

IMAGE PROCESSING APPLICATIONS IN LIFE SAVER DRONES

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Abstract : Many people residing in hilly regions have a serious problem with their health that needs to be monitored. Due to the insufficient medical support provided in the rural areas, people living there face difficulties during medical emergencies. So we have designed a system that detects human pulse and heart rate (BPM) using Image Processing without the body contact. It can also be used in cases of national security force in mountainous regions at adverse climatic conditions. In such cases the human body may not support the climatic condition and might require medical support at any instance of time. In such cases an immediate medical assistance and regular monitoring of the person's health condition is required. So, Doctor who lives nearby the location will understand the state of an injured person before he arrives to the hospital. The main principle involved in our system, it helps to calculate the heart rate (BPM) through the face detection by using Deep Learning and the results are forwarded to the nearby physician using which the required medical assistance is provided.

1. Introduction

The method of performing useful operations on images so as to acquire an enhanced image or to extract information that are useful is termed as Image Processing[1]. It is also a form of signal processing wherein the input is an image and the output might be another image or some information extracted from the image. The technologies using image processing are growing at a faster rate, according to the current scenario. Thus it forms another important research area in the Computer Science discipline within engineering. Generally, image processing is nothing but a combination of processes such as:

- Image acquisition using tools
- Image analysis and manipulation

- Resulting image or report based on the imported input image

The methods used for image processing are of two types, namely analogue and digital. Analogue image processing uses hard copies such as prints and photographs. Fundamentals of interpretation at various levels are used by the image analysts as they use some of the visual techniques. Digital image processing on the other hand contains techniques which aid in the manipulation of the images in digital form by using computers. Digital techniques enforce three stages while processing the image, namely, pre-processing, enhancement and display and information extraction. The fundamental terminologies frequently gone through are image, digital image and digital image processing. There are various sources for digital images such as CCTV footage, camera, sensor images, etc. Nowadays, there has been a drift in the research area of image processing and it is called as computer vision. Taking an image into the account, a pixel is the term used to represent the elements.

Images play a vital role with respect to the human perception because human vision is the most advanced sense in us. But the human vision is limited to the visual band within the electromagnetic (EM) spectrum. Whereas the imaging machines can cross this obstacle and can record images in the entire EM from gamma to radio waves. These machines can handle the data, i.e., images generated by weird sources which humans cannot. This includes computer-generated images, ultrasound and electron microscopy. Thus, digital image processing expands over a wide area of application because of its distinct feature. Image processing can combine with AI to emulate the human intelligence. Though there are no clear cut boundaries between image processing and computer vision, image analysis falls somewhere in between. There are three processes within the paradigm of image processing namely low-level, mid-level and high-level processes. Low level process includes operations like image preprocessing which is

used to reduce noise in the image as well as contrast enhancement and image sharpening. Mid – level process includes operations like segmentation, classification, etc. At last, higher-level processing includes ensembling of objects which are recognized and also other functions such as image analysis, computer vision, etc.

2. Related Work

With respect to health and mental conditions, heart rate varies greatly, thus it serves as a source to indicate various health care applications. Detection on heartbeat without coming in contact with the human body can be carried out using Doppler radar which is widely researched. In the Doppler radar method, the radar transmits a un-modulated wave against human chest[1]. When this happens, it detects heartbeats and respiration when it is captured as there is a variation in the frequency or phase shift of the reflected wave.

Generally, there is a displacement in the chest from 4 to 12 mm during respiration, which is caused due to the heartbeat that is between 0.2 to 0.5 mm. So, the effects of respiration are highly unavoidable according to major researchers[2]. Signals that fall below the limit of spatio-temporal sensitivity is mostly information which is apart from the capacity of the human visual system. For example, there is always a variation in the human skin color with respect to the blood circulation in the body. This variation is only identifiable by special means other than the naked eye. The same way, low spatial amplitude motion is impossible for the human eye to see, but can show interesting behavior which needs to be much more magnified. Thus, it serves as an encouragement for the development of new technology to reveal these interesting characteristics invisible to normal naked human eye[3].

Revealing the invisible signals have become the highest priority research area and there are many techniques designed for this. Also the success rate of tools developed for this purpose is very high. The spatial and temporal processing are combined together and it can amplify subtle 23 varieties of videos which reveal significant attributes. So amplifying in giving the temporal frequency band of interest can generate interesting results in terms of time series of color values of the frames at pixel value. Thus, with this technique without tracking the feature or motion estimation, the motion can be magnified. Another non-intrusive method to measure the movements of the human body without coming in contact is called Ballistocardiography[4]. Movements due to respiratory and cardiac activity can be measured using this technique. This measures the vibrations caused due to the change in the center of mass of blood to the other end of the human body. Even

without the aid of a medical staff this process can be carried out which is an added advantage. Ballistocardiography is in a renewed interest for scientific research due to the advancement in the signal processing techniques[5]. Originally discovered in 19th Century, Ballistocardiograph can be embedded into daily use objects like chair, bed, etc. It can also detect abnormalities in the human heart[6][7]. Monitoring heart activity should involve checking all parameters like electrical, mechanical, fluid, etc., since heart is the important subsystem of human body with all these activities. The ballistocardiograph (BCG) calculates the force of systolic contraction of the body after calculating the pumping of blood into the aorta and pulmonary artery also it reflect signals in the form correlated with ECG signal[8]. The BCG signal records distinctive peaks, which is due to the ejection of blood into various vessels during each heartbeat. Low frequency impulse noise, time varying noise and high frequency impulse noise is generally added to it. Analysis of the spectrum of the BCG signal is done to extract the frequency components which corresponds to the distinctive peaks recorded in the BCG signal.

ECG and Microcontroller (MCU) is interfaced to perform serial communication protocol[9]. ECG Front End Circuit supports ECG signal acquisition, monitors heart rate, measures respiration rate all based on the impedance pneumography. Various low spatial amplitude motion reveal interesting mechanical behavior when magnified. These are also a matter of concern when it comes to the field of Bioinformatics[11][12].

3. Proposed System

In the proposed system, various entities related to human heart is diagnosed such as Pulse Rate, Heart Beat, BPM, BREATHING RATE, through Facial recognition of an individual by acquiring live capture or digital image data along with the stored record of the person. The method takes an input video of a person's forehead and returns a pulse rate along with a series of beat locations which can be used for the analysis of the variations between heartbeats. Many people residing in hilly regions have serious problem related to heart and their health needs to be monitored periodically. But due to insufficient medical support provided in the rural areas this is literally impossible. So a system is designed to detect the human pulse and heart rate (bpm) using Image Processing. It can also be extended for national security force in mountainous region at adverse climatic conditions. In adverse cases of harsh climate the human body may not support the regular human activities and might require medical support at any state of time. In such scenario an immediate medical assistance and regular monitoring of

the person's health condition is very essential. The Doctor who resides nearby the location can understand the situation of an injured person through the data acquired by the camera before he arrives to the hospital. The system takes an input video of a person's head and returns a pulse rate as well as a series of beat locations which is used for the analysis of heartbeat variations. First the motion of the head is extracted using feature

tracking. Then the motion corresponding to the pulse is isolated and is projected onto a 1D signal that further extracts individual beat boundaries from the peaks of the trajectory. For this purpose PCA is used and the component whose temporal power spectrum best matches a pulse is selected. The trajectories of feature point are extracted onto this component along with the beat locations as local extreme.

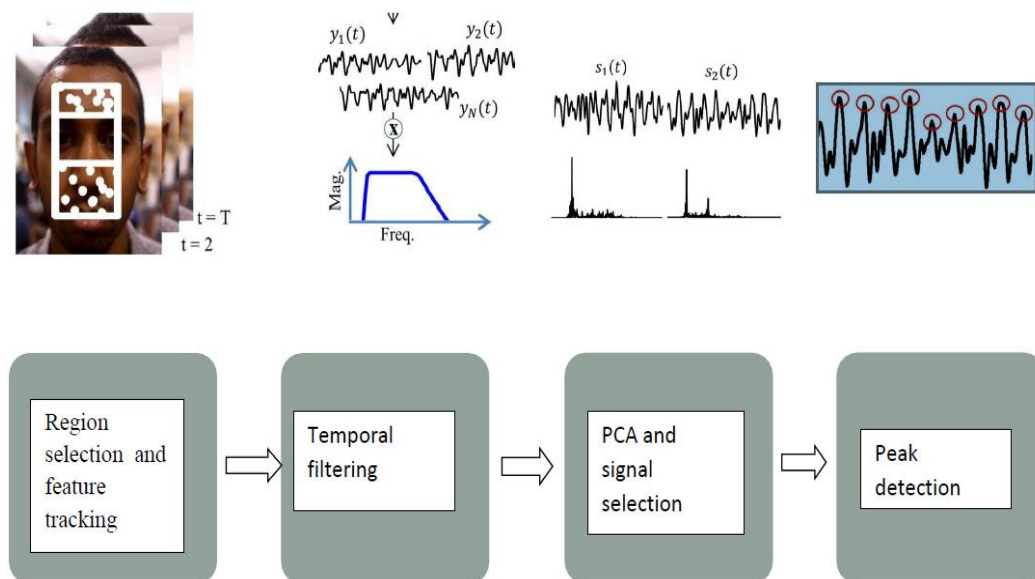


Figure 1. Architecture Diagram

Fig. (1) Presents an overview of the technique. Assuming the recorded subject is stationary and sitting upright for the duration of the video, the system starts by locating the head region and modeling head motion using trajectories of tracking feature points. The vertical component of the trajectories for analysis is considered. The trajectories showcase extraneous motions at frequencies exceeding the range of possible pulse rates, and so there is a need to temporally filter them. PCA is then used to separate the trajectories into a combination of independent source signals to describe the main elements of the head motion. To choose the correct source for analysis and computation of the duration of individual beats, the system examines the frequency spectra and selects the source with the clearest main frequency. The average pulse rate is identified using this frequency. For more fine-grained analysis and calculation of beat durations, peak detection within the time-domain is performed.

3.1 Overview of pulse estimation approach

- (a) A region is selected within the head and feature points are tracked for all frames of the image.
- (b) The vertical component is extracted from each feature point trajectory. Each trajectory is then temporally filtered to remove extraneous frequencies.
- (c) PCA decomposes the trajectories into a set of source signals s_1, s_2, s_3, s_4, s_5 .
- (d) The component which has clearest main frequency is selected. Peak detection identifies the beats of the signal.

3.2 Region Selection and Tracking

The system finds a region of interest containing the head and track feature points within the region. For videos where the front of the face is visible, the Viola Jones face detector from OpenCV 2.4 is used to first find a rectangle containing the face. The middle 50% of the rectangle widthwise and 90% heightwise from top is chosen in order to ensure the entire rectangle is within the facial

region. The eyes from the region is removed so that blinking artifacts do not affect the results. To do this, subrectangle spanning 20% to 55% heightwise is removed and thus it works well. For videos where the face is not visible, the region is marked manually. The movement of the head throughout the video is measured by selecting and tracking feature points within the region. OpenCV Lucas Kanade tracker is applied between frame 1 and each frame $t = 2 \dots T$ in order to obtain the location time-series $x_n(t)$, $y_n(t)$ for each point n . Only the vertical component $y_n(t)$ is used for analysis. Since a modern ECG device operates around 250 Hz to capture heart rate variability and the captured videos were only shot at 30 Hz, thus apply a cubic spline interpolation to increase the sampling rate of each $y_n(t)$ to 250 Hz. Many of the feature points can be unstable and have erroneous trajectories. To sustain the most stable features the maximum distance (rounded to the nearest pixel) traveled by each point between consecutive frames are calculated and points with a distance exceeding the mode of the distribution are discarded.

3.3 Temporal Filtering

All frequencies of the trajectories aren't required for pulse detection. A normal adult's pulse rate measured falls within [0.75, 2] Hz, or [45, 120] beats/min. Frequencies lower than 0.75 Hz can negatively affect the system's performance since low-frequency movements like respiration and changes in posture directly affects the amplitude and dominates the trajectories with respect to the feature points. However, other frequency higher than 2 Hz marks to provide useful precision which is needed for peak detection. Taking these details into account, each $y_n(t)$ is filtered to a passband of [0.75, 5] Hz. The 5th order butterworth filter is used for detecting the maximal flat passband.

3.4 PCA Decomposition

The source signal of the movement of the head is mainly caused by the cardiovascular pulse. The feature point trajectories constitutes to be a combination of this movement as well as other motions due to respiration, vestibular activity and changes in facial expression. The mixed motion must be decomposed into sub signals in order to isolate pulse which is mainly required. The multidimensional position of the head at each frame is considered to be a separate data point and PCA is used to find a set of main dimensions along which the position variation occurs. A dimension is selected on which the position time-series is projected in order to obtain the pulse signal. Formally, given N feature points, the N

dimensional position of the head is represented at frame t as

$$m_t = [y_1(t), y_2(t), \dots, y_N(t)]. \quad (1)$$

The mean and the covariance matrix of the positions are:

$$m^- = \frac{1}{T} \sum_{t=1}^T m_t \quad \Sigma_m = \frac{1}{T} \sum_{t=1}^T (m_t - m^-)(m_t - m^-)^T \quad (2)$$

PCA finds the principal axes of variation of the position as the eigenvectors of the covariance matrix:

$$\Sigma_m \Phi_m = \Phi_m \Lambda_m \quad (3)$$

where Λ_m denotes a diagonal matrix of the eigenvalues $\lambda_1, \lambda_2, \dots, \lambda_N$ corresponding to the eigenvectors in the columns of Φ_m , $\phi_1, \phi_2, \dots, \phi_N$.

The first two eigenvectors for two of the subjects. Each eigenvector represents the N -dimensional direction and magnitude of movement for the feature points. The eigenvectors differ for each subject. The 1-D position signal $s_i(t)$ is obtained by projecting the position time-series onto

$$\phi_i: s_i(t) = (m_1 \ m_2 \ \dots \ m_T) \cdot \phi_i \quad (4)$$

There are periods in the video during which the head moves abnormally (e.g. swallowing, adjustments in posture). Such movement adds variance to the position vectors, thereby affecting the PCA decomposition. To deal with this one could discard a percentage α of the m_t with the largest L_2 -norms before performing PCA. However, all of the m_t must still be used in the projection step (Eq. 4) to produce a complete signal. Therefore α is set at a value of 25% for the sake experiments. A popular alternative to PCA is independent component analysis (ICA). There is no improvement recorded while using ICA.

3.5 Signal Selection

The question remains of which eigenvector to use for pulse signal extraction. The eigenvectors are ordered such that ϕ_1 explains the most variance in the data, ϕ_2 explains the second most, and so on. Although ϕ_1 explains most of the variance, s_1 may not be the clearest pulse signal for analysis. The s_i that is most periodic is chosen. A signal's periodicity is quantified as the

percentage of total spectral power accounted by the frequency with maximal power and its first harmonic. It is not necessary to consider any signals beyond the first five, i.e. $s_1, \dots, s_5$ for any of the subjects. The maximal frequency of the chosen signal f_{pulse} is labeled and approximate the pulse rate is measured as 60 f_{pulse} beats per minute.

3.6 Peak Detection

Average pulse rate alone is insufficient to fully evaluate the cardiovascular system. Clinicians often assess heartbeat variations to form a complete picture. To allow for such analysis, peak detection on the selected PCA component signal is performed. The peaks are close to 1 f_{pulse} seconds apart with some variability because of the natural variability of heartbeats, variations of the head motion, and noise. Each sample in the signal is labeled as a peak if it is the largest value in a window centered at the sample. The length of the window (in samples) is set to be $\text{round}(f_{sample}/f_{pulse})$, where $f_{sample} = 250\text{Hz}$.

3. Simulation

The proposed system has been executed with Math works and Pi. In the first scenario Fig: (2) we will be locking the head moment of the human body and then the forehead will be detected and it will be locked off.

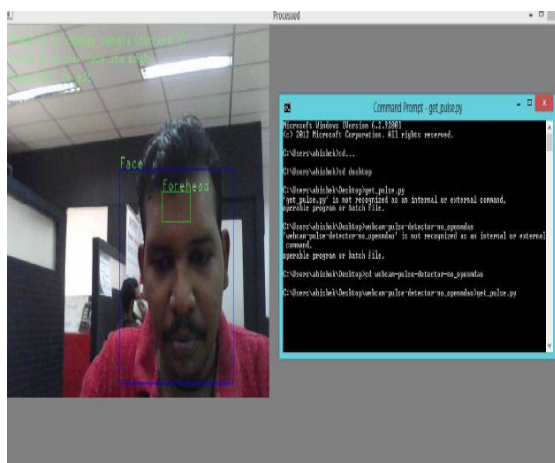


Figure 2. Head Movement

The heart rate will be identified by the general principle “Newton’s Third Law i.e., $F_{\text{blood}} \rightarrow \text{head} = F_{\text{head}} \rightarrow \text{blood}$. The blood pumping from the carotid artery will be showing off slight variations in the head position in the Digitized cam as shown in the fig(3).

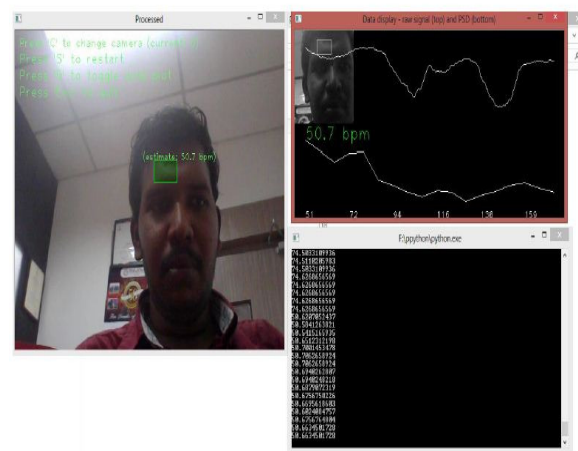


Figure 3. Detection of heart rate

In the final scenario Fig: (3) shows the detection of heart rate of a human body without the contact of any Medi-equipment’s.

4. Conclusion

The Proposed system shall be very useful, if the rescue team is provided with first hand information of critical parameters of victims and a GPS based tracking system to locate the victims. A drone mounted with a camera which has the capability to identify the injured victim is alive or not, by measuring the heart rate and all such vital parameters of the victim, also senses the location of the victim found injured/unconscious. This innovation provides solution to injured soldiers in war fields and at borders, disaster management, flood relief operations, landslide rescue missions, and forest fires. This technology shall enable the rescue team and doctors to go well prepared for the rescue operations and carry necessary materials too, by which the death rate of victims and also the soldiers in war field and Borders can’t be stopped but can be reduced comparatively.

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