SmartMirror: An Embedded Non-contact System for Health Monitoring at Home

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Abstract. The ‘Smart Mirror’ project introduces non-contact based technological innovations at our homes where its usage can be as ubiquitous as ‘looking at a mirror’ while providing critical actionable insights thereby leading to improved care and outcomes. The key objectives is to detect key physiological markers like Heart Rate (HR), Respiration Rate (RR), Inter-beat-interval (IBI) and Blood Pressure (BP) and also drowsiness using the video input of the individual standing in front of the mirror and display the results in real-time. A satisfactory level of accuracy has been attained with respect to the reference sensors signal.

Keywords: Physiological parameters · Photo plethysmography · Heart rate · Respiration rate · Inter-beat-interval · Blood pressure and drowsiness

1 Introduction

Non-contact based physiological parameters extraction research was started almost 2 decades before e.g. in 1995 [1] and after a long gap the first successful experiment was initiated in 2011 by Poh et al. [2] which opens the window of non-contact based health monitoring system. Thisarticle focuses on design and development of a non-contact based camera system to detect, track and recognize a human face and provide individuals’ current state of biological signals. The goal is to display the outcomein real-timeon a screen. As soon as the system recognizes a person it calculates the users HR, IBI and RR as well as BP and displays values on the output screen using a text massage. Also, the proposed system detects eyes and notifies the user about individual’s drowsiness state. Additionally, the system can work as a personal reminder e.g., remind the identified person in a certain time of the dayto take his or her daily medicine. To set up the data in the database, the system has an independent web application for saving new reminders to a persistent database.

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2 Data Collection, Methods and Implementation

There were two different sessions for the data collection and in each session there were 10 test persons (3 Female and 7 male) of different height, weight and skin color. In the first session, facial video was recorded for all the test persons from approximately 1 m from the laptop webcam in normal sitting position on a chair without any movement in constant environmental illumination. Thephysiological parameters were extracted in offline and saved in an excel file. In the second session, physiological parameters were extracted in real time considering normal movement of the test person in varying amount of environmental illumination. In both the session a reference sensor systems called cStress[1] was used for the evaluation of proposed algorithms. The system was developed in Visual Studio 2015 and the programming language was C++. Additionally, we use several libraries that help us with implementation details: OpenCV is used for the image processing and for most of the detection, tracking and recognition algorithms. Boost is used for providing us with timestamp tool and threadsafe data structures such as circular buffers. Finally, ptheards library is used for parallel executions.

The system can be divided into three modules, namely input gathering module, face detection/tracking/recognition module and biological parameters extraction module which are operated independently in three distinct threads. The face detection/tracking/recognition module works with the buffer that contains the raw frames and stores its result in several other buffers for cropped face, eyes and hands detected in the raw input. Finally, the module for biological extraction itself can be thought of like 3 sub-modules - one for extraction of heart beat, inter-beat interval and respiration rate, one for blood pressure and one for eye analysis. The first one works with the buffer containing faces and outputs to a buffer of foreheads, the second one - with the buffer containing detected eyes and the third one with the buffer containing foreheads and hands. In this way we achieve parallel execution and thus the frame rate is not reduced and is at its maximum capacity.

3 Parameters Extraction, Results and Evaluation

Three different physiological parameters such as HR, RR and IBI were extracted in the first phase in offline considering sitting position using the method used in [3]. In the second phase, again the parameters were extracted in real time considering normal movement and environmental illumination variation [4, 5]. A comparative result for these parameters for a test person is seen in Table 1. For BP, we calculate the pulse transit time (PTT) between forehead and the palm as Fig. 1(b) like [6].

PTT is calculated from the phase difference of the heartbeat frequency component of the forehead and palm video streams. However, instead of using a formula for calculating the blood pressure, we train a three-layer artificial neural network to determine whether the blood pressure is low, medium or high. In order to have the artificial neural network well trained, we created learning data set by measuring BP and

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[1] http://stressmedicin.se/neuro-psykofysilogiska-matsystem/cstress-matsystem/.

Table 1. Comparative analysis of HR, RR and IBI

Sources	HR	RR	IBI	ΔHR	ΔRR	ΔIBI	%ΔHR	%ΔRR	%ΔIBI
cStress	69.4	18.8	867.5						
Only R	82.8	24.5	724.7	13.4	5.7	(142.8)	19.23	30.5	(16.5)
Only G	66.7	24.5	899.4	(2.7)	5.7	31.9	(3.93)	30.3	3.7
Only B	72.2	24.5	831.4	2.7	5.7	(36.1)	3.92	30.5	(4.2)
Mean RGB	69.4	24.5	864.8	(0.1)	5.7	(2.69)	(0.1)	30.3	0.3

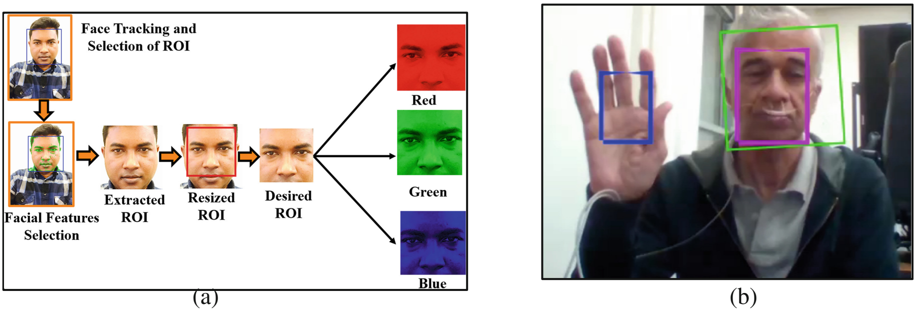

Fig. 1. (a) Overview of the image processing steps (b) ROI selection for BP

PTT of different people. We feed that data to an artificial neural network (ANN) which has four input perceptrons. The other three are obtained from the personal information database - height, weight and age. The ANN has three output perceptrons which correspond to BP being low, medium or high. We find the one that is triggered the most and select it as the final result for BP measurement.

For detecting drowsiness we extract six parameters such asPERcentage of eyelid CLOSure (PERCLOS), maximum closure duration (MCD), blink frequency (BF), average opening level of the eyes (AOL), opening velocity of the eyes (OV), and closing velocity (CV) of the eyes are extracted according to [7] and the steps are shown in Fig. 2.

These measures are combined using Fisher's linear discriminant functions using a stepwise method to reduce the correlations and extract an independent index. Here, fuzzy logic is appliedto determine drowsiness. From the facial cropped image, area of the both eyes are extracted, then each eye is separately processed in order to decrease false positive blinks and if person has ticks, it has been ignored. In preprocessing, RGB image of the eye is first converted to grayscale image, afterwards we apply histogram equalization on image, so binarization is easily done.

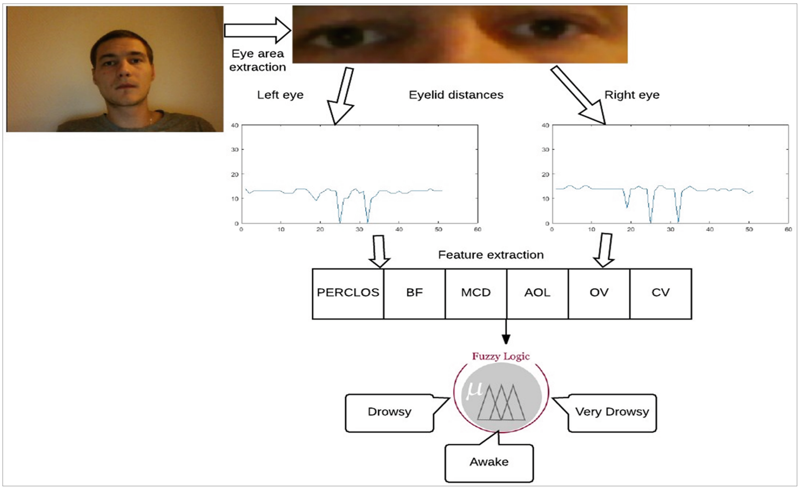

Fig. 2. Overview model for eye detection and drowsiness detection

4 Conclusion

The 'Smart Mirror' application developed to calculate physiological parameters and analyze the state of drowsiness was largely successful in performing the measurements in real time with relatively fast response times. The accuracy of the numbers obtained and verified by comparison with sensor readings was also satisfactory. Implementation of the improvements identified earlier in the paper would further improve the reliability of the system. The intent of the 'Smart Mirror' application being ubiquity, several improvements need to be incorporated in order that the system works under differing environmental conditions in everyday household and workplace scenarios. Possibilities exist to adapt the system for remote analysis and diagnostics, especially in locations where medical facilities are not available. Another applications area which may be explored is the determination of stress levels in the workplace. In conclusion, the 'Smart Mirror' application offers an intelligent lifestyle choice to society providing a means for improving the quality of one's life.

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References

1. Costa, G.D.: Optical remote sensing of heartbeats. Opt. Commun. **117**, 395–398 (1995)
2. Ming-Zher, P., McDuff, D.J., Picard, R.W.: Advancements in noncontact, multiparameter physiological measurements using a webcam. IEEE Trans. Biomed. Eng. **58**, 7–11 (2011)

3. Rahman, H., Ahmed, M.U., Begum, S.: Non-contact physiological parameters extraction using camera. In: The 1st Workshop on Embedded Sensor Systems for Health through Internet of Things (ESS-H IoT), October 2015
4. Rahman, H., Ahmed, M.U., Begum, S.: Non-contact heart rate monitoring using lab color space. In: 13th International Conference on Wearable, Micro & Nano Technologies for Personalized Health (pHealth2016), Crete, Greece, 29–31 May 2016
5. Rahman, H., Begum, S., Ahmed, M.U., Funk, P.: Real time heart rate monitoring from facial RGB color video using webcam. In: 29th Annual Workshop of the Swedish Artificial Intelligence Society (SAIS) 2016, Malmö, Sweden (2016)
6. Parry, F., Dumont, G., Ries, C., Mott, C., Ansermino, M.: Continuous noninvasive blood pressure measurement by pulse transit time. In: 26th Annual International Conference of the IEEE Engineering in Medicine and Biology Society, IEMBS 2004, pp. 738–741 (2004)
7. Fathi, A.H., Mohammadi, F.A., Manzuri, M.T.: The eyelids distance detection in gray scale images. In: 2006 International Symposium on Communications and Information Technologies, pp. 937–940 (2006)