# Chapter 65
# Non-contact Measurement of the Heart Rate by a Image Sensor

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Nowadays there is a great attention in the biomedical field on the possibility to measure physiological parameters on a subject using a minimal invasive approach. In this paper, the authors propose an innovative, non-contact measurement method for the assessment of the heart rate (HR). The novel approach is based on the use of a digital camera to assess the color variation measureable on a subject face and caused by the periodic pumping action operated by the heart which allows the blood circulation. The paper report the methodological approach followed and the results obtained on ten voluntary subjects. Measured data are compared with HR values simultaneously measured by reference instruments. Cameras are available in many devices and this permits a large diffusion of this new method for the measurement of the heart rate that is the most important parameters to determinate a subject status of health.

## 65.1 Introduction

In the world, every year, 17 million of people die of cardiovascular diseases particularly heart attacks and strokes. The heart is one of the most important organ of the body and therefore the monitoring of its activity, in some cases, could be of primary interest for diagnosis purposes. The heart is a muscle which function is to periodically pump blood throughout the blood vessels allowing blood to reach the various parts of body. The energy that stimulates the heart occurs in the sinoatrial node, where an action potential is produced, which is sent across the atria and later to the ventricles. This periodic electric pattern, which invest the whole cardiac muscle, generates its contraction and consequently its pumping action. The frequency of the periodic contractions per minutes (bpm) is named Heart Rate (HR) and, in an adult, its normal rage can vary between 50 and 200 beats-per-minutes [1].

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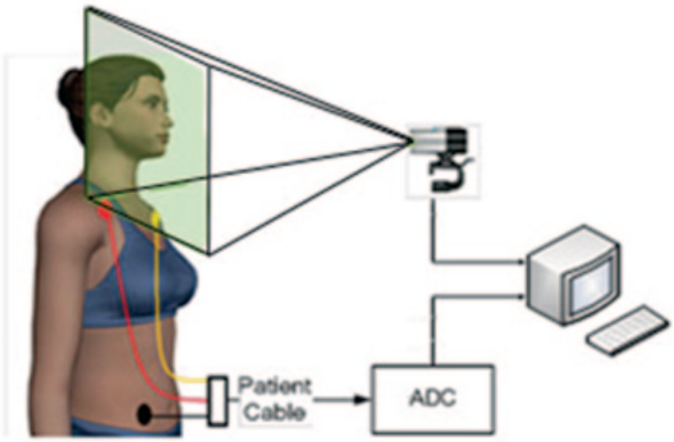


**Fig. 65.1** The experimental setup used is composed by: CMOS Camera, ECG and an *ADC* board, a PC is used to record video and ECG signals and to operate the data computation

Routinely, the electric heart activity is monitored using an electrocardiogram (ECG) [2] which provides a time signal related to the different phases of the electrical activity of the heart. The sensing action is operated through the use of many skin-electrodes (up to ten electrodes) which are attached to the skin surface. HR is universally considered one of the most important physiological parameter and it is related to the health status of a subject [3]. Its values are related to his/her health status and also to his/her metabolic rate [4].

In this paper, the authors propose a novel measurements method for the measurement of the heart rate on a subject, based on the use of a digital imaging sensor (in our case a CMOS camera) which is characterized by complete absence of direct contact with the subject.

## 65.2 Materials and Methods

The measurement method proposed is based on the test set-up schematically reported in fig. 65.1. It is composed by a CMOS Camera (Microsoft LifeCam Studio, CMOS Technology) connected to a personal computer via USB and a reference ECG (ADInstruments) used to simultaneously measure the subject HR values. ECG is also connected to the PC via an analog-to-digital board and an USB. The camera video frames are acquired at 30 fps and are composed of single frame with a resolution of $320 \times 240$ pixels. The ECG measures the II lead and the sampling frequency set is of 1 kHz; an antialiasing filter is used on the ECG signal.

The passage of the blood pressure pulse along the vessels tree causes a local vasodilatation during the systolic pressure peak. This phenomenon is in particular

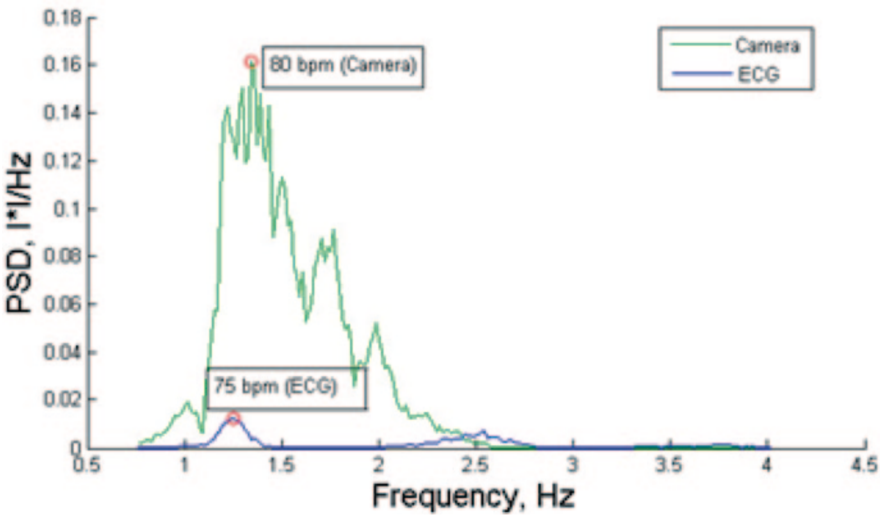


**Fig. 65.2** Power spectrum densities of the measured (Camera) and reference (ECG)signals

visible in correspondence to the face surface vases. In fact, it causes an variation of the skin color intensity in correspondence to the vases. Typically the variation of color change is little and could not be perceived by eye. In this work a dedicated algorithm has been realized in order to emphasize the color variations due to passage of the blood pulse. In our experiments, 10 (5 male, 5 female) subjects have been used. The procedure consists of recording a video frame (duration 30 s) of the subject's face and simultaneously to acquire the ECG signal. A region of interest (ROI) is automatically select as rectangular box of the subject face.

The RGB channels from the digital camera are separated and from a specific study it resulted that the most sensitive channel for HR extraction is the green. Following the approach presented in [5], an Independent Component Analysis (ICA) [6] algorithm is applied and a wavelet decomposition is operated in order to obtain a signal with the same periodicity of the heart. A Power Spectrum Density (PSD) is applied on the signal in order to extract the HR values from its maximum peak (multiplying by 60) as reported in Fig. 65.2.

## 65.3 Results

The scatter plot obtained from the tests operated on the ten subjects (Fig. 65.3) shows a good correlation between the data measured with the proposed method and the data measured with the reference method (ECG): Pearson coefficient of 0.91. From our analysis, the HR values are affected by an uncertainty of ±4 bpm (k = 1).

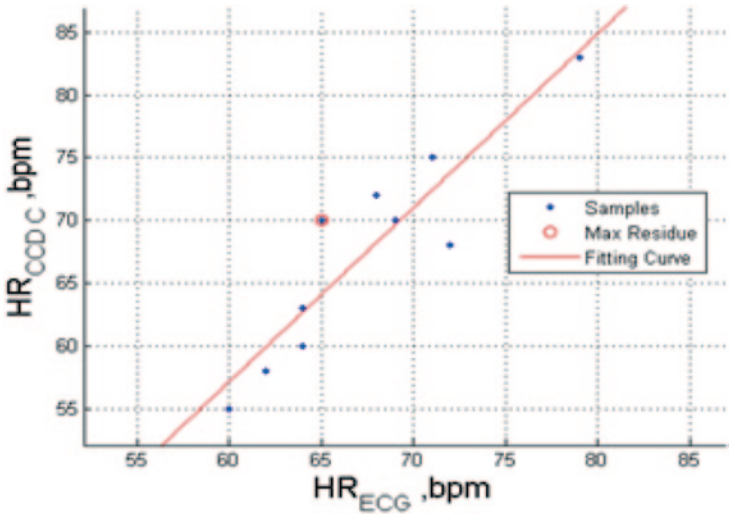


**Fig. 65.3** Scatter plot of HR data measured with the proposed method (HR_CCD C) vs reference method (HR_ECG)

Identified possible sources of uncertainty are: the relative position of the digital camera respect to the subject face and his eventual movements artifacts during the test, the illumination pattern and also the color characteristics of the skin.

## 65.4 Conclusions

In this paper, the use of a standard digital camera for PC has been demonstrated to be feasible for non-contact remote heart rate monitoring. Result have been compared with a reference method/ECG) and a uncertainty of ± 4 bpm (k = 1) is reported from our tests.

The proposed method is characterized by the important advantage to operate without contact with the subject and its contactless nature is very important in particular operative conditions where the traditional ECG cannot be used (i.e. contaminated or dangerous area, such as the MRI machines) or where its use can be limited due to the skin conditions (i.e. burned or infectious patient).

From our tests, it results that the illumination conditions of the subject, rapid movements and camera to subject directions are the main limiting factors. To address such limits, redundancy of the imaging systems and optimization of the processing algorithm are under study.

Possible future use of the proposed method could also see non clinical scenarios such as the domestic environment where digital camera are already largely present (TV, smart phones, tablets, notebooks, home games, etc.).

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