Heart Rate Measurement and Blood Pressure level Detection from (Black and White or Colored) Videos

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Abstract: Medically, heart rate is the number of Heart Pulses per minute. Blood pressure level detection is a technique developed here to detect the level of blood pressure every second (**N**ormal, **H**igh or **L**ow).The Heartbeat causes two invisible effects on human being. First, tiny motions in the human head (movement). Second, the blood that flow into skin cause a slight change in skin color (brightness). In this paper, an algorithm was proposed to detect the heartbeat from video depending on these effects (non-contact based system). Then the detected heart beat is used to measure the heart rate in per second (not in per minute) for unlimited time (video in any length) with Heart Wave drawing and detecting the level of blood pressure. The results show that this algorithm able to measure the heart rate and detect blood pressure level from Colored or Black and White Videos.

Keywords: Heart Pulse Detecting, Maxima Peaks Detection, Heart Wave Drawing, Blood pressure Detection.

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1. Introduction

Measuring Heart rate is the most common medical procedure used by physicians. It is comfortable to patient use a non-contact based system to measure the heart rate without putting sensors on his body [1]. The background of this idea is that the heartbeats and blood flowing through the body cause a small motion in a human head with invisible tiny changes in a skin color (brightness) that appears in video frames. Some research uses techniques based on the small head motion to measure the heart rate [2] and the other use techniques based on skin color change (brightness) to measure the heart rate [3]. In this paper, algorithm was proposed that combine between the previous two techniques (head motion and skin color change) to detect heartbeat from video. The results show for the first time, the proposed algorithm able to detect heartbeat and drawing Heart Wave, measuring heart rate and detecting blood Pressure level from Black and White videos (not only from colored videos). The heartbeat was detected not only from the face, but from any part in the human body, in different situations and from different distances.

2. Related Work

In 2012, H.Yu Wu [4], Use Eulerian Video Magnification (EVM) 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 colored videos (not from Black and White videos).

In 2013, G. Balakrishnan [5],extract heart rate from videos by face tracking and track feature on it 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, M.Sushma [6], 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 [7], display approach based on video zoom layer to amplify the 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 2015, A. Lam [8],calculate 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[9], proposed a method that detect heartbeat in real-time, using computer camera and face tracking to record 30 video frames for person face, then analyzing the three colors (RGB) of these frames to measure 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 only thresholds which are used to detecting the heartbeat from all video frames at any video length.

In 2016, P. Kooij [10], an extension proposal binary filters for non-gaseous. That filters allows 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. Proposed Algorithm

In this algorithm, 100 frames from video are taken as a sample to extract two thresholds that are used to detect Heart Pulses (Maxima peaks). The first threshold represents the value of the shortest Heart Pulse and the second threshold represents the average of all Heart Pulse. Those thresholds (Shortest and Average) are used later to detect the Heart Pulses and measure the heart rate with blood Pressure level detection from all video frames during video playback (video in any Length).

```
Algorithm : Heart Rate Measurement and Blood Pressure level
            Detection
Input  :  Video
        Dynamic Vector1 //* Save complete Heart Wave values that
                          extract from 100 frames *//
        Dynamic Vector2//*Save only the Heart Pulses values  that
                          isolated from Heart Wave*//
Output: Heartbeat Rate, Blood Pressure level , Heart Wave drawing
////*=== Extract Heart Pulse Thresholds from 100 frames =====*////
Step 1. Load Current_Frame   //* Load Colored or Black / White video  *//
Step 2. For No = 1 to 100       //*loop*//
        Load Next_Frame .
//* Steps to extract Heart Wave values from 100 frame *//
//*1- Subtract  the neighbored frames from each other *//
        Result_frame = ABS (Current_Frame  - Next_Frame)
//*2- Binaries the value of Result_frame*//
        B_frame =Convert to Binary (Result_frame)
//* Binary frame (B_frame) it just two dimension array containing two value 0 and
1 *//
//*3-  Calculate the Sum of one's bits in binary fame (B_frame ) *//
         [Row, Column]= size of (B_frame)
         Sum = 0
         For I=1 to Row
         For J= 1 to  Column
         Sum = Sum + B_frame[I , J]
        End For J , I
//*4-  Sum value it just one value form complete Heart Wave , save it in Vector1
*//
       Vector1 [No] =sum
//* Swap Current frame with Next frame  *//
       Current_Frame = Next_Frame.
Step 3.  End for No  //*End of loop No *//
//* steps to calculate the two thresholds of Heart Pulse (Maxima peaks)*//
//* The thresholds use later to detect Heart Pulse from all video frames*//
//*(Horizontal check)*//
//* Detect Heart Pulse (Maxima peaks) by comparing each value in Vector1 with
its four neighbors and save them in Vector2*//
    X =0;
   For I = 3 To Size of (Vector1) - 2
       if (Vector1 ( I ) > Vector1 (I-1) AND Vector1 (I) > Vector1 (I-2) AND
          Vector1 ( I ) > Vector1 (I+1) AND Vector1 (I) > Vector1 (I+2) )
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```
            X=X+1
            Vector2[X]= Vector1[I]
            End if
      End for I
// *Not that Vector2 contents only Heart Pulses values (Maxima peaks) *//
//* Vertical check*//
//* 2- Use Bubble Sort to Sort the Maxima peak values in Descending order  *//
    For I = 1 to X
       For J= 1 to I-1
        If (Vector2[J] < Vector2[J+1])
           Swap = Vector2[J]
           Vector2[J]= Vector2[J+1]
           Vector2[J+1]=Swap
       End if
   End For J,I
//* Find position (P) which separates between the Real and False Maxima peaks*//
    P=0;
    S1=ABS (Vector2[1]-Vctor2[2])
    For I = 1 to X
        S2 = ABS (Vector2[1]-Vctor2[2])
        If S2  >  S1
                S1=S2
                P=I
        End If
    End For I
//* find Threshold 1 that represent the Shortest Real Heart Pulse (Maxima peaks) *//
Threshold1= Vector2[P]
//* calculate Threshold 2 that represent the Average of all Real Heart Pulse (Maxima peaks)*//
      Threshold2=0
      For I = 1 to P
         Threshold2 = Threshold2 +  Vector2[I]
      End For I
       Threshold2= Threshold2 / P
//* Threshold 1 , Threshold 2 use to detect Heart Pulse from video at any length*//

////*======= Heart Rate Measurement and Blood Pressure level Detection=====*/////
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```
        Time=1  //* to calculate one second of a time depending on video speed*//
          Frame_ counter = 1 //*Video frame counter *//
          Pulse_ counter =0 //* Heart Pulse counter *//
Step 4. Load Current_Frame  //* Read  video from beginning*//
Step 5. While ( Not End of video) do  //*loop to end of video*//
          Load Next_Frame .
          Frame_ counter = Frame_ counter +1 //* The number of current frame*//
          Result_frame = ABS (Current_Frame  - Next_Frame)
          B_frame = Convert to Binary (Result_frame)
          Calculate the sum of one's bits in B_frame.
//* Draw Heart Wave (ECG) *//
Step 5.1.Draw Heart Wave  using Sum values with Sine function
//* Measuring Heartbeat Rate from all video frames *//
            //* Detect Heart Pulses (Maxima peaks) using Thresholds *//
Step 5.2. If ((sum >= Threshold1) AND (sum >= Threshold2))
                Pulse_ counter = Pulse_ counter +1      // * The Number of Heart Pulse *//
  //* Heartbeat Rate in per second *//
    Heartbeat_Rate = Pulse_ counter * 60 / Time
    Output (R=Heartbeat_Rate)
//*Blood Pressure level Detection *//
// * The average of Pressure = The average of Maxima peak *//
//*Note that , if sum value detect by Thresholds this means it is Maxima peak *//
    Pressure= (Pressure + sum) / 2      //*The average of Pressure*//
                 Switch (sum)
                    case (sum > Pressure) : Output (P= "High") , break;
                    case (sum = Pressure) : Output (P= "Normal") , break;
                    case (sum < Pressure) : Output (P= "Low") , break;
                 End switch
           End if    //* End of If in step 5.2*//
//*Calculate one second of a time depending on video speed  (not on real computer time )*//
//* in MATLAB video speed can read by "Video. Frame Rate" function *//
Step 5.3. If ((Frame_ counter) MOD (Video. Frame Rate))  /2 = 0)
             Time = Time +1
             Output (S=Time)  //* The Time in seconds* //
             End if  //* End of If in step 5.3*//
Step 5.4.  Current_Frame = Next_Frame
           End For No.   //*end of loop in step 5*//
```

3.1. Extract Heartbeat Wave (Heart Wave)

Single heartbeat causes two effects on a human as in below:

A- Small periodic motion in head (movement**).**

B- Small changes in pixels that represent the color of the skin (brightness).

To detect the previous effects and extract complete Heart Wave values, neighbored frames are subtracted from each other. The Pixel value of subtraction may be negative, so absolute function (ABS) is used to convert it to positive. In the resulting frame, some pixels will be removed and others will be remaining as in follow:

I. The Removed pixels.

Fixed background and skin pixels which have no color changes over the time will be removed.

II. The Remaining pixels (heartbeat wave).

The pixels of head motion (movement) and the pixels of skin whose color changes over time due to effect of blood flow in to skin (skin brightness) are remained, see figure (1).

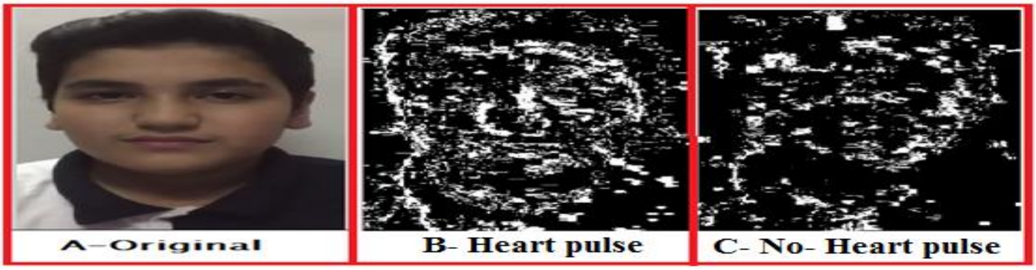

Figure 1. (A) Original frame,(B) Heart Pulse,(C) No Heart Pulse.

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Figures (A, B and C) shows that the number of pixels in figure (B) (have a Heart Pulse) is more than the number of pixels in figure (C) (does not have Heart Pulse). In this work, the small difference in pixels number will be used to detect the Heart Pulse. Note that, in both cases (B, C), the pixels do not disappear completely because the blood continues to flow in skin and the head motions never stop (periodic motion).in this algorithm, even if there is a small change in background (camera in a room), The process of subtracting neighbored frames from each other works well to delete the background of frames. But in the case of background repeatedly changing (Mobile camera), Face tracking or Skin Segmentation techniques can be used after load frames steps to improved background delete.

3.2. Acquiring Heartbeat Waveform values (Complete Heart Wave values)

Each frame contains a part of Heart Wave, and the sequences of frames represent the complete Heart Wave. So, to acquire all values of Heart Wave, the frame result from subtraction is converting to binary format and then sums the one's bits in it. Each sum represents a part of Heart Wave and all the sums values represent the complete Heart Wave values that extract from 100 frames and all sum values are stored in Vector1.

3.3. Heartbeat Waveform (Heart Wave)

Medically, the doctor uses his fingers to detect the Heart Pulses. Therefore, from complete Heart Wave only the Heart Pulses (Maxima peaks) are used to measure the heart rate. The normal Heart Wave has a pattern similar as in figure (2).

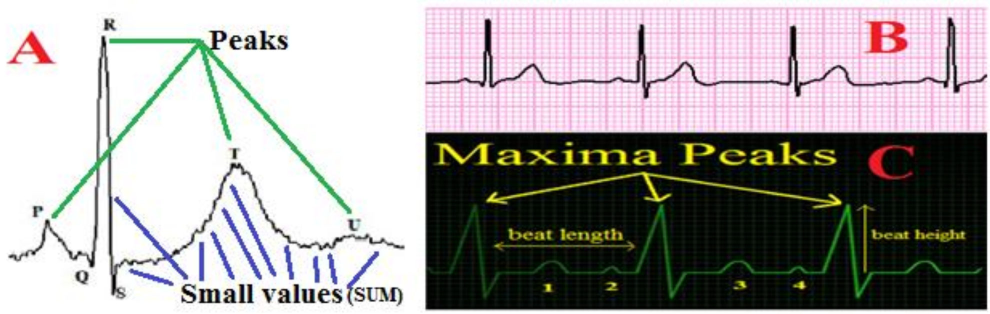

Figure 2. (A) single heartbeat, (B) Heart Wave (C) The pattern Heart Wave.

As it is shown in figure (A), a single heartbeat build from several small values (sum) and contains one Heart Pulse (Maxima peak R) and several small peaks (r, t, and u). As well in figure (B), the complete Heart Wave contains many Heart Pulses (Maxima peaks). Only the Heart Pulses (Maxima peaks) are used to measure the heart rate, and the small peaks (r, t, and u) do not used because the finger of a doctor can not feel it (it just reaction to heartbeats). As it is shown in figure (C), the pattern of Heart Pulses (Maxima peaks) in Heart Wave has properties as in flow:

- The Heart Pulses (Maxima peaks) appear almost at specific intervals of time.
- The Heart Pulses (Maxima peaks) not exactly uniform in heights (in this work, the shortest Maxima peak is used as threshold to detect the Heart Pulses).
- The Heart Pulses (Maxima peaks) higher than its four neighboring small peaks that come before it (1 and 2) and after it (3 and 4).

Any wave doesn't have that pattern; either it is not a Heart Wave or an irregular Heart Wave (Heart disease).

3.4. Detect Maxima peaks (Heart Pulse) by Horizontal check

In order to measure the heart rate, Maxima peaks (Heart Pulses) should be detected. Maxima peak has value larger than its four neighboring (Two small peaks before it and two after it). So to detect the Maxima peaks, each peak value in Vector1 (Vector of sums) is test with its four neighboring values and if the current value larger than its four neighboring (small peaks), it save in Vector 2 as a Maxima peak value (Heart Pulse value). As a result, Vector 2 contains only the Maxima peaks values (Real and False (noise)).

3.5. Real and False Maxima peaks (noise)

The process of extracting heart rate values from frames may be affected by frames noise. Where in some cases, small and short peaks (False Maxima peaks) are growing between the Real Maxima peaks. Such this peaks considered as a noise and do not used to measure heartbeat rate, and it must be removed, as shown in figure (3).

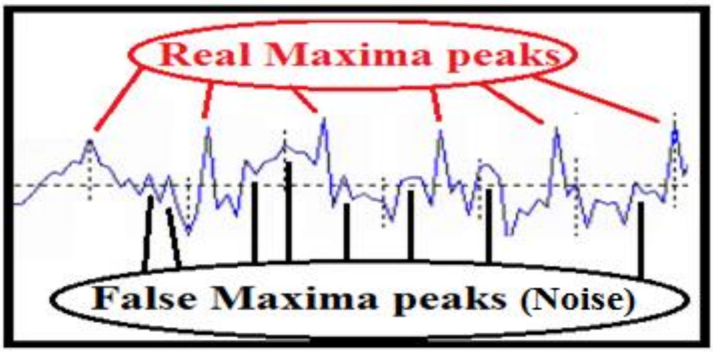

Figure 3. The difference between Real and False (noise) Maxima peaks.

3.6. Detect Real Maxima peaks by Vertical check

To detect only the Real Maxima peaks and remove the false Maxima peaks (noise), vertical check on height of Maxima peaks is used as in follow:

A. Sort the Maxima peaks values in descending order

Use Bubble Sort to sort all values in Vector2 (Maxima peaks values) in descending order, as shown in figure (4).

B. Find position (P) which separates between the Real and False Maxima peaks

Subtract each two neighboring peaks values from each other to find the biggest difference between them. Position (P) (before the biggest difference) is the position that separate between the Real Maxima peaks (to the Right) and the False Maxima peaks (noise to the Left), as shown in figure (4).

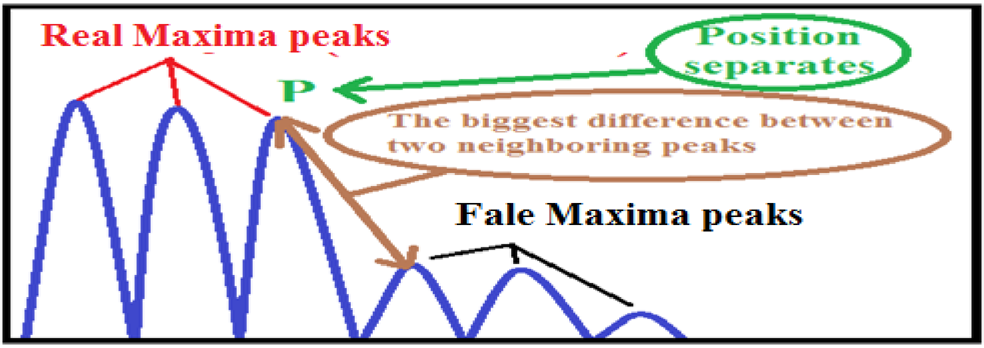

Figure 4. Isolate between the Real and False Maxima peaks.

As a result, Position (P) indicates the place of the shortest Maxima peak. Therefore this value is used as a **vertical threshold1** to measure the heights of real Maxima peaks, where the heights of all real Maxima peaks must be equivalent or higher than it.

C. The average of Maxima peak heights

In case of, some false Maxima peaks are too high and they are considered as real Maxima peaks, Threshold1 value (Shortest Maxima peak) will be short and allows some false Maxima peak to be passing. Therefore, in order to limit the value of Threshold1, the average for all Real Maxima peaks in Vector 2 is calculated to become Threshold2. Some time the value of Threshold1 becomes higher than the value of Threshold2 and vice versa. Anyway, the upper threshold is always is used to check the height of Real Maxima peaks.

3.7. Heart Wave drawing

Sine function with **sum** of one's bits from binary frame (B_frame) is used to draw Heart Wave in a sequential manner with drawing scale between (0 and 1). As it is shown in Figure (5), the Heart Pulses (Maxima peaks) in colored video appear almost at specific intervals of time.

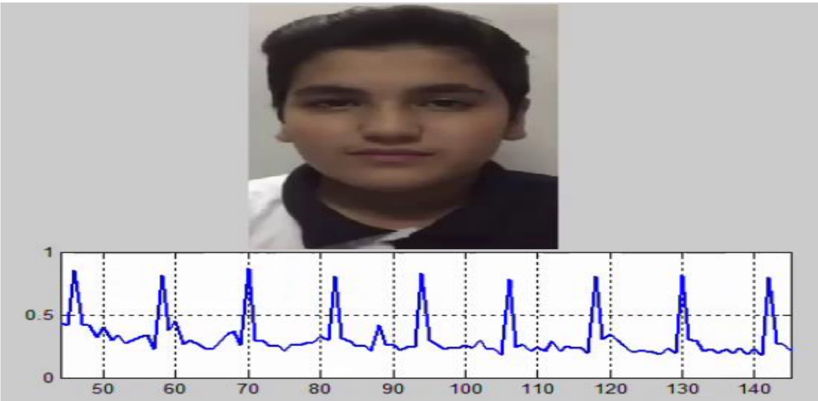

Figure 5. heartbeats pattern appear as Heart Wave in colored video.

The old vedios are not Black and White (pixel value 0 or 1) , but it Grayscale vedios (pixel value between 0 and 256). Therefore, in this algorithm subtract grayscale frames from each other, gives same results as in colored video. As it is shown in figure (6) Heart Pulses appear at specific intervals of time in Black and White video.

Figure 6. heartbeats pattern appear as Heart Wave in Black and White video.

3.8. Heart Rate Measurement

Traditionally, the equation of Heart rate is the number of Heart Pulses per minute. But in this algorithm, that equation has been modified to calculate the heart rate in per second rather than per minute and for unlimited time (Depends on video length) not only for one minute, as in below:

Heart rate = Sum of heartbeats in 1 **minute** (1)

That heartbeat rate can also be measured every 30 second as follows:

Heart rate **= (**Sum of heartbeats **in 30 seconds) * 2** (2)

As we know that the minute is 60 seconds, so from equation (2) the equation (1) can be modified as follows:

Heart rate **= (**Sum of heartbeats **in 1 second) * 60** (3)

In order to calculate the average heart rate for two second:

Heart rate **= ((**Sum of heartbeat **in 2 seconds) * 60) /2** (4)

The final equation modified to calculate the heart rate for videos in any length:

Heartbeat rate **= ((**Sum of heartbeat **in N seconds) * 60) /Time** (5)

Since the speed of the video varies from device to other ,therefore the time in the equation is not computer time ,but it calculated depending on the video speed by finding the Modulo (MOD) between the number of current frame and the number of video frames rate in **second**.

3.9 Blood Pressure level Detection

In this paper, a technique was developed to detect the level of pressure (**N**ormal, **H**igh or **L**ow). The idea is, the human pressure is directly affected by Heart Pulse (Maxima peak) at that moment .To clarify the relationship between Heart Pulses and the level of pressure, in below comparison between the affects of strong Heart Pulse and weak Heart Pulse.

	The affects of strong Heart Pulse	**The affects of weak Heart Pulse**
1	A large amount of blood flows into skin	A small amount of blood flows into skin
2	High heart pulse (Maxima peak) will be drawn	Low heart pulse (Maxima peak) will be drawn
3	High heart pulse increase the blood pressure level	Low heart pulse decrease the blood pressure level

As it clear in comparison, when the height of Heart Pulse (Maxima peak) increased, the level of blood pressure also increased and vice versa. Therefore, to detect the blood pressure level (Normal, High or Low) at that second, the average of all highs for all Heart Pulses (Maxima peaks) is compared with the high of last one (last Heart Pulse). This technique can be developed to measure the rate of blood pressure, or it can be used in lie detector programs.

4. Experimental Results

This algorithm programmed by MATLAB 2014. The Maximum frame pixel resolution in 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). In order to test the efficiency of Heartbeats detection, Heart Rate measuring and Blood Pressure level detecting, many videos were taken with different specifications as in follows:

- Videos from different sources (I Phone , Digital Camera and YouTube site).
- Videos in different lengths.
- Videos contain different parts from body.

- People appear at different depth (distances) within the video.
- People appear in different situations within the video.
- People appear in Black and White Video

4.1. Detect Heartbeat from the skin of the human face

The colored video in figure (7) was taken from an "iPhone" Phone to person. Where:

Time in seconds (S): Video in a second 48.
In this work, the reading of heart rate begins stability after 30 seconds and the final reading is approximately after 1 minute (60) seconds.
Heartbeat Rate Measurement (R): The Heart rate is 92 .
Medically, the range Heart Rate between 60 to 100, it depending on human age , health and situation (sleep or not) , his health and his current state (sleep or not).
Blood Pressure level (P): High (H).
Blood Pressure level can be one of three values (**N**ormal, **H**igh or **L**ow), and it detect every per second. This reading be developed to calculate the blood pressure rate, or it can be used in lie detector programs that works on the principle of measuring heart activity.

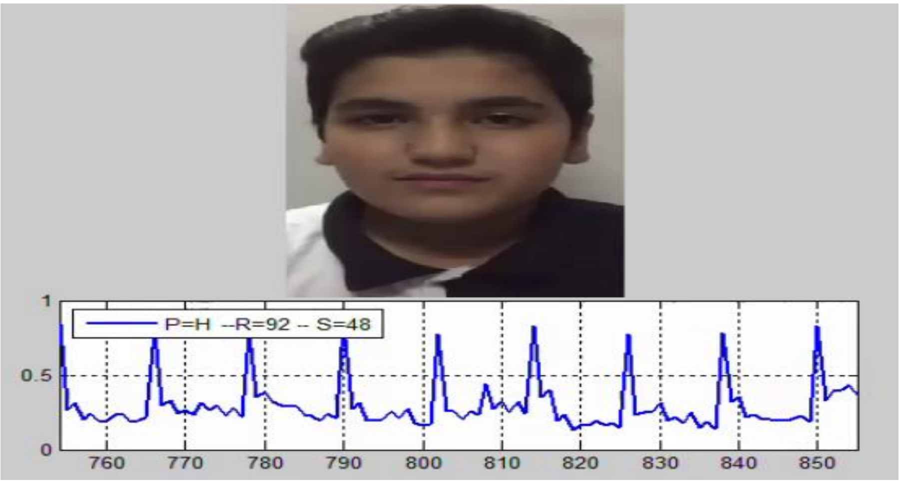

Figure 7. Detect Heartbeats from the skin of the human face

4.2. Detect Heartbeat from any part of body (Check the efficiency of the algorithm)

The algorithm can detect Heartbeats from any part of human body, for example, it can detect **Heartbeats** from the skin of the human arm , as it is show in figure (8). Where:

Time in seconds (S): Video in the second 71.
Heartbeat Rate Measurement (R): The Heart rate is 88 .
As it is shown, the Heartbeat Rate in proposed algorithms (88) is similar to medical device on the hand that appears on the video.
Blood Pressure level (P): Normal (N).

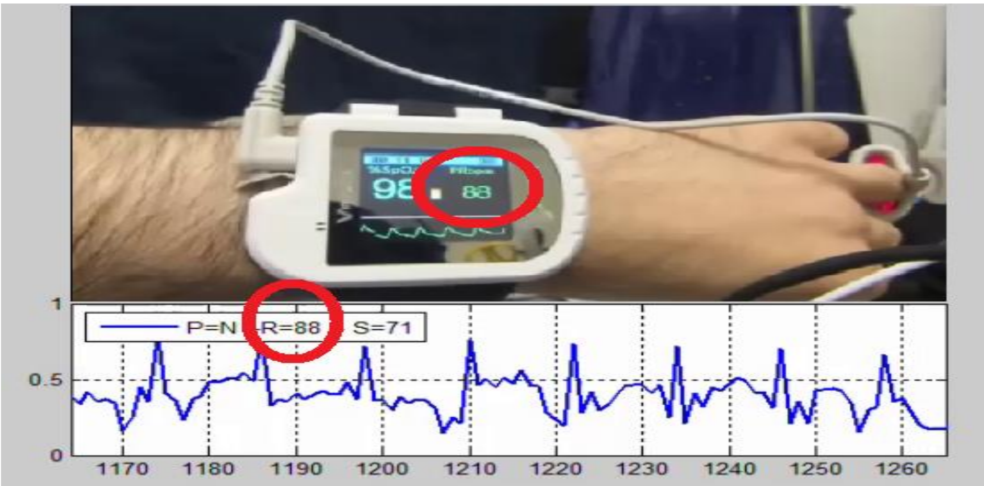

Figure 8. Detect Heartbeats from the skin of the human arm.

4.3. Detect heartbeat from a far away distance

The heartbeats in all previous videos were detected from close distances. The video in figure (9) was filmed from a far away distance by digital camera,the person has “unstable” motion while he speaking. The video in the second 60, Heart rate is 74, Blood Pressure level is N.

Figure 9. Detecting heartbeats from a far away distance.

4.4. Detect Heartbeat to a person wakes up from a sleep

The figure (10-(A)) show a sleeping person, The video in the second 14, Heart rate is 67, Blood Pressure level is N. Figure (10-(B)) after he waking up suddenly from sleep, The video in the second 16, Heart rate is 71, Blood Pressure level is H, with irregular Heart Wave.

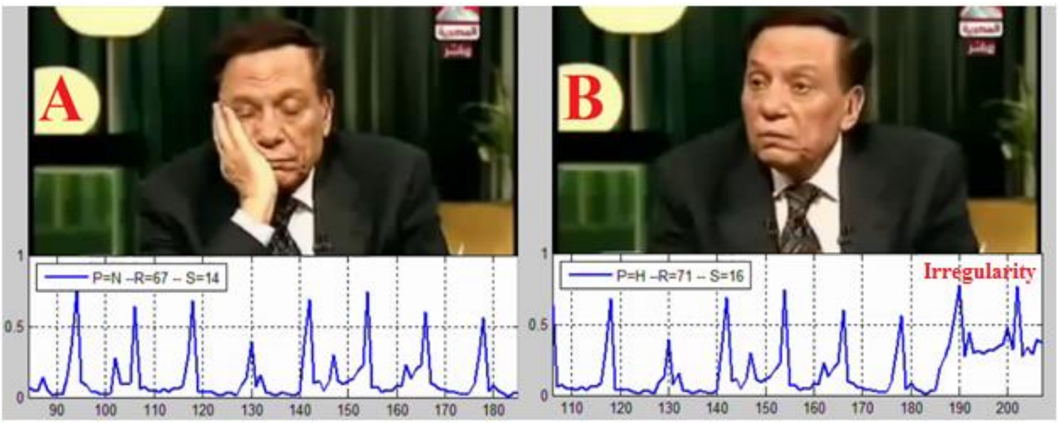

Figure 10. (A) a sleeping person, (B) waking up suddenly from sleep.

4.5. Detect Heartbeats from Black and White Video

Without any change in algorithm steps ,This algorithm works on Black and White videos in same efficiently when it works on colored videos. Figure (11-(A)), “Charlie Chaplin” video. The video in the second 69, Heart rate is 90, Blood Pressure level is N. Figure (11-(B)),”Abdel-Karim Kassem” video, The video in the second 52, Heart rate is 75, Blood Pressure level is N.

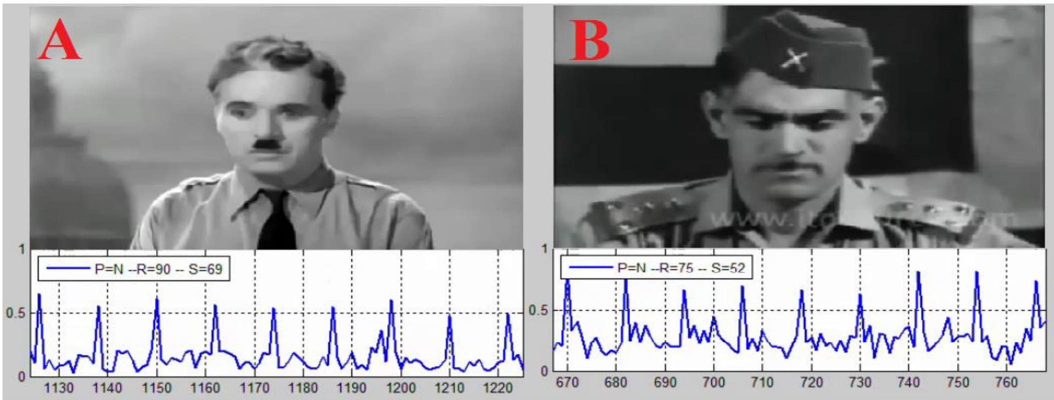

Figure 11. (A) B/W video to “Charlie Chaplin”, (B) B/W video to “Abdel-Karim Kassem”.

5. Conclusions And Future Works

As it is shown in results, for the first time, this algorithm was able to detect the heartbeat from Black and White videos not only from colored videos. Heartbeat has been detected from various parts of the human body in various situations and from different distances. As a result, the heart rate was measured, Heart Wave was drawn and the blood Pressure level was detected. In future, this algorithm can be developed to work in real-time and the technique of blood pressure level detection can be developed to calculate the blood pressure rate.

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قياس معدل ضربات القلب وكشف مستوى ضغط الدم من الفيديوهات (اسود وابيض أو ملون)

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المستخلص: معدل ضربات القلب هو عدد نبضات القلب لكل وحدة من الوقت (عادة في الدقيقة أو في الثانية كما في هذا العمل). الكشف عن مستوى ضغط الدم هو تقنية وضعت هنا للكشف عن مستوى ضغط الدم في الثانية (عادي N أو مرتفع H أو منخفض L) . الفكرة الرئيسية هي الكشف عن نشاط القلب من الجلد الذي يظهر في الفيديو دون استخدام الأقطاب الكهربائية (عدم الاتصال). تقترح هذه الورقة خوارزميات تعمل على تحليل صور الفيديو للكشف عن ضربات القلب من التغيرات الصغيرة التي تحدث في إضاءة لون البشرة (السطوع) ثم استخدامها لقياس معدل ضربات القلب ورسم تخطيط القلب (ECG أو EKG) وكشف مستوى ضغط الدم . أظهرت النتائج أن هذه الخوارزميات قادرة وللمرة الأولى على قياس معدل ضربات القلب والكشف عن مستوى ضغط الدم من الفيديوهات الأسود والأبيض (وليس الفيديوهات الملونة فقط).

الكلمات المفتاحية: اكتشاف نبض القلب، اكتشاف قمم ماكسيما، رسم موجات القلب، كشف ضغط الدم.

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