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The Brady Prize : Essay Competition (Topic 2)

Diagnosis is based on discovering the nature and causes of a disease through the symptoms showed by the disease. In the past physician expertise was the only available method to assess clinical conditions of the patient. In fact the doctor often used to make diagnosis only considering medical history, symptoms on looking face skin color, for example yellow-looking corresponded to a liver disease, without need of clinical exams. However, it' s important to see beneath the surface, into the complex structure of human body, in order to take more precise decisions, especially in case of serious pathologies. A possible way could be observing beneath the skin by surgery, but it' s a complicate and discomfortable task, because of invasivity and possible blood loss. Invasivity is a parameter used in medicine to describe when, during a clinical procedure, a break in the skin is created or there is a contact with the mucosa or internal body cavity beyond a natural or artificial orifice.

The physician can also give a look into the body with many medical imaging systems today. In clinical environment the natural tendency is to choose the less invasive method, so there is an increasing interest in this field. Medical imaging includes the set of techniques that noninvasively produce images of the internal aspect of the body. But… how and when did medical imaging become a new chance?

In 1826 Jean -Daniel Colladon invented ultrasounds, using an underwater bell to determine the speed of sound in the water. At the beginning of 20th century Karl Theo Dussik, a neurologist at the University of Vienna, first applied ultrasound in medical diagnosis for locating brain tumors by sending a beam through the skull, producing an ecographic A-mode image. It was possible to see both sides of the skull and the midline of the brain. The image was recorded on heat-sensitive paper.

These events have increased the attention of the research in the field of medical imaging and they have lead to a fast development and discovering of new methods like X-ray Tomography and Nuclear Magnetic Resonance. All these systems are daily used for diagnostics in hospitals and clinics. Ecography is the least injurious. In the other two techniques the image of anatomical structure is obtained through the interaction between the X-ray beam or the magnetic field and the interface of different tissues. Despite that, the best imaging technique should be chosen taking in consideration the kind of tissue to observe. However the physician opinion is essential, in fact an image without a person able to "read" is valueless. Only the doctor has the skill and the knowledge to state if a spot can correspond to a tumor or it' s due to an artifact.

An innovative technology developed in 20th century is telemedicine, that allows storing, transmission of physiological imaging and data, communications between patient and medical responsible, who don' t need to be in the same place, with safety and quality. This innovation is carrying many advantages, in fact it aims to reduce the hospital follow up incidence and to perform home checkup, saving fiscal resources. Some systems are needed for telemedicine services like home monitoring devices, videotelephony, bidirectional communication networks. In that way the doctor could consult the clinical recorded data and make diagnosis remotly. Obviously his role is essential in the interpretation of the physiological parameters' values and to prescribe the best treatment.

Among the most significant physiological signals there is the heart rate (HR), the number of heartbeats per unit of time, HR is typically measured monitoring the time duration among two successive contractions of the ventricles (systole) and results are provided as beats-per-minutes (bpm) or frequency (Hz). Usually HR measurements are collected by means of electrocardiograph (ECG) or pulse oximeters [2]. Non-contact monitoring of physiological parameters represents a challenge at home as well as in hospitals.

In recent years, the attention to non-contact measurement methods for HR assessment has significantly grown [4-7]. An optical approach has also been proposed using a laser Doppler vibrometer able to provide very detailed information on the velocity of one point of the subject [4-7]; in particular the thoracic and the carotid area have been investigated providing precise information respect to the golden standard (ECG) [6]. At the moment, this approach has not still found wide diffusion in the clinical environment probably due to the high cost. An interesting approach for HR has been recently demonstrated, on adult subjects in controlled conditions, using a webcamera [8], which results to be of interest because of the low manufacturing cost and flexibility of use.

My research group presents a measurement method, based on image processing of the patient face acquired by a low-cost webcam, which allows to determine the heart rate. The method is based on measurement of movements of portion of the skin surface, transmitted by propagation of hemodynamic waveform. The setup is constituted by a digital webcamera placed perpendicularly to the subject face at distance of 20 cm, using a frame rate of 15 fps on a video frame of 320 x 240 pixels, II-lead ECG signal acquired at a sampling frequency of 1 kHz and bandpass filtered (0.05 - 150 Hz), a large band light source placed about 1 meter far from patient to uniformly illuminate the interested area. ECG signal and video data were synchronously recorded. All data were analyzed offline using custom algorithm in MATLAB. The region of interest (ROI) was manually selected, all the frames inside it were separated into the three RGB channels and spatially averaged over the ROI pixels. The algorithm used for ICA is based on the Joint Approximate Diagonalization of Eigenmatrices [8]. The HR was extracted as the peak of the power spectral density (PSD) made after ICA, and converted to bpm multiplying peak's frequency by 60. Between different lights [1], green illumination seems to be the most suitable for HR extraction, with the highest correlations with the values provided by ECG. The proposed approach has been tested on 7 patients in clinical environment (a neonatal intensive care unit) and results have been compared to the reference data measured with an ECG. The Bland-Altman analysis shows that 96% of samples were placed within the 1.96 standard deviation range. A bias (overestimation) between the WeC data and the ECG data is reported (-0.9 bpm), while the standard deviation of the residuals is 4.5 bmp (<5% of the full scale). A Pearson 's coefficient of 0,94 was found, confirming the correlation. Uncertainty has been estimated as 4.5 bmp (k= 1).

The test condition can be considered severe, considering the harsh environment, patient health conditions (weight and dimensions) and recovery factors (presence electrodes, other instrumentation, artificial lights, etc.), nevertheless the estimated uncertainty can be considered adequate considering that the proposed method should be conceived as a general monitor of the patient. The use of a standard market-available web-camera, image processing and independent component analysis (ICA) has been demonstrated to be feasible also in adults for non-contact, distance, heart rate monitoring [8]. Future steps will be making the system more robust respect to the movement and the light reflections as well as to shading or partial covering of the ROI. Artifact problems due to patient movement were infrequent because the preterm baby were placed supine in the center of crib. Face detection algorithm needs to reduce uncertainty due to small movement of head's patient.

Finally I would like to remark the importance of the remote monitoring allowed by this method: easy-deployment of the system, reduced cost for the apparatus, availability of a video image of the patient.

But it’s also important to consider a possible use of the proposed system not only for patients, but also for healthy subjects in daily routine in home, education and sport environments for prevention and monitoring the cardiac, and also respiratory, rithm and activating an alarm when it’s out of a physiological range.

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