# Video Magnification and Photoplethysmography Based Heart Rate Measurement System

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*Abstract*— Magnification of subtle temporal changes like motion or color is known as video magnification. This paper explores Eulerian method for video magnification. It involves Gaussian and Box filters magnifying motion and color variations in video respectively. This algorithm has been applied to detect human heart rate by obtaining Blood Volume Pulse (BVP) signal from magnified video of finger. The finger video is obtained using low-cost mobile camera. The heart rate obtained by our method is very close to clinical heart rate obtained using Phillips multipara monitor. Preprocessing involves the converting the video into frames array. After this conversion of the video into frames, an individual frame goes through the noise removal process. Video-frames may contain many types of noise that directly affect the result of the video magnification. Motion denoising is one of the techniques that deal with motion noise in the video frames. Further processing continues with the motion and color magnification which is a main part of a video magnification algorithm. In this work, Eulerian and Lagrangian motion magnification methods are implemented. This helps in ameliorating the final results of the video magnification process. Algorithm revel subtle changes in the video which are visible to the necked eye and is useful in analyzing vital signs of person, like observing the facial blood circulation. It is also useful in monitoring object subtle movement under various constraints.

***Key words:*** Video Magnification, Subtle Temporal Variations, Eulerian and Lagrangian Magnification

## I. INTRODUCTION

Our project is based on research carried out by MIT, USA by William Freeman & Michael Rubinstein [1]. We have implemented Eulerian video magnification algorithm in java using multithreading. Such magnified videos are useful in applications like observing blood circulation from skin video, observing, and counting pulse signals, civil structure analysis. We have also developed contact based heart rate measurement system using blood volume pulse (BVP) signal. BVP is the phasic change in blood volume with each heartbeat which consists of beat- to-beat differences in intervals between successive heartbeats.

Current camerawork delivers us with useful gears to capture, physical facts happening over different scales of time. The ultra-high speed camera can support the much higher frame rate. One can see the phenomenon as shock waves and other natural activity. Long term processes can also be analyzed using the time-lapse such as expansion of the city, melting of polar ice. All this data is easily available across the globe with the help of advancing communication mediums. This makes content arability on the click of the button. Data is growing rapidly, but analysis tools are not. This means all the data containing relevant information have to be analyzed manually for extraction of the relevant information. Video magnification process focuses on examining and operating on subtle changes in the video. Video magnification process enhances these changes with certain amount. A change which was not substantial becomes easily notable for better analysis and make the analysis of the video much easier. Over the time changes in the varying intensities are recorded that mainly caused due to the motion or color variations. In this video magnification process noise is reduced using noise reduction method in preprocessing phase. This makes video more suitable for the optimal results, as noise in the video will not be affecting the video magnification process. This methodology is useful in the long term analysis like time-lapse sequences and even in the short term analysis. Very long duration events can be enclosed with the minutes or even in seconds. Significant time aliasing pixels can be getting inconsistent temporally. This is especially useful for time-lapse sequences that are often used for long-period medical and scientific analysis, where dynamic scenes are captured over long periods of time. When day or even year-long events are condensed into minutes or seconds, the pixels can be temporally inconsistent due to the significant time aliasing. This aliasing may cause the effect of making the object suddenly disappearing and reappearing. It may cause change in illumination rapidly between frames within this frame sequence. This makes the long-term process in this process difficult to analyze. By treating the short-term changes as the noise and long-term changes as the relevant change, helps in reveling long-term events in the video magnification process. In the final output there is a decomposition of original video into two short-term and long-term components of the motion. Naive filtering approaches are incompetent of achieving the results and current computational approach. To make the motion in the input video less noisy without any explicit analysis on the which makes it versatile and can be applied to different videos that contain high motion dynamics. Magnifying indiscernible changes that is magnification of the motion and color changes in the video which was not noticeable to the observer and then amplifying those changes to the extent that common observer can easily notice that changes by naked eye. This subtle motion may include the changes in the skin tone of the human due to the blood flow. These variations are too subtle that cannot be seen by simple observation. With this video magnification algorithm one can determine the pulse rate using the blood circulation pattern which is not possible by using human vision. Similar process can also uncover the motion of lower amplitude that is also hard to detect in the videos. If such video data containing similar type information remain unanalyzed and unprocessed, then subtle changes in those videos remain unseen. Thus video magnification process is important tool in subtle motion analysis.

## II. EXPERIMENTAL SETUP

In this experiment we have used Philips IntelliVue MP20 Multipara meter Monitor for clinical validation of Data as shown in figure 1. In this Philips IntelliVue MP20 multipara monitor by setting display setting one can see pulse rate and oxygen saturation in blood. If human finger is attached to pulse oximeter probe as input in figure 2 monitor shows pulse rate and oxygen saturation in subject's blood. For recording samples from the subject first we have attached pulse oximeter probe to subject. Then in second step we put another finger of subject on mobile camera in such way that fingertip should cover most of the camera. Video sample of subject finger is recorded up to 30 sec. As human heart rate is measured in beats per minute sample recorded close to 60 sec give more correct results. Number of beats found in recorded sample then compared with video duration and accordingly heart beats per minute is calculated. Calculation is relative to video duration. Because of this relative calculations Longer duration video that is more than sixty sec recording or shorter duration video such as less than sixty sec recording can be used for calculation of heart rate.

## III. EULERIAN VIDEO MAGNIFICATION

In preprocessing noise reduction is performed, and inconsistency as well as noise in the video frames is reduced. Figure 1 is cropped sample of recorded human face showing the impurities in skin tone and recoding noise in the frame. Noise reduction techniques are used to reduce these kinds of impurities in the video frames. Figure 2 is cropped frame of the recorded human face, showing the frame after the preprocessing. This frame has gone through the noise reduction process, there are many possible methods for noise reduction like Gaussian blur given by the equation $\frac{1}{\sqrt{2\pi\sigma^2}} e^{-\frac{x^2}{2\sigma^2}}$, Median filter, Bilateral filter represented by the bilateral filter equation as $\frac{1}{W_p}\sum_{x_i\in\Omega} I(x_i) f_r(||I(x_i)-I(x)||) g_s(||x_i-x||)$ another filter that can be used is a Wiener filter which is given by the equation $H(f)=\frac{S_{ss}(f)}{S_{yy}(f)}=\frac{S_{ss}(f)}{S_{ss}(f)+S_{nn}(f)}$. Depending on the estimated noise, noise levels and type of noise the reduction method can be selected for the noise reduction. After the processing of the video frames that is after enchantment there processing noise is generated due to saturation and distortion of the frame pixels. This processing noise can be taken under the consideration and noise reduction can be performed after amplification of the video frame. This post processing noise reduction can be achieved by two specific methods one method is Gaussian blur and another method that is used is the Box blur [1]. Both work as the radial blur, depending on the motion and color magnification processing these methods can be applied independently. These post processing filtering methods produce different results when applied to the video. Gaussian blur when applied to the processed video it is found that it makes the subtle motion more visible than subtle color variations. In contrast Box blur when applied to processed video it is found that it makes subtle color changes more visible than the subtle motion. This gives two distinct uses of Gaussian and box blur methods. Two methods can be differentiated on the basis of their output. For enhancing motion in the video Gaussian blur method can be used, and for enhancing the subtle color changes in video box blur can be used. Similarity between applied Gaussian and Box blur is both method works as the redial blur methods and need external radius parameter as blur radius.

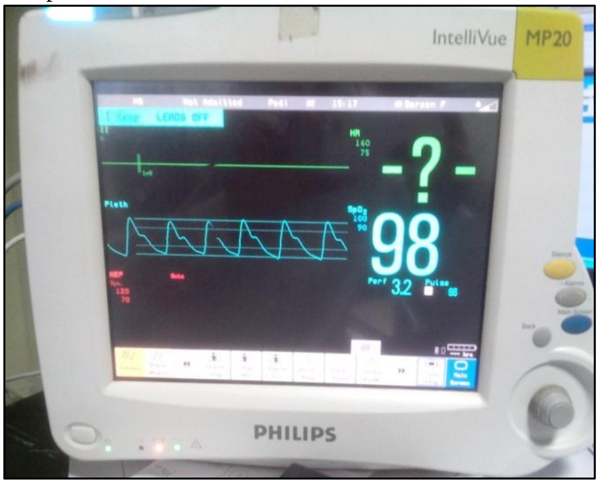

Fig. 1: Philips Intellivue MP20 Multipara Meter Monitor Used In Clinical Validation of Data


Fig. 2: Pule Oximeter Probe Attached To Philips Intellivue Multipara Monitor (Input)

## IV. PROCESSING

Video magnification process has many applications. Such as structural analysis which includes motion analysis of object. Video magnification application can also benefit for medical and healthcare. Applications like blood flow analysis and Heart rate measurement can be constructed using video magnification methods. In this thesis chapter we describe our implementation of heart rate measurement system based on video magnification. This section describes processes involved in heart rate measurement. Human heart rate assessment system works on prerecorded video. For input to the process human fingertip is recorded for duration say 30 sec or 60 sec. In this video due to the systolic and diastolic cycles of human heart blood variation are present. These variations are subtle variations that can be magnified using the video magnification process. In this experiment we have recorded clinical data along with video. One finger of test subject was attached to Philips Multipara meter monitor

 

MP20. This is done using pulse oximeter probe. This pulse oximeter act as input to Phillips MP20 monitors and provides photoplethysmographic signal for calculation of subject heart rate. Figure 3 Philips IntelliVue MP20 Pulse Oximeter Probe (RED LED inside probe) used in this project. Whereas figure 4 shows experimental setup of Pulse Oximeter attached to human finger. Figure 5 shows how the samples are recorded for experimentation. In this processing we used the human fingertip as input to video magnification process. After recording this human fingertip video it is processed with video magnification application. This application has parameter that can be adjusted with user interaction. These parameters are amplification, threshold and blur mode. Amplification parameter gives how much amplification is to be performed on video. Another parameter is blur mode this decides the changes in video that are going to amplify. Gaussian blur mode used to amplify motion change in video. Box blur is used for amplifying color variation in video. In this implementation we have used box blur as to amplify color variation in human fingertip video. After this amplification in the video of human fingertip subtle changes get highlighted. First we extract individual frames from video and then subject those frames under video magnification algorithm. These magnified changes are reflected in mean computation of individual frames. This computing step gives signal vector for further computation. This signal vector is blood volume pulse signal used for calculation of heart rate. This signal may contain peaks that not represent blood volume changes. These peaks can be eliminated using our curve smoothing algorithm. In this curve smoothing algorithm blunt peaks are smoothed out and signal remains prominent for peak counting algorithm. In next step we calculate number of peak present in blood volume pulse signal. This peak counting algorithm uses mask of n element when the curve fits into this mask it is counted as peak. Number of peaks occurred during this process is stored. These numbers of peaks then put in mathematical formula which considers length of signal and number of peaks as input and calculate human heart rate depending on input parameters. This calculated human heart rate is reported back to user as well as blood volume pulse signal. Smooth signal calculated on original blood volume pulse signal is shown to user graphically.

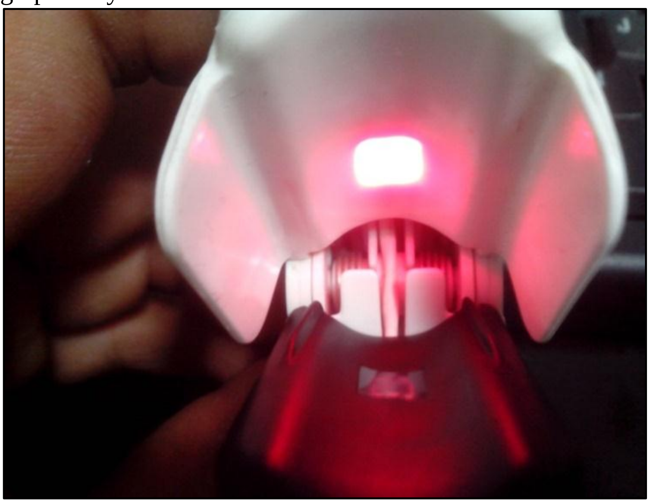

Fig. 3: Philips IntelliVue MP20 Pulse Oximeter Probe (RED LED inside probe )

Fig. 4: Pulse Oximeter Probe Attached To Human Finger

Fig. 5: Human Fingertip Sample Recording

## V. EXPERIMENTAL RESULTS

| Video id | Video Format | Capture Device | Resolution Of Video | Camera Resolution | Sample Duration |
|---|---|---|---|---|---|
| Sample 1 | 3gp | Hand held mobile camera | 640x480 | 5 Mega Pixels | 30 sec |
| Sample 2 | 3gp | Hand held mobile camera | 640x480 | 5 Mega Pixels | 30 sec |
| Sample 3 | 3gp | Hand held mobile camera | 640x480 | 5 Mega Pixels | 30 sec |
| Sample 4 | 3gp | Hand held mobile camera | 640x480 | 5 Mega Pixels | 30 sec |
| Sample 5 | 3gp | Hand held mobile camera | 640x480 | 5 Mega Pixels | 30 sec |

Table 1: Sample Details Used In Experiment

We have conducted experiment on many samples some of the experimental findings are shared in Table 2. Details of these samples are given in Table 1.Table 1 shows details of five samples, this include their format, resolution, hardware used in capturing, resolution of video capturing hardware and duration for which video was captured.

| Video id | Clinical heart rate | HR using magnified BVP Signal |
|---|---|---|
| Sample 1 | 82-84 | 84 |
| Sample 2 | 66-69 | 68 |
| Sample 3 | 62-64 | 62 |
| Sample 4 | 80-84 | 84 |
| Sample 5 | 70-75 | 72 |

Table 2: Experimental Findings

In table 2 entries shows video samples, clinical heart rate computed on the basis of Philips IntelliVue MP20 monitor and heart rate computed using implemented algorithm. Human heart rate varies depending on many conditions. Because of this clinical heart rate is shown in ranges. Whereas our implementation of video magnification algorithm works on peak counting algorithm thus it gives single value. Sample analyzed in this experiment produced blood volume signal shown in figure 6, 7, 8, 9, 10. All subject's clinical data and fingertip recording is taken at the same time. One finger of subject in attached to the Philips IntelliVue MP 20 multipara meter monitor probe. Another fingertip is recorded with mobile camera specified in (as specification given in Table 1).

Monitor reading range is recorded as clinical data, fingertip video served as input for heartbeat measurement system. In this experiment all sample are taken for 30 sec duration. Samples can be taken for longer duration or for shorter duration also. Longer video duration closed to 60 sec lead to higher accuracy as human heart rate is calculated for beats per minute that is for every 60 sec.

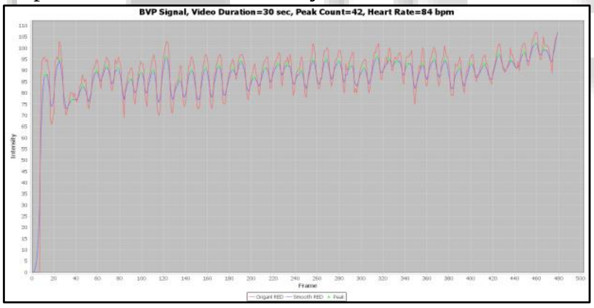


Fig. 6: Blood Volume Pulse Signal (Red Signal) And Peak (Green Triangles) Counting On Smoothed Blood Volume Pulse (Blue Signal) For Sample1

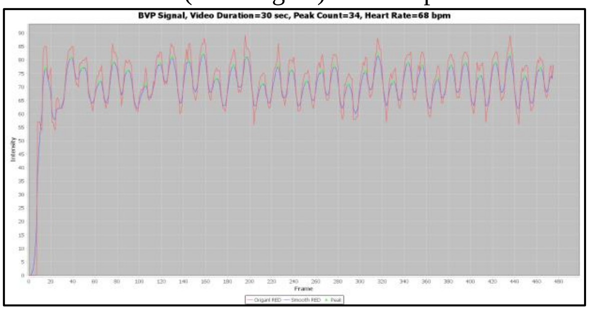


Fig. 7: Blood Volume Pulse Signal (Red Signal) And Peak (Green Triangles) Counting On Smoothed Blood Volume Pulse (Blue Signal) For Sample2

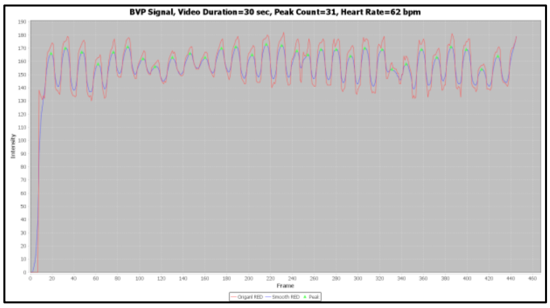


Fig. 8: Blood Volume Pulse Signal (red signal) And Peak (green triangles) Counting on Smoothed Blood Volume Pulse (blue signal) for sample3

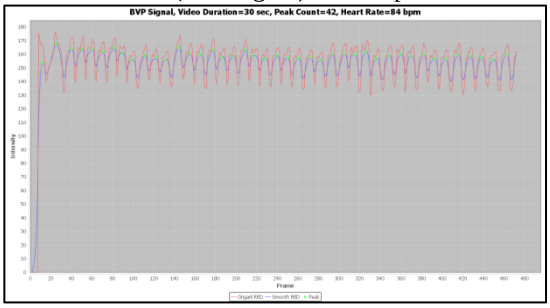


Fig. 9: Blood Volume Pulse Signal (Red Signal) And Peak (Green Triangles) Counting On Smoothed Blood Volume Pulse (Blue Signal) For Sample4

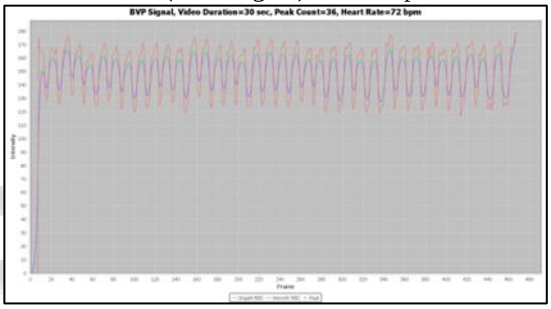


Fig. 10: Blood Volume Pulse Signal (Red Signal) And Peak (Green Triangles) Counting On Smoothed Blood Volume Pulse (Blue Signal) For Sample5

## VI. CONCLUSION

The paper illustrates an upcoming application of image processing. The algorithm presented demonstrates that a video captured by even a low resolution (640x480) camera can be magnified to highlight the subtle temporal variations in color and motion. The results on HR measurement using this algorithm are quite close to clinical data.

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