A Portable Plug-and-Play Imaging System for Physiological Monitoring

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Abstract

Non-contact physiological monitoring has garnered interest in the research community. However, studies employ different imaging system configuration, including illuminant profile and wavelength, camera type and frame rate, and distance to the skin. In this paper, we propose an easily customizable imaging system for evaluating physiological monitoring parameters. The system's design allows plug-and-play compatibility with various illumination sources, camera types, lenses, and optical components. Results using one configuration shows the feasibility of spatial blood perfusion analysis using this imaging system, where areas exhibiting clean blood pulsatility can be identified at the surface level.

1 Introduction

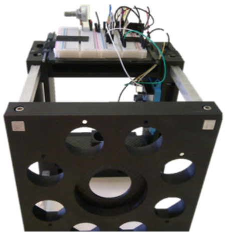
There has been a surge of research investigating camera-based systems for non-contact physiological monitoring. Although non-contact photoplethysmographic imaging is feasible at long distances [1], there is no consensus as to which type of imaging setup is optimal for this type of sensing. Imaging systems used across studies differ in design, ranging from ambient [2] to actively illuminated [3] systems. A systematic analysis on the effect of different optical configurations would elucidate the most effective components at extracting physiological signals. As a first step, a customizable imaging system must be proposed where different cameras, illumination sources, and optical components can be swapped easily. In this paper, we propose such an imaging system. Up to eight independent illuminants can be used concurrently. Different cameras can be used with standard mounting hardware. Many components of the resulting system's design were inspired by widely used optomechanical assemblies.

2 Proposed Imaging System

We propose an imaging system that co-integrates hardware, electronics, and software for customizable imaging. Aimed at being a research device, it was important to develop an illuminant interface that allowed for easy prototyping of different illuminant types and optical components in a plug-and-play manner. Fig. 1 shows a graphical overview of the system. The system was designed to support high-powered light emitting diode (HPLED) modules, since HPLEDs are offered in many different wavelength ranges, their optical power are dimmable via analog (current) or pulse width modulation, and various beam optics can be applied to create different spatial profiles. Various optical components can be applied to HPLEDs for a desired beam profile. Thus, the chassis interface was designed to accommodate Thorlabs' SM1L 1" lens tube system, which are modular and accept many different types of optical components with precise placement. The camera can be mounted onto a 1" optical post, which can be inserted into a custom post holder slot with thumb screw tightening for coarse height and rotation adjustment. The base's thickness allows mounting of custom electronics for precise illumination and frame capture control. The front plate can be adjusted so that it is flush with the front of the camera's lens, making it adjustable to different lens types. The front and rear components were assembled using four metal rods for tunable distances, inspired by optical cage systems. A 1/4"-20 threaded hole was tapped at the base of the unit for portability on a tripod or other mounting equipment.

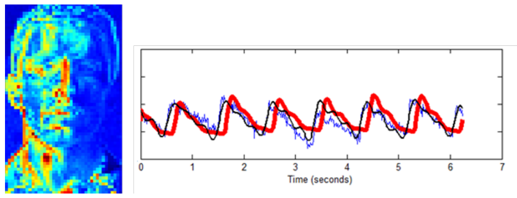
3 Results

Figure 1c shows an example result of extracting a blood pulse signal across the area of a face using the proposed imaging system in MATLAB. This setup consisted of an 850 nm longpass filter, a Point Grey GS3-U3-41C6NIR-C monochromatic camera, and no active illumination. The system was mounted on a tripod approximately 1 m from the participant's face. The participant was positioned such that ambient light illuminated half of their face. The pixel-wise spectral signal to noise ratio (SNR) map across the scene is shown (red is high SNR, blue is low SNR). The carotid artery at the base of the neck can be observed with high SNR. The temporal signal at this point (blue) is filtered using an ideal bandpass filter (black), and accurately matches the ground-truth finger photoplethysmography signal (red), with an expected temporal offset indicative of the difference in pulse transit time between the neck and the finger.



(a) Imaging system

(b) Optic module



(c) Extracted blood pulse

Fig. 1: Imaging system overview. The chassis (a) incorporates a solid base designed for mounting a scientific camera and electronics, and a length-adjustable front with eight slots for custom optics (b). This system can be used, for example, to extract blood pulse fluctuations across a spatial area (c).

4 Conclusion

A multi-illuminant research imaging device is proposed for assessing the effect of different camera-based setups for physiological monitoring. The results from a sample setup is shown which demonstrates the ability to assess spatial blood pulse perfusion. Different illumination and optical configurations can easily be configured, enabling more extensive system analysis.

Acknowledgments

This work was supported by the Natural Sciences and Engineering Research Council (NSERC) of Canada, AGE-WELL NCE Inc., and in part by the Canada Research Chairs program.

References

[1] Amelard, R., Scharfenberger, C., Kazemzadeh, F., *et al.* Feasibility of long-distance heart rate monitoring using transmittance photoplethysmographic imaging (PPGI). *Scientific Reports* (2015).

[2] Poh. M.-Z., McDuff, D. J., Picard, R. W. Non-contact, automated cardiac pulse measurements using video imaging and blind source separation. *Optics Express* (2010).

[3] Sun, Y., Hu, S., Azorin-Peris, V., *et al.* Motion-compensated noncontact imaging photoplethysmography to monitor cardiorespiratory status during exercise. *Journal of Biomedical Optics* (2011).