Video-based Heart Rate Measurement From Human Faces

T. Pursche (Faculty of Electrical, Information, Media, Engineering), J. Krajewski (Faculty of Experimental Businesspsychology), and Reinhard Moeller (Faculty of Electrical, Information, Media, Engineering), University of Wuppertal, Germany

Abstract--The paper describes a video-based heart rate detection system that enables contact-free determination of a person's physical behavior under relaxed and active conditions. The heart rate or heart rate variation is an important measure for phases of human activity or relaxation. The common ways of measurement such as finger pulse amplitude and Heart Rate Belt sensor technologies are not applicable since their usability is limited in every day use. Our system uses face detection for ROI constrained near-realtime signal analysis. The experimental environment has been tested on a personal computer workplace. Although, with some optimization it can be easily ported to a mobile phone with an integrated camera.

I. INTRODUCTION

The heart rate describes how many times a heart beats per minute (Bpm). The greater demand is put on one's body through physical exercises or through illness or mental stress, the harder does one's heart work and the higher is one's heart rate. Therefore, the heart rate is a parameter of high significance to medicine, physics, psychology and to many other fields[1]. At present, the current gold standard techniques for heart rate measurement like electrocardiograms (ECG) are uncomfortable and hinder the patient. Other, more comfortable techniques like pulse oxymetry or sphygmology have their very own penalties in addition to a lower accuracy compared to the gold standard. An example for the disadvantage when using the pulse oxymetry is the measuring error or complete malfunction when the patient has cold hands or a circulatory disorder. The ability to measure the heart frequency completely contact-free would be a great benefit to all these fields where the knowledge of the heart rate would be eligible but hardly to obtain, e.g. cars, control centers, and pc-workplaces. In this paper, we introduce a video-based and completely contact-free method for heart rate measurement based on processing video-data of the human face recorded by a webcam. The idea of using the human face for physiological measurements was first introduced by Pavlidis and associates in 2007 and later demonstrated by analyzing thermal videos of the frontface. [2,3,4]

II. Methods

A. Experimental Set-up

The test set-up was designed in a way to eliminate most of the interfering environmental influences, as we wanted to find the relation between the heart rate and the information extracted from video-data. The participants were placed right in front of a webcam (1.3 Megapixels (mp), 24 Bit RGB, 8 Bit per channel) and colour-videos were recorded with a length of 2 minutes at 30 frames per second (fps), and a resolution of 640x480 pixels. All of the participants were seated at a distance of about 0.5 m from the webcam (Table 1) with indirect sunlight as the only source of illumination in the 1st setting whereas in the 2nd setting we added office fluorescent lights to the indirect daylight. Each setting consisted of phases, in the first phase the participants were completely recorded at rest (around 60 Bpm), in the second phase the participants started on a higher heart rate level (around 100 Bpm) and in the last phase they started on a high heart rate level (around 140 Bpm). For reference, measurements form a Heart Rate Belt (sampling rate 256Hz) were chosen.

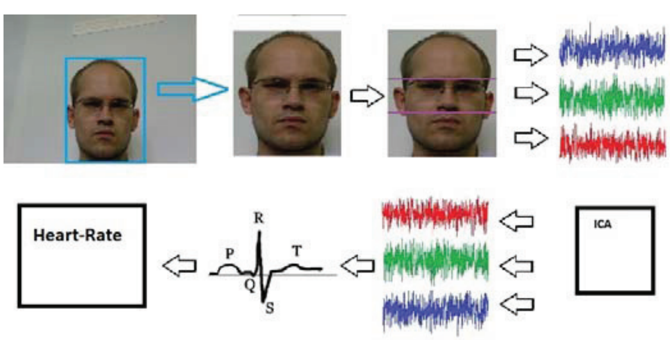
Table 1: Experimental Set-up

B. Analysis of the gathered Data

The basic idea of photoplethysmography is based on similar principles as the detection of finger pulse amplitudes. The pulse wave, which is initiated by a heartbeat, travels through the whole arterial body vascular system and reaches the face, where it causes a short-termed volume change of blood. The intensity of the absorbed light depends on this volume similar to the finger pulse measurement. The principle, originally based on trans-illumination of the finger tissue, will be extended by sensitive signal processing so that the mere illumination with ordinary daylight or conventional indoor lighting is sufficient. The problem of the gathered video data is that no clean RGB-signals are recorded by the 3 channels of the webcam, but instead an overlapping mixture of the three components plus noise caused by motion artifacts or change in illumination. Against this background we used the mathematical model of independent component analysis (ICA) to obtain the raw-signals of the three components. [5,6,7]

Processing and analyzing the obtained data is done by a self-written software realized in C and MATLAB. Firstly, a region of interest (ROI) is extracted from the video, in this specific case it is the face of the participant. This ROI is divided into 3 parts: forehead, the area around eye and nose, and a mouth area. For all frames in the video each of the sub-regions of a frame is separated into its three RGB components, and each component is reduced to a unique value by calculating the arithmetic average over all pixel values for the specific color component. The resulting nine time signals contain pulse and noise, i.e. resulting from patient movement. We applied the ICA method to obtain clear raw-signals by removing the noise from the signal. Finally, we implemented two algorithms to obtain the heart rate out of the video data. The first is a peak detection algorithm applied to the time signals that provides us with satisfactory but improvable results. Secondly, we calculate the Fourier transforms of the time signals to obtain the related power spectrum. We expected that the heart rate frequency corresponds to the highest power in the spectrum. For this reason, we chose a range from 0.3 to 3 Hz for the frequency band which equals to a heart rate range of between 18 and 180 Bpm. This range covers most of the common heart rate measurements. By analyzing the computed power spectrum of the data, we obtained a much higher correlation with the reference measurement than with the previously used peak detection algorithm. Table 2 shows a general overview of the process.

Table 2: Overview



III. Results

In the channel-trend diagrams a tendency is perceivable towards the reference heart rate (Table 3). After applying the peak-detection-algorithm respectively the power-spectrum-analysis algorithm on the data we obtain the value of the calculated heart rate. The percentage difference to the reference data is displayed in Table 4. By using the peak-detection-algorithm we obtain relatively good results but after using the second algorithm we obtain much better results.

Table 3: RGB-channel trend for a high activation level

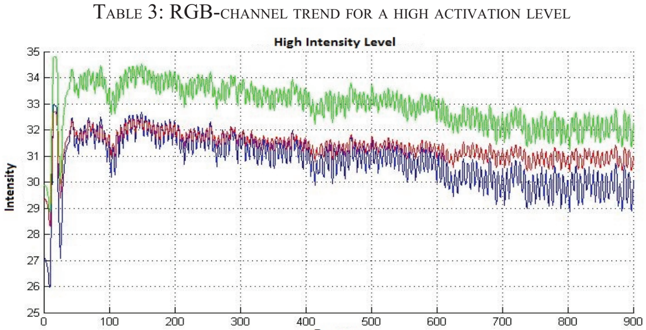


Table 4: Percentage Divergence after using Algorithms

Peak-Detection	Rest(68Bpm)			Medium(103Bpm)			High(138Bpm)		
	Region 1	Region 2	Region 3	Region 1	Region 2	Region 3	Region 1	Region 2	Region 3
Red	8,0936	12,5778	15,2872	-0,5363	-5,2652	-15,5377	5,2097	2,2611	2,5340
Green	8,7025	4,2432	2,2909	2,3065	-2,2816	-8,7569	1,0865	1,5623	11,2295
Blue	7,6055	7,1181	14,6359	6,9758	0,6882	-2,2313	2,8376	3,1126	19,9527
Power Spectrum	Rest			Medium			High		
& ICA	Region 1	Region 2	Region 3	Region 1	Region 2	Region 3	Region 1	Region 2	Region 3
Red	0,5987	3,2695	3,6236	0,3424	2,4253	-6,2352	3,4144	2,1415	2,8546
Green	1,5632	0,5347	1,6432	1,3523	-0,3522	4,1424	1,4125	2,1455	5,1412
Blue	0,9645	2,9635	3,4643	5,1441	1,2124	-2,5232	2,6234	3,1451	8,2141

IV. Conclusion

As we demonstrated in this paper we are able to provide a measurement system to obtain heart rates with an accuracy similar to the reference measurement system (Heart Rate Belt) but with the additional feature of complete absence of body contact. There are already systems which have been realized as iphone apps that allow you to simply hold one finger on top of a front-camera – but again body contact is needed which is exactly what we want to avoid. Or alternatively we want to show a complete contact-free process is possible. Furthermore, the system is very attractive because of the low price. The only measuring equipment that is needed is a webcam-like digital camera that is easily purchased for 10 to 20€ or is already part of a mobile phone and a computing device. All analyses are done by software that runs without problems on any actual personal computer. “Realtime” measurement in 60 to 80 seconds is currently not yet possible with our experimental system but can be obtained by transferring the code into hardware or firmware which should be easily achievable. Another task would be to prove the test-setup under rather realistic circumstances including changing light effects, stronger moving artifacts, facial expressions, change of temperature and many more. Next to the above mentioned fields of application there are additional ideas to be mentioned. Possible applications are for example fatigue and sleepiness detection systems in cars, airplanes and PC-workplaces. Gaming application, security, e.g. airport etc. and many other fields are conceivable.

References

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