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Heartbeat Amplification and ECG Drawing from Video (Black and White or Colored Videos)

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Abstract

Electrocardiography (ECG or EKG) is the process of recording the electrical activity of the heart over a period of time using electrodes placed on the skin. The main idea is how to detect activity of the heart from skin that appears in video without using electrodes. This paper, proposes an algorithm that works on analyzing video frames to detect heartbeats from tiny changes that happen in a skin color luminance (brightness) and then using them to amplifying heartbeat and drawing ECG. The results show that the heartbeat was detected and amplified and ECG was drawing from any part of the human body in different situations and from different video.

Keywords: Electrocardiography (ECG or EKG), Heartbeats Detecting, ECG Drawing, Skin Segmentation, Changing colors detection, Maxima Peaks Detection.

تضخيم نبضات القلب ورسم تخطيط القلب (ECG) من الفيديو (فيديوهات اسود وابيض أو ملون)

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الخلاصة

عملية تخطيط القلب الكترونياً (Electrocardiography) والتي يرمز لها اختصاراً (ECG أو EKG) هي عملية تسجيل النشاط الكهربائي للقلب ولفترة زمنية محددة باستخدام أقطاب كهربائية توضع على جلد الإنسان. الفكرة الرئيسية هي كيفية اكتشاف نشاط القلب من الجلد الذي يظهر في الفيديو دون استخدام الأقطاب الكهربائية. تقترح هذه الورقة خوارزمية تعمل على تحليل أطر الفيديو للكشف عن ضربات القلب من التغيرات الصغيرة التي تحدث في انارة لون البشرة (السطوح) ومن ثم استخدامها لتضخيم ضربات القلب ورسم تخطيط القلب. وتظهر النتائج أن نبضات القلب تم اكتشافها وتضخيمها وأن تخطيط القلب يمكن اكتشافه من أي جزء من جسم الإنسان ومن فيديوهات مختلفة.

1. INTRODUCTION

In the past few years, murder videos have proliferated online, where it became necessary for the police to verify that the person in the video is dead and no heartbeat has, or is not really dead and has a heartbeat. The same is true for health care, where it is useful to monitor the heartbeat of the patient in his bed without putting electrodes on his body. The Background of the idea is, Human heartbeats and blood flowing through the body cause a slight invisible change in luminance (brightness) of skin color that appears in video. This reaction can invest to achieve three goals. First, detect heartbeats [1]. Second, the heartbeats are used for ECG drawing [2]. Third, the heartbeats are amplified on skin [3]. This paper, proposes an algorithm include several techniques to achieve the above goals. The

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results show that for the first time, this algorithm was able to detect the heartbeat from black and white videos. It can also detect the heartbeat from colored videos and then amplify it and draw ECG.

2. RELATED WORKS

In 2013, G. Balakrishnan[4]. Extract heart rate from videos by face detection and feature tracking on the face to measure the small head motion caused by heartbeat. This method can detect the heartbeat from the face but it is unable to do so from the rest of the body.

In 2015, A. Lam [5]. The heart rate from the videos is calculated by tracking the face, then selecting random patches on it, and measuring the heart rate from those patches by skin luminance variations over the time. It limited by face tracking and use only green (G) channel to detect illumination variations. For more robust, in this paper all three color channels (RGB) will be used.

In 2016, H. Rahman[6]. A method was proposed to calculate real-time heartbeat, using computer camera and face tracking to record 30 video frames to person face, then analyzing the three colors (RGB) of these frames to calculate the heart rate, and then output the results. It's fast method but it's not in real-time due to recording and analysis frames. The problem here is that the heart rate may change after frame No.30 due to a person effort. For more robust, in this paper, 100 frames are taken to extract thresholds which are used to detecting the heartbeat from all video frames at any video length.

In 2012, H.Yu Wu[7]. Eulerian Video Magnification (EVM) is used to see the blood flow in the face by applying spatio-temporal processing video frames to amplify small color and motion changes. In this paper, modified motion detection technique is used to detect heart rate from B/W videos (not only from colored videos).

In 2015, M.Sushma. [8] Propose methods to analyze the motion using time frequency analysis. In this work, address two problems: (i) Small Motion Magnification in Videos and (ii) Motion Detection in Perfusion Weighted Imaging (PWI). The Weakness here is that work based only on standard videos taken from (EVM) database. The method doesn't try to use non - standard videos. The method in this paper will be tested on standard or non- standard videos.

In 2015, M. A. Elgharib [9].Display approach-based video zoom layer that can amplify small movements within large ones. The area / layer examined are chronologically aligned and inflate the exact differences. The motion is used to enlarge the area of interest only while maintaining the safety of nearby locations. The results show larger movements, larger inflation factors and a significant reduction in the latest model.

In 2016, P. Kooij [10]. An extension proposal binary filters for non-gaseous. That filters allows ham to process pixels at very different depth layers as missing values. The missing values were ignored, and not show in the painting. It improves the current baselines for maximizing and measuring the movement (tremors) to shows the results of medical applications.

3. A PROPOSED WORK

The normal ECG waveform (heartbeat signal) has a pattern similar as in Figure-1.

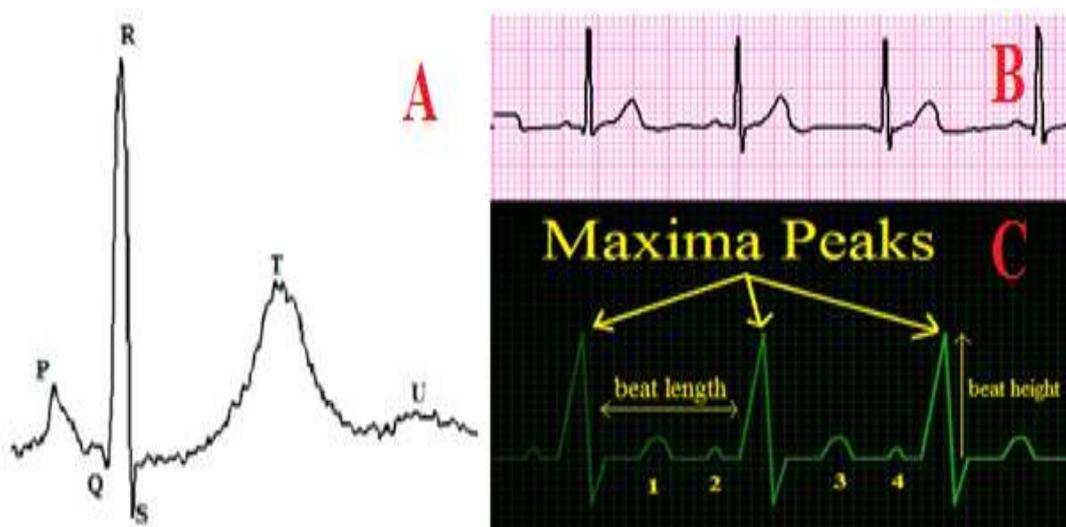


Figure 1- (A) one heartbeat, (B) ECG waveform (C) The pattern of ECG waveform [11].

As it is shown, one heartbeat plot from several small values and contains many peaks. ECG waveform contains several heart beats. The pattern of ECG waveform has properties as in flow:

- The Maxima peaks (Heart pulse) appear almost at specific intervals of time (beat lengths).
- The Maxima peaks looks like they are equal in heights, but they are not exactly uniform in heights (a shortest Maxima peak is used as Threshold).
- The Maxima peaks higher than its four neighboring that come before (1 and 2) and after it (3 and 4).
- Only the Maxima peaks (Heart pulse) are used to calculate the heartbeat rate. The small peaks do not used because it just reaction to heartbeats.

Note. Any wave doesn't have that pattern; either it is not a heartbeat signal or an irregular heartbeat signal.

In this work, we searched for heartbeats wave pattern in the videos by decompose the frames into its three colors (RGB), and then sine wave operation is used to plot the heard wave. Each color was tested to see which of them are affected by heartbeat. The results were as follows:

3.1. ECG testing on video showing a person (man)

The result is, all colors were affected by heartbeats, where the skin becomes more darkness and the color of skin can be used to detect heartbeat. Figure-2 shows the heartbeats pattern appear as ECG peaks in all colors of frames. As it is shown, the maxima peaks appear almost at specific intervals of time. For this reason, all colors were used to detect the heartbeat in this paper.

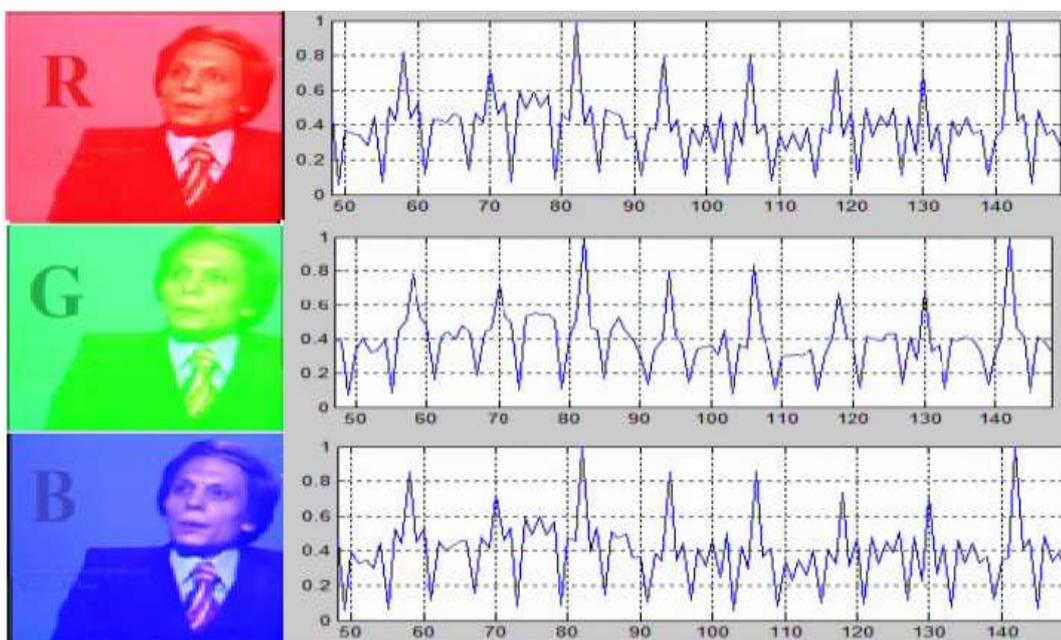


Figure 2-heartbeats pattern appear as ECG peaks in all colors of frames (RGB).

3.2. ECG testing on white noise video:

To make sure from previous results, the color TV static white noise video was tested and it did not show the maxima peaks that represent the heartbeat pattern, see Figure-3.

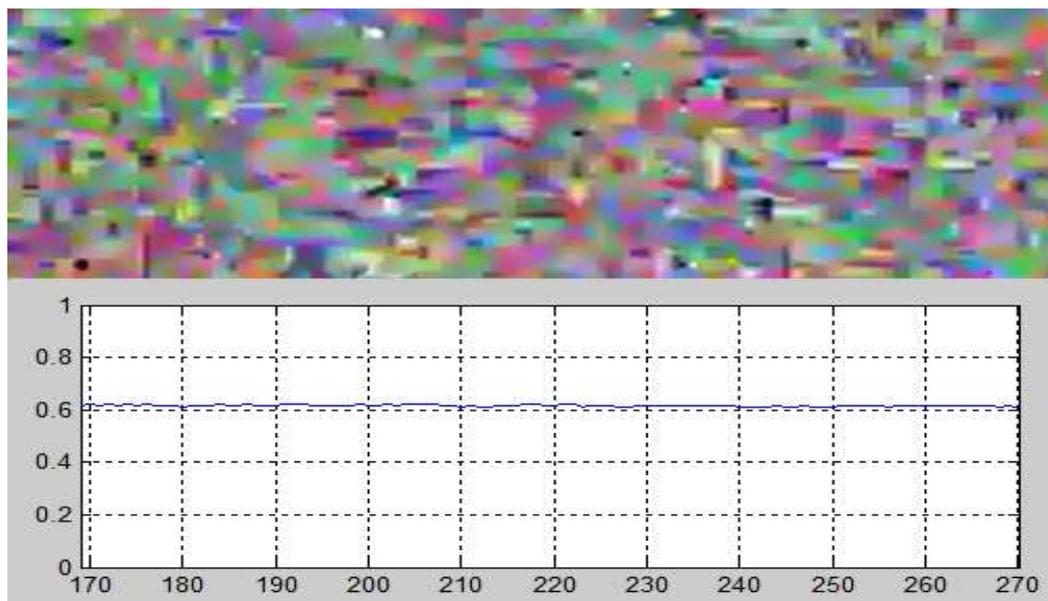


Figure 3-ECG testing on color TV static white noise video (No peaks).

3.3. ECG testing on video showing an object (Guitar):

Guitar with vibrating strings was tested as object. The vibrating strings make some peaks randomly, but it does not appearing at specific intervals of time as in a heartbeats pattern. So it doesn't heartbeats signal, see Figure-3. Moreover, even if the signal of guitar (or any object) appears as a signal of heartbeat, it does not considered as a heartbeat signal, because the guitar is not a human being.

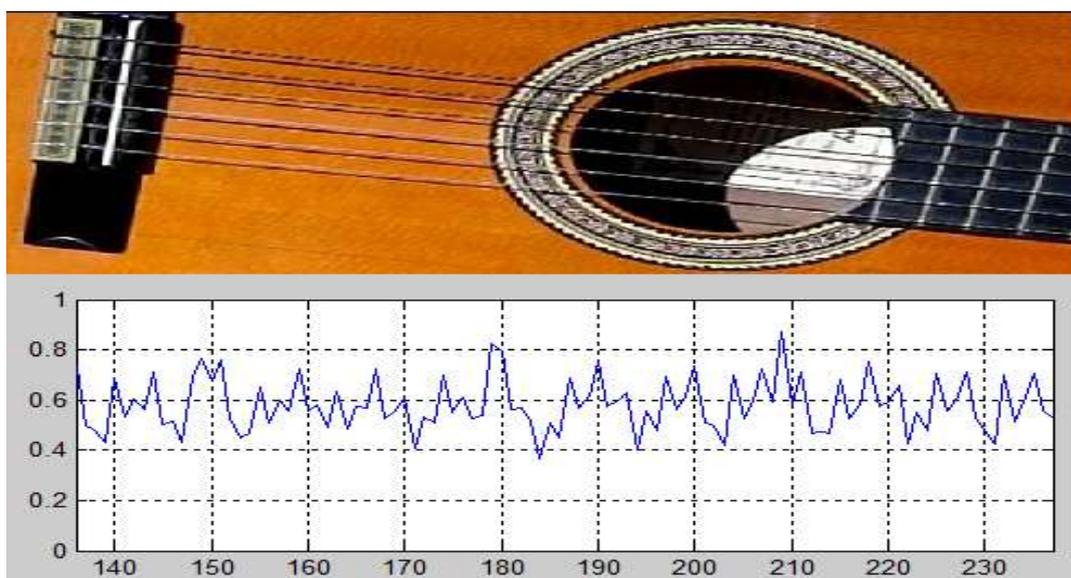


Figure 3-ECG testing on guitar with vibrating strings as object [7].

4. A PROPOSED ALGORITHM

The proposed algorithm contains two parts, first part is initial processing and the second part is heartbeat amplification and ECG drawing. Initial processing part is used to extract thresholds values that are used to detect heartbeat. This part includes several operations. HSV segmentation (Hue, Saturation and Value) is used to detection and recognition human skin (face, foot, arm or any part of the skin). Eliminate the surrounding noise from detected skin by subtract the current frame from the next frame to delete skin which has no color changes over the time. Binaries the result of subtraction, calculate the sum of one's bits of binaries and save the results in Dynamic Vector. After that, the Dynamic Vector is used to extract the thresholds values that are used in second part to detect heartbeat. Heartbeat amplification and ECG drawing part includes several operations, most of them

are similar to those found in the first part, but the difference is: First Drawing ECG using sum values and sine wave operation. Second, the thresholds (from first part) are used to amplifying heart pulse by increasing the (red or green) color intensity in the skin segmentation frame and the result added back to the current display frame. Algorithm (1) demonstrates the previous operations.

Algorithm (1): Heartbeat Amplification and ECG Drawing

Input : Video

Dynamic Vector /* Contains all small values of heart beats that extract from 100 frames*/

Output: Plot and Amplifying Heartbeat signal

/Part 1: Initial processing to measure the vertical and horizontal thresholds of maxima peaks in heartbeat*/**

Step 1. load Current_Frame

Step 2. Apply Skin Segmentation on Current_Frame and put the result in Current_skin

Step 3. For No = 1 to 100 /*loop*/

Load Next_Frame .

Apply Skin Segmentation on next_Frame and put the result in Next_skin .

Apply motion detection by subtract Current_skin from Next_skin.

Binaries the absolute value of subtraction result.

Calculate the **sum** of one's bits from the result of Binaries.

Vector [No] =**sum**.

Let Current_skin = Next_skin.

Step 4. End for /*end of loop*/

Step 5. Use Vector to measure the vertical and horizontal thresholds of maxima peaks in heartbeat

/ Part 2 : Heartbeat Amplification and ECG Drawing from Video*/**

Step 6. load Current_Frame /* Start again*/

Step 7. Apply Skin Segmentation on Current_Frame and put the result in Current_skin

Step 8. While (not end of video frames) do /*Loop*/

Load Next_Frame.

Apply Skin Segmentation on Next_Frame and put the result in Next_skin.

Apply motion detection by subtract Current_skin from Next_skin.

Binaries the absolute value of subtraction result.

Calculate the sum of one's bits from the result of Binaries

Draw ECG use sum values (small values of heart beat) with sine wave operation to plot heartbeat signal.

/*Detect maxima peak to Amplified heart pulse */

If (sum >= thresholds) then

Amplified heart pulse by increasing the color intensity (red or green) in a current display frame or skin part.

End if

Let Current_skin = Next_skin.

Step 9. End while. /*end of loop*/

4.1. Part 1: initial processing.

The purpose of part1 is to extract thresholds values. In heart pulses each single heartbeat (pulse) represented by maxima peak which has horizontal and vertical dimensions. In order to detect all maxima peak from video, a sample of frames (100 frames) is taken before video played to extract thresholds values (dimensions) which are used in part 2 to detect maxima peaks during video played, this can achieve as in below.

4.1.1. Skin Segmentation (optional).

This step is optional; it used when there is unfixed camera (Smartphone camera) to isolate the skin from rest of frame components (face, arm, foot or any part of human skin) and delete the rapidly changing background. see in Figure-4.

Note that. With a fixed camera and fixed background (camera in a room), this steps can be canceled to reduce processing time, because the next step works on deleting the fixed background.



Figure 4-(a) input frame, (b) Skin segmentation

As we note from previous figure, the process of skin segmentation is not perfect, a part of clothing has been revealed. This segmentation error does not affect on the results for two reasons:

A. The color values to static objects remains constant all the time and does not change like the color of the skin. Mathematically such as adding constant value (static objects) to a set of variable values (color of the skin).

B. The next step in this algorithm is changing colors detection. In This step, the contiguous frames are subtracted from each other to delete any pixel does not change over time and carries a constant value. Thus the fixed objects will be deleted. Note that, this point makes a skin segmentation steps optionally used with fixed background.

4.1.2. Motion detection.

To detect the slight changes in pixels color luminance (brightness) of frames, neighbored frames are subtracted from each other in sequentially. In that way, if a fixed camera is used, all fixed background will be deleted because the background color does not change, and all skin pixels which have no color changes over the time will be deleted too. While the skin pixels that are affected by blood flow and there colors continually changes over the time, will be remain, see Figure-5.

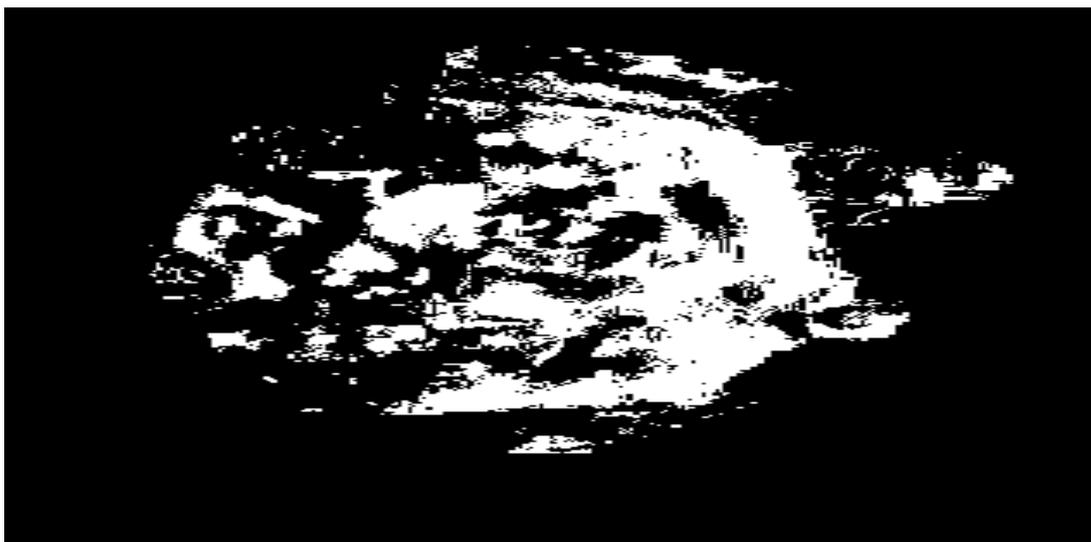


Figure 5-Changing colors detection (Note: binary image is used to see the results).

4.1.3. Heartbeat values acquisition

Each frame has a part of the heartbeat and the sequences of frames represent the complete heart pulse signal. So, to acquire the heartbeat values, the result of subtraction from previous frames are converted to a binary format and then sum the one's bits which represent the heartbeat values.

4.1.4. Maxima peaks detection

As explained previously, only the maxima peaks are used to detected heartbeats, and the small peaks (1, 2, 3, and 4) are disregard, see Figure-1. To do this, the peaks values are measured horizontally and vertically to extract threshold that are used later (in part 2) to detect maxima peaks in heartbeats to all video frames, as in stages below:

Stage1. Horizontal Threshold of peaks (Threshold 1)

A maxima peak is a heartbeat value that has value larger than its four neighboring. So the **horizontal threshold** is testing every heartbeat value with its four neighboring.

Stage2. Vertical Threshold of peaks (Threshold 2)

Irregularity of the signal is the biggest problem facing the process of acquiring a heartbeat from the video. Where in some cases, small and short peaks are growing between the maxima peaks, but it isn't maxima peaks and it must be removed, see Figure-6. To remove that type of peaks the vertical test is done as in followed:

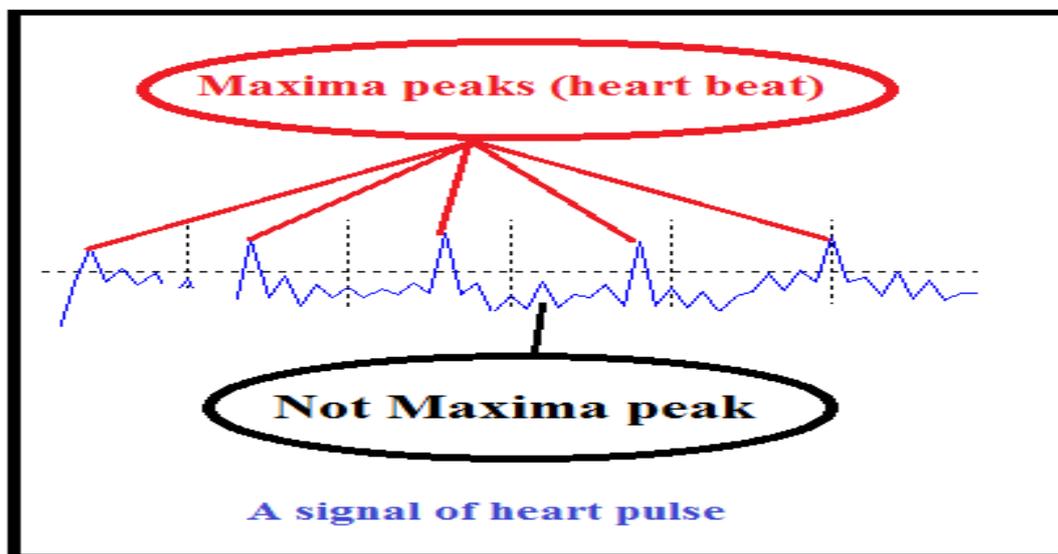


Figure 6- A heart pulse signal acquired from video frame.

A. Sort peak values:

Sort the values of peaks in descending order (the values acquired from previous Horizontal test), See Figure-7.

B. Isolate the Maxima peaks:

Subtract each two neighboring peaks from each other to find a biggest difference between them. This position (P) separates between the maxima peaks (to the right) and other peaks (to the left).

C. Measuring Vertical threshold:

Position (P) is the location of the shortest maxima peak; this value is used as a **vertical threshold** for measuring the height of the peak, where the values of all other maxima peak must be higher than it.

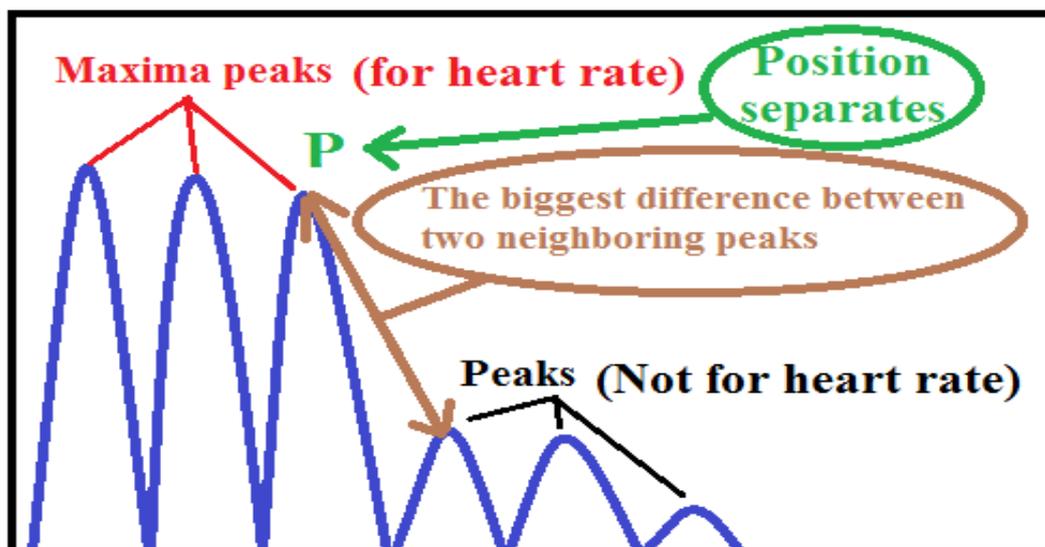


Figure 7-Isolate the maxima peaks (heart beat).

Stage 3. The Average Threshold (Threshold 3)

In some cases, the vertical threshold value is too short and allows unwanted peaks to be read. Therefore, in order to limit the value of the vertical threshold, the overall average of all peaks is calculated to become higher than the value of vertical threshold and vice versa (the value of threshold may become higher of average).

4.2. Part 2: Heartbeat Amplification and ECG Drawing

Most of the steps in the heartbeat amplification and ECG drawing part are similar to those in the Initial processing part. So, the explanation is focused on steps that are not explained.

4.2.1. ECG Drawing

As is evident in algorithm, the absolute value of sum one's bits is used to draw the heartbeat signal between the two values 0 and 1. Always the sum is a large integer, and to make its value fit with the drawing process, the sum is divided on appropriate threshold value that make it suitable with drawing scale. The output is then used to draw sine wave signal in a sequential manner, see Figure-8.

Note: use a small number as a threshold, leads to drawing a large scale signal, and vice versa.

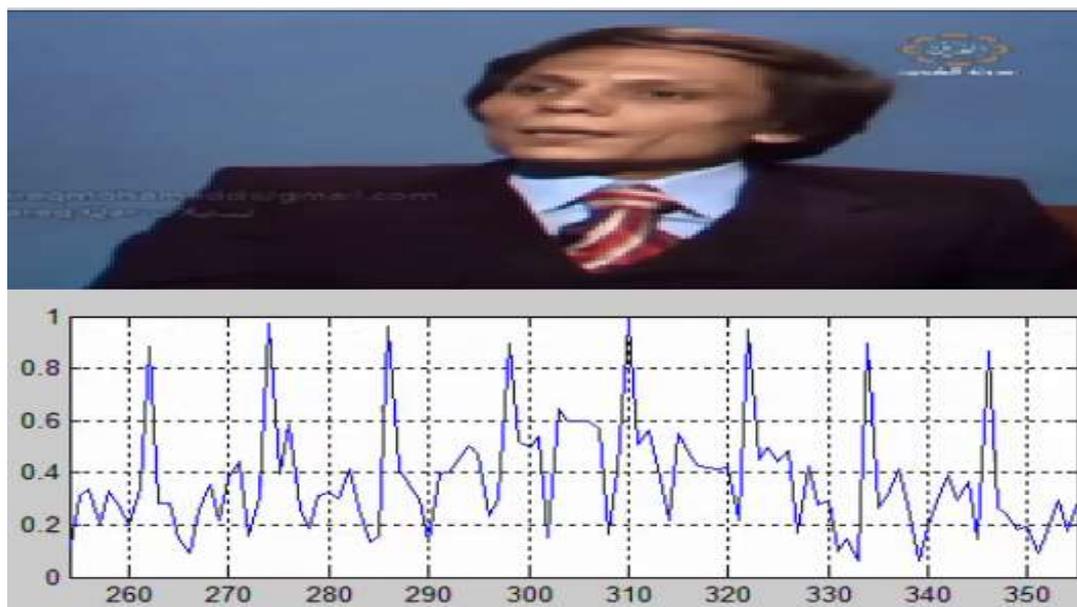


Figure 8-Drawing a signal of heart pulse.

4.2.2. Heartbeat Amplification

The amplification process takes place only at Maxima peak is detected by thresholds. The method of amplification based on use or not uses the skin segmentation steps. If the skin segmentation steps are used, then the amplification process is done on Skin area only, otherwise it don on all frame by changing the color of current frame or skin to one color only (Green or Red), as in Figure-9.

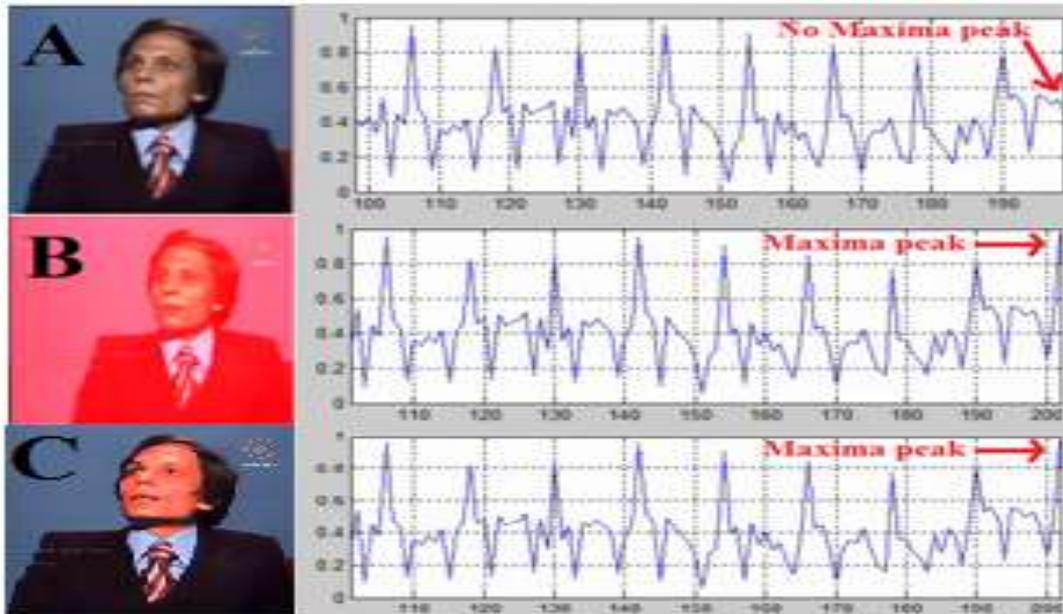


Figure 9-Amplify with each Maxima peak have detected. (A) The original, (B) frame amplifying. (C) Skin amplifying.

5. EXPERIMENTAL RESULTS

In this work, numeric values are not displayed to be compared with each other. The results are just internally image processing to amplifying heartbeat and drawing ECG. This algorithm was programmed by MATLAB 2014. In order to test the efficiency of heart beat detection, many videos were taken with different specifications (Non-standard video) as in follows:

- Videos from different sources (I Phone , Digital Camera and YouTube site).
- Videos in different lengths.
- People appear at different depth (distances) within the video.
- Videos contain different parts from body and do not contain the face.

To make the test success, you must select the suitable video by taking into account the following conditions:

- A. To detect heart beat for one person you must select a video with only one person. I.e. more than one person gives more than heart beats reading.
- B. This algorithm depends on the principle of motion detection, and much movement may confuse the results. So choose a person has a little movements.
- C. The Maximum frame pixel resolution used by MATLAB 2014 is (640 x 480). So before analyzing the video, the pixel resolution of video frame must be converted to (640 x 480). You can use any video editing software to save video frames in that resolution, such as (Free Video Editor).

After achieving the above conditions, many videos have been tested to amplifying Heartbeat and Drawing ECG as follows:

5.1. Detect from Colored Video.

The video in Figure-11 was taken from an "iPhone" Phone to person has a "stable" motion. The heartbeat was amplified and ECG was Drawn, using and without using skin segmentation process.

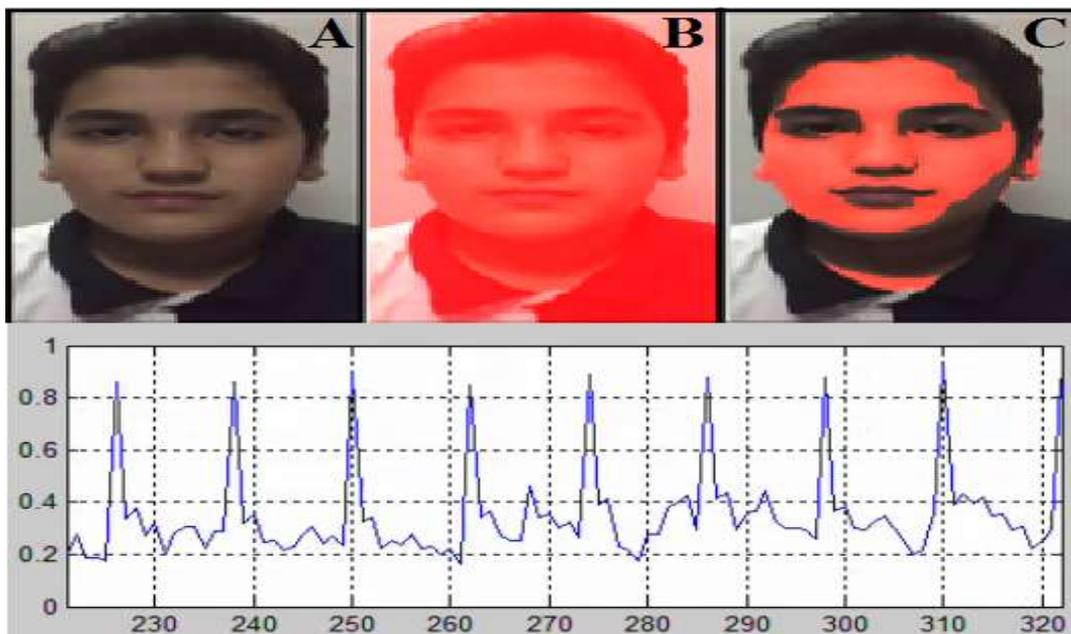


Figure 10-(A) The original, (B) Frame Amplifying,(C) Skin Amplifying

5.2. Detecting from a far away distance.

The heartbeats in all previous videos were detected and amplified from close distances. The video in Figure-13 was filmed from a far away distance by digital camera, he has “unstable” motion while he speaking.

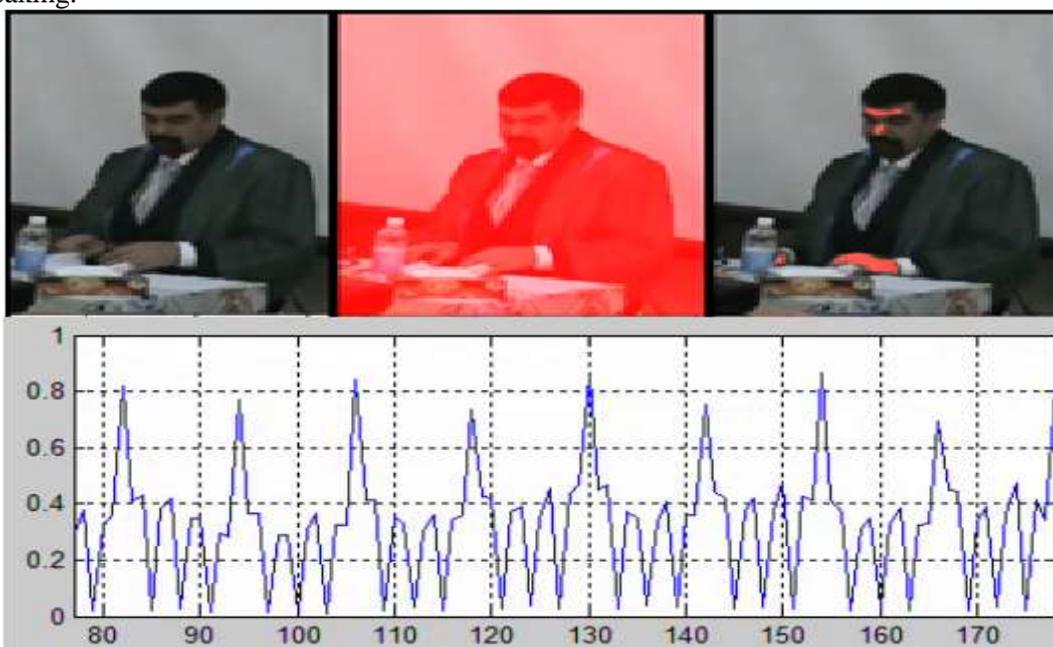


Figure 11-Detecting from a far away distance to person have “unstable” motion (digital camera).

5.3. Detecting from any part of body

Heartbeat has been detected from most parts of the body. the process of heartbeat detection depends on the appearance of the skin in the video and no matter where the skin appears,as in Figure-14.

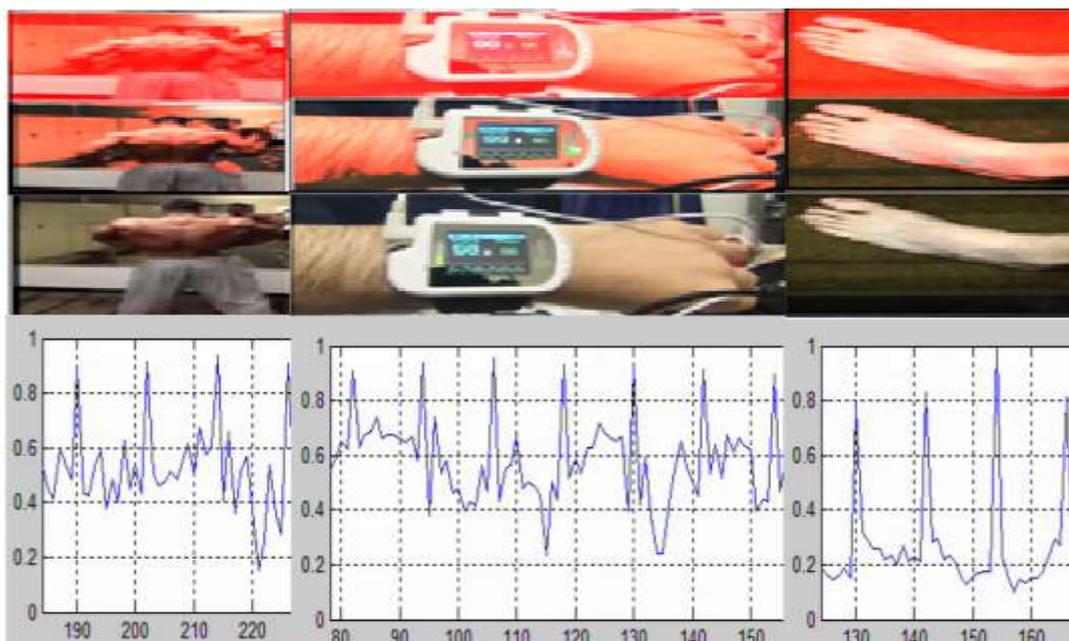


Figure 12-Detecting from any part of body.

5.4. Detecting from black and white video:

All old vedios are not real black and white (pixel value 0 or 1) , but it Grayscale (pixel value between 0 and 256). Therefore, in this algorithm using motion detection to subtract the grayscale frames from each other, gives same results as in colored video. Figure-14 for “Charlie Chaplin” video is tested after removing skin detection steps from algorithm.

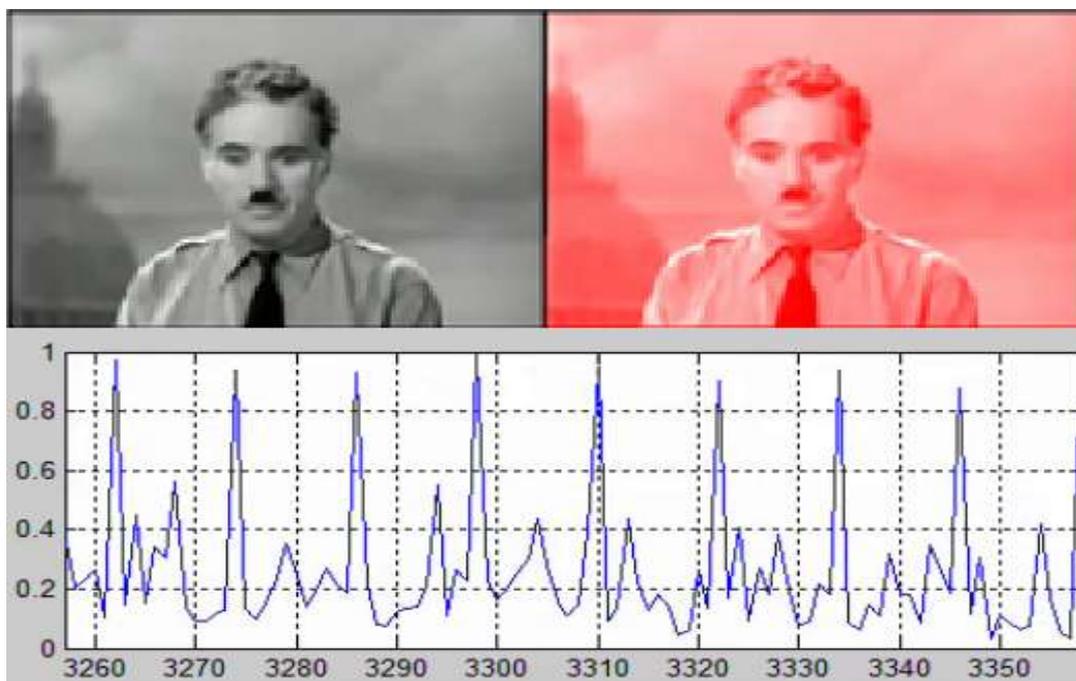


Figure 13-Detecting from black and white video.

6. CONCLUSION

For the first time, this algorithm was able to detect the heartbeat from black and white vedios (not only from colored vedios). The heartbeat was detected not only from the face, but from any part of the human body, in different situations and from different distances. As a result, heart pulses was drawn and amplified in two ways, with skin detection technique (Colored Vedios) and without it (Black and White or Colored Vedios). This algorithm can also be used in several other applications such as

calculating heart rate from Maxima peaks and computing human pressure from the height different of Maxima peaks (more pressure, led to, more blood flow, lead to, higher maxima peaks). Note that, the mechanism of this algorithm can be modified to measure the temperature of the boilers from a far by infrared camera.

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