Advancements in Remote Physiological Measurement and Applications in Human-Computer Interaction

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Abstract

Physiological signals are important for tracking health and emotional states. Imaging photoplethysmography (iPPG) is a set of techniques for remotely recovering cardio-pulmonary signals from video of the human body. Advances in iPPG methods over the past decade combined with the ubiquity of digital cameras presents the possibility for many new, low-cost applications of physiological monitoring. This talk will highlight methods for recovering physiological signals, work characterizing the impact of video parameters and hardware on these measurements, and applications of this technology in human-computer interfaces.

Keywords: remote, non-contact, vital signs, photoplethysmography, human-computer interaction.

I Imaging Photoplethysmography

Non-contact and low-cost methods of quantifying vital signs and other cardio-pulmonary parameters have applications across numerous domains. From designing more comfortable clinical measurement devices to designing computers that can sense changes in emotion.

Remote imaging photoplethysmography (iPPG) allows measurement of the blood volume pulse (BVP) from small variations in light reflected from the skin using an imaging device such as a webcam. The first results showing remote PPG measurement using a digital camera found that of the red, green and blue (RGB) camera color components, the green channel had the strongest BVP signal [Verkruysse et al. 2008]. Under ideal conditions (e.g. no video compression, constant illumination and no subject/camera motion) averaged pixel values from one color channel can be sufficient for recovery of the BVP. However, our work seeking to fully automate measurement using face tracking revealed that more advanced methods were required to preserve the signal-to-noise ratio. We found a combination of signal detrending, filtering and blind source separation [Poh et al. 2010] to be quite effective at recovering the BVP waveform from webcam videos of the human face in the presence of small natural head motions. A neat approach of spatial sub-space rotation has also been shown to provide a benefit over methods that utilize spatial averaging of pixel values [Wang et al. 2016]. From the BVP signal important vital signs including the heart rate [Poh et al. 2010], breathing rate and heart rate variability (HRV) can be measured [Poh et al. 2011]. Whilst many have since validated new methods for the measurement of heart rate, only a few studies, including ours, have evaluated performance on HRV metrics. HRV measurement presents many more compelling applications, such as automatic detection of changes in autonomic nervous system activity [McDuff et al. 2015].

Video parameters naturally influence the accuracy of iPPG measurements. Video compression has a significant impact on the signal-to-noise ratio (SNR). We performed a systematic study of the effects of compression and found a linear relationship between average video bit-rate and the recovered BVP SNR when using common video compression algorithms [McDuff et al. 2017]. However, other video parameters seem less influential with results showing that neither large reductions in video resolution nor frame rate strongly impact heart rate measurement [Blackford et al. 2015]. A similar systematic analysis of HRV measurements would be a valuable contribution.

Through experimentation with multispectral imaging methods we found that the RGB channels that most digital cameras capture are not optimal for measuring the PPG signal [McDuff et al. 2016]. Further systematic analysis could inform the design of optimized hardware for this problem. However, whilst custom imagers may benefit measurement accuracy they may be of limited practical use due to their cost and lack of ubiquity.

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While state-of-the-art iPPG methods can enable very accurate measurement of the BVP signal under ideal conditions there is still a need for research to develop methods for robust measurement in the presence of motion (rigid head and body movements, and facial muscle actions) and dynamic illumination conditions. I will discuss our future directions for this research both from the perspective of novel algorithms and systems, building on research with multiple imagers [Blackford et al. 2015] and analyzing less constrained dataset.

II Interfaces and Applications

Remote PPG measurement and vital sign monitoring has numerous applications in traditional healthcare settings (such as intensive care units (ICU) [Aarts et al. 2013]). Video-based methods are particularly well-suited to cases where traditional contact-based measurement using electrodes may lead to significant discomfort, damage to the skin or restrict movement. However, the ability to measure physiological signals without contact with the body presents the possibility of creating many other novel healthcare devices and computer interfaces. Monitoring could be integrated into everyday devices, such as a mirror [Poh et al. 2011], enabling health tracking that is effort-less and convenient. Computer-based work, online learning, or gaming applications could incorporate real-time physiological measurement to help track when the user is engaged or distracted. Our preliminary work illustrated the potential of predicting changes in mental load using remotely measured physiological parameters [McDuff et al. 2016]. I will discuss extensions of this research to longer and more naturalistic tasks. Remote physiological measurement is a nice complement to automatic coding of facial expressions, body gestures and speech patterns, all of which can be performed via ubiquitous hardware. Tracking of emotional responses will ultimately require a fusion of these signals. I will present work fusing remotely measured physiology and other non-verbal cues for affective computing applications.

References

Blackford, E. and Estepp, J. 2015. Effects of frame rate and image resolution on pulse rate measured using multiple camera imaging photoplethysmography, in SPIE Medical Imaging. International Society for Optics and Photonics, 94172D–94172D.