems, the processing of unimodal pulse waves can enable non-invasive, continuous blood pressure estimation for cases where arterial catheterization is not justified.

PPG-based blood pressure estimation using residual neural networks and spectrograms

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Introduction

Recent advances in machine learning, especially convolutional neural networks (CNNs), show promising results in the domain of medical applications such as image classification. Here, we propose to utilize residual neural networks (RNNs), i.e. a particular type of CNN, to estimate the systolic and diastolic blood pressure on the basis of spectrograms derived from finger clip PPG and camera-based PPG.

Methods

We derived PPG and arterial blood pressure (ABP) signals of 1000 subjects from the MIMIC-III waveform database. The physiological signals were segmented into 20s time windows. For each window we derived the median systolic and diastolic blood pressure as the ground truth from the ABP signals and calculated spectrograms from PPG. We constructed training (95%) and test sets (5%) and trained a residual neural network (ResNet34) to predict the diastolic (DBP) and systolic blood pressure (SBP). The mean absolute error (MAE) between predicted blood pressure and ground truth was evaluated. Moreover, we conducted an explorative analysis based on camera-based PPG data recorded in an experimental study.

Results

Our method reveals an overall MAE of 15 mmHg for SBP and 8.5 mmHg for DBP respectively. The error depends systematically on the ground truth value. The SBP error is lowest for blood pressure values ranging from 125 mmHg to 155 mmHg. In this range the SBP error was ±20 mmHg. For the DBP the lowest deviation from the ground truth occurs between 55 mmHg and 75 mmHg. Here the error was ±10 mmHg.

Conclusion

We were able to show that the estimation of SBP and DBP based on the spectrogram of finger clip PPG using CNN is generally possible. The results suggest that the estimation error can be further decreased by increasing the number of samples in the lower and higher ranges of the BP values.

Utilizing automatically estimated facial descriptors for pain detection during surgical interventions

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Introduction

Automated pain detection is of great interest in medical research, e.g. when treating people not able to self-report their pain, e.g. neonates or patients with dementia. In this work, we utilized OpenFace to estimate the intensities of facial descriptors from videos recorded during minimal invasive surgical interventions. We employed these intensities to analyse systematic differences between pain and non-pain facial expressions in individual subjects and similarities between facial expressions related to pain among subjects.

Methods

A clinical study at the Leipzig Heart Center was conducted to record videos from 28 participants who underwent a cardiac catheter ablation. These videos were processed using the open source software toolkit OpenFace, which allows to determine the facial behaviour based on the Facial Action Coding System (FACS) and its Action Units (AUs). The AU intensities were used to identify systematic differences for individuals before and after pain events and to categorize the subjects into groups with similar facial expressions during pain. Pointbiserial correlation (R_{PB}) was used to investigate significant differences of AU intensities between pain and non-pain situations.

Results

The maximum R_{PB} values for the groups largely exceeded the relevance limit of 0.20. This reflects systematic differences between pain and non-pain facial expressions within groups and the occurrence of different facial expressions during pain between groups. This is in accordance with findings from experimental studies based on manual AU coding reported in literature.

Conclusion

We investigated whether AU intensities derived from OpenFace might be used for automated pain detection. We were able to show significant differences between pain and non-pain situations based on AU data conducted in a clinical setup during surgical intervention. Further research will be directed towards the development of a method to automatically estimate pain during surgical interventions.

Dual-Lead 55 mm Impedance Pneumography

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Introduction

Respiratory monitoring has gained attention due to the high prevalence and severe consequences of sleep apnea, post-anesthesia respiratory instability and respiratory diseases. Nevertheless, respiratory monitoring oftentimes relies on obtrusive masks and belts. Impedance pneumography (IP) is a bioimpedance method aiming to assess respiratory parameters unobtrusively. However, most IP configurations require far-spaced electrodes. We propose a dual-lead, wearable IP setup with 55 mm electrode spacing to estimate respiratory flow and rate (RR).

Methods

In a study including 10 healthy subjects (26±2 years, 2 female), participants lay in the supine, lateral and prone position while following an 11 minute long breathing protocol. Two 55 mm IP leads were simultaneously recorded alongside a respiratory reference provided by the SOMNOmedics GmbH SOMNO HD™ system using a pneumotachometer and facial mask. The 55 mm wearable IP signal was acquired at the upper right thorax using our novel, multimodal digital stethoscope patch. The 55 mm Icon IP lead was recorded by the Osypka Medical GmbH ICON-Core™ monitor at the middle left thorax. We employed time-delay neural networks (TDNN) with two to three hidden layers, 5 to 15 neurons each and input delay vectors from 1 to 30 taps as regressors. Models were selected using the Bayesian information criterion.

Results

Using both IP signals in a TDNN regressor, we estimated the flow with a correlation of 0.88 and a relative error of 25 %. Respiratory rate estimation errors were below 0.6 breaths per minute in all cases. The dependency of the estimation errors on the subject position was minimal.

Conclusion

We conclude that using two independent, wearable IP leads can substatially increase the respiratory flow and rate estimation performance compared to a single lead. Performances close to half-thorax configurations can be achieved. Further research could focus on subject position dependencies and the influence of motion on the signals.