A real-time stress monitoring system using a high sensitivity camera

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I. Abstract

Main contribution of this paper is we introduced a real-time stress monitoring system which could estimate heart rate and mental state simultaneously. We measure heart rate remotely from continuous facial frames grabbed through a high-sensitivity camera, employ independent component analysis (ICA) to each frame to extract haemoglobin signals. Heart rate will derive from frequency analysis on hemoglobin sequence, finally spectrum analysis will be applied to HRVs to get powers of low-frequency and high-frequency band, the ratio of low frequency to high frequency powers will be used as a stress index to indicate whether the driver is under pressure or not.

Key words: heart rate estimation, rPPG, HRV, LF/HF ratio, Stress Index

II. Introduction

Recent years, methods of non-contact Heart Rate (HR) estimation has been well studied, many of them have reached high accuracy. This is quite helpful for detecting potential physiological problems in advance. Nowadays, growing evidence shows that Heart Rate Variability(HRV) provides health-related information with long-term values. HRV is a time series of variation of beat-to-beat interval, provides an indication of the degree to which the sympathetic and parasympathetic nervous systems are modulating cardiac activity. Moreover, lack of sufficient variation indicates that the subject may not perform well under stress. People with decreased HRV may be at an increased risk of healthy issues.

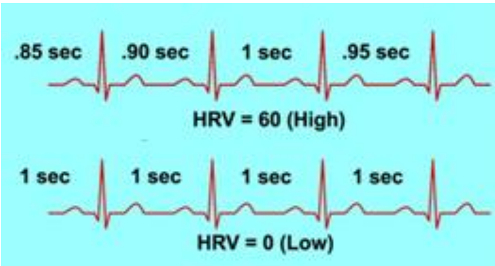

Figure 1. Assuming the heart rate is 60 beats per minute, that doesn't mean the heart beats once every second. Rather, there is variation among the intervals between heartbeats. The interval between successive heartbeats can be, for example, 0.85 seconds between some two succeeding beats, and e.g. 1.35 seconds between some other two.

In this paper, we have extended an HR monitoring system to a stress monitoring system which allows us not only grab the pulse rate but also how stressed the person is. The overview of our framework is shown in Fig. 2, which will be introduced in detail in the following subsections.

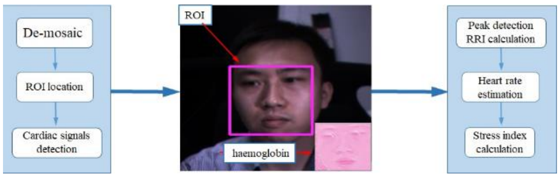

Figure 2 The ROI and overview of our framework

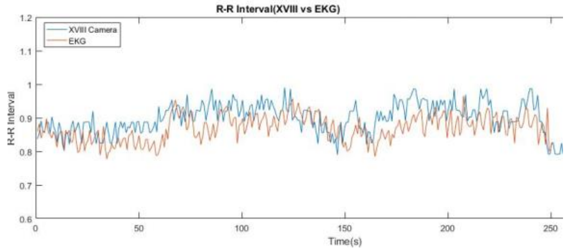

Figure 3. Result of RRI detection: PPG equipment vs our algorithm

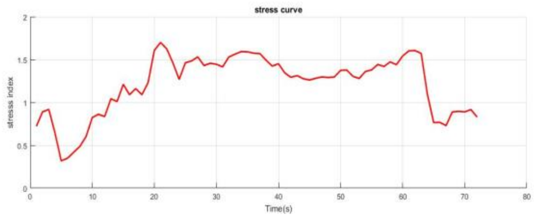

Figure 4. Mental state evaluation: 60 seconds` stress index curve when the subject is mental calculation

III. Methods

According to previous research, human skin colour will keep changing periodically along with the cardiac pulse, these subtle changes are caused by blood circulation. Our basic approach is to track the subject's face, single out the skin part by a skin-detection method, employ independent component analysis (ICA) to extract haemoglobin signals. We estimate heart rate from these signals by counting how many R peaks contain in 60 seconds and calculate stress index by analysing the HRV`s frequency spectrum. Stress index is defined as an indicator to evaluate the subject`s mental status.

$$S_{idx} = \frac{\sum_{0.04}^{0.15} P}{\sum_{0.15}^{0.4} P}$$

Here, S_{idx} represents stress index, *P* is the powers derive from spectrum analysis. Low Frequency powers range from 0.04 to 0.15, High frequency powers range from 0.15 to 0.4.

In this system, we applied power spectrum analysis to 30 seconds` R-R intervals to generate powers of low frequency(LF) band and high frequency(HF) band. The ratio of both bands, so-called LF-HF ratio, will be delivered as stress index to indicate the mental state. If the value of stress index is lower than 1.0 the person is relaxed; otherwise, stressed.

IV. Experiments and Results

Two main functions of the proposed system are heart rate estimation and mental stress evaluation. We have designed 2 experiments to validate them. In either experiment, the video resolution is 640*512, frame rate is around 25 fps.

1.**Heart rate estimation(**Fig.3**)**

We consider the R-R intervals obtained by a PPG equipment the ground truth. Our system and PPG equipment will start at the same time, R-R intervals detected by PPG and our system are recorded and compared. Recording time was 267s and 289 R-R intervals were detected. The accuracy is 94.6%. Average HR derives from PPG is 66.88, from our system is 69.14.(Fig.3)

2.**Mental stress evaluation(**Fig.4**)**

When a person is doing arithmetic calculation, his sympathetic nervous system will go exciting which will lead to tension. In this experiment, we asked the subject to keep calculating for 1 minute from the beginning. As we can see in Fig4, about 8 seconds later the stress curve started rising, then kept being over 1.0 for almost 60 seconds. This result is consistent with our expectation.

V. Conclusion

Our system combined the functions of heart rate measurement and mental state estimation together. And we have introduced a novel real-time stress monintoring system using remote photo plethysmography**.** In the future, we plan to apply this system to an autopilot system to monitor the driver, and more efforts will be devoted to lift the accuracy on the occasion when the light varies or the motion occurs in the person.

References

1. Kurita K, Yonezawa T, Kuroshima M, Tsumura N (2015) Non-contact video based estimation for heart rate variability spectrogram using ambient light by extracting haemoglobin information. Colour Image Conf 2015(1): 207-211

2. Okada G, Yonezawa T, Kurita K, Tsumura N (2018) Monitoring emotion by remote measurement of physiological signals using an RGB camera. ITE Transactions on Media Technology and Applications, 6(1):131–137

3. G. Balakrishnan, F. Durand, and J. Guttag. Detecting pulse from head motions in video. In *IEEE Computer Vision and Pattern Recognition (CVPR)*, pages 3430–3437, June 2013.

4. X. Li, J. Chen, G. Zhao, and M. Pietikainen. Remote heart rate measurement from face videos under realistic situations. In IEEE Computer Vision and Pattern Recognition (CVPR),pages 4264–4271, June 2014

5. W. Verkruysse, L. Svaasand, and J. Nelson. Remote plethysmographic imaging using ambient light. Opt. Express.**16**(26), 21434–21445 (2008).

6. Y. Sun and N. Thakor. Photoplethysmography revisited: from contact to noncontact, from point to imaging. IEEE Trans. Biomed. Eng. **63**(3), 463–477 (2016).

7. D. J. McDuff, J. R. Estepp, A. M. Piasecki, and E. B. Blackford. A survey of remote optical photoplethysmographic imaging methods. in Proceedings of IEEE conference on Engineering in Medicine and Biology Society (IEEE,2015), 6398–6404.

8. X. Li, J. Chen, G. Zhao, and M. Pietikainen. Remote heart rate measurement from face videos under realistic Situations. in Proceedings of IEEE Conference on Computer Vision and Pattern Recognition (IEEE, 2014), 4264–4271.