Real-time Heart Rate and Blood Pressure Estimation Using Video Analysis

With advances in computer vision and signal processing, it's now possible to estimate physiological signals, such as heart rate and potentially even blood pressure, by analyzing video recordings from standard webcams. In this article, we explore a practical method for extracting and analyzing these signals through video capture, face detection, and digital signal processing techniques.

Capturing Video Data and Selecting Region of Interest

The process begins by capturing frames from a webcam using OpenCV, a popular computer vision library in Python. Each frame captured from the camera contains important visual information related to subtle changes in blood flow, particularly visible in the green channel of the image. However, capturing accurate physiological signals requires isolating a reliable region of interest (ROI) from each frame.

To address this, we employ face detection techniques. Specifically, Haar cascades are used to detect a face in real-time video. Once detected, a smaller region on the forehead is automatically selected because it's rich in superficial blood vessels, making it sensitive to subtle changes caused by blood flow. Capturing data from the forehead significantly improves signal stability compared to arbitrary areas of the face, providing better-quality signals for further analysis.

Extracting the Physiological Signal

After selecting the appropriate ROI, we calculate the average pixel intensity of the green channel within this region for each frame. Changes in blood volume beneath the skin, driven by each heartbeat, cause subtle variations in the reflected green light intensity. By continuously collecting these average intensity values, we generate a raw time-series signal that encodes heartbeats over time.

Signal Processing for Heart Rate Extraction

Once the raw signal is collected, we must enhance it to clearly identify individual heartbeats. We achieve this by applying a Butterworth bandpass filter. This specific filter is carefully designed to isolate frequencies commonly associated with human heartbeats (approximately between 0.7 Hz and 4 Hz), effectively removing other irrelevant frequencies and noise.

The filtered signal is then analyzed to detect peaks that correspond directly to heartbeats. By counting these peaks within a defined period, we can calculate an individual's heart rate in beats per minute (BPM).

Blood Pressure Estimation (A Conceptual Demonstration)

While heart rate estimation via video analysis is increasingly reliable, estimating blood pressure from video alone is significantly more challenging and is still largely experimental. Clinically accurate blood pressure measurement typically requires specialized sensors. However, for the purpose of demonstrating potential applications, we've included a simplified mathematical model. This conceptual model estimates systolic and diastolic pressures

based on the heart rate and the average amplitude of the filtered signal. Although not clinically accurate, it demonstrates a foundational approach for how future algorithms might combine video-based physiological signals to approximate blood pressure.

Visualization and Practical Implementation

The raw and processed signals collected during the video capture session are plotted clearly, providing visual feedback to help users better understand the process. These visualizations illustrate the subtle variations in green channel intensity (raw signal) and the more defined peaks detected after applying the bandpass filter.

The entire method is designed with user-friendliness in mind. Users simply position themselves in front of a webcam, and the system automatically detects their face and selects a stable ROI for signal extraction. Upon completion, the application immediately outputs clear visual graphs of both raw and filtered signals, along with numeric estimates of heart rate and blood pressure.

How to Use the Application

- Start the application and position yourself so your face is clearly visible to the webcam.
- Allow the face detection algorithm to automatically identify your face and select the forehead area as the measurement region.
- Wait approximately 30-60 seconds while the system collects sufficient data for analysis.
- Press the "q" key to stop recording. The application then processes the data and provides visualizations and numeric results.

Future Improvements

To enhance the accuracy and reliability of this system, future improvements could include using machine learning methods to refine the ROI selection dynamically, integrating calibration procedures for different lighting conditions, and validating the blood pressure estimation algorithm using clinical datasets.

In conclusion, video-based physiological signal estimation is a promising field with significant potential in telemedicine, remote monitoring, and general health tracking, providing an affordable, non-invasive method accessible to anyone with a simple camera device.

GitHub Links - MehrCodeLand