**TOUCHLESS HEARTBEAT DETECTION AND CARDIOPULMONARY MODELLING**

Alladi Saiteja  
UG Student  
dept.of computer science and engineering  
S.R.M institute of science and technology  
Kattankulathur,India  
at4854@srmist.edu.in

Swaroop Duppala  
UG Student  
dept.of computer science and engineering  
S.R.M institute of science and technology  
Kattankulathur,India swaroopduppala\_vijayakumar@srmuniv.edu.in

S.Ushasukanya

*Assistant professor*

*dept.of computer science and engineering*  
S.R.M *institute of science and technology*

Kattankulathur,India

**ABSTRACT:**

This paper displays a contact-less heartbeat identification framework and a cardiopulmonary demonstrating.Utilizing a vector organize analyzer,our proposed microwave framework shows the capacity of recognizing the heartbeat signal at various frequencies,just as at various yield power levels.In view of parameters extricated from genuine estimations,a model speaking to the heartbeat and the breath signals is displayed.Diverse preparing strategies are utilized so as to isolate the heartbeat and the breath signals.For various sign to commotion proportions,wavelet channels show higher exactness over great channels in deciding both the heartbeat rate and the pulse changeability

1. **INTRODUCTION:**

Heartbeat area is of most outrageous centrality in todays ebb and flow prescription.The heartbeat and its variability are used and evaluated for a wide display of medicinal problems,for model during tasks,routine tests and peril evaluations[1].Other significant regions of employments evaluating beat lie,for instance,in the fifield of genuine games,where certain essential parameters should be kept in an appealing reach.The generally exact and by and large used procedure for beat estimation is the electrocardiography(ECG).It evaluates the electrical activity of the heart muscles at explicit zones of the patient's body and requires the association of up to ten cathodes.A remedially arranged individual is required for joining the cathodes accurately.In expansion the used pads and gel at the anodes can cause skin irritation and signifificantly discourage the chance of advancement of the patient.

A heartbeat oximetry sensor can be used then again to procure a heartbeat signal with less exertion.The sensor is for the most part attached to a finger and measures the beat using the light maintenance changes realized by the changing blood volume in the skin during a heartbeat period.Because of the by and large used spring-cut sensors an estimation over longer time allotments can be cumbersome or agonizing and blocks the customary usage of one hand.The estimation standard of the oximetry sensor(photoplethysmography,PPG)has been grasped for remote estimation through cameras.

Not many makers have proposed approaches to manage perceive heart pounds by exploring the slight concealing differences achieved by the consistency standard moves because of the blood volume changes in the skin,including using ordinary off-the-rack cameras.This methodology offers easy to game plan pulse estimation with no obstacle of improvement of the subject and therapeutic staff and new applications for telemedication,serious games or human machine interfaces.Numerous circulations use self-made or"their own"private data while evaluating and presenting new heartbeat estimation counts and techniques.

These datasets are typically not straightforwardly available for various researchers,which thwarts the advancement of new philosophies and assessments with existing techniques.In this way,openly available databases for pulse estimation are relied upon to impel the fifield quicker,however the arrangement of a broad dataset addresses a significant effort in time and cash.The archiving and move of video data can in like manner repre sent an amazing effort with regards to the gigantic fifile sizes of uncompressed video information.

one minute uncompressed 1080p video with a concealing significance of 8bit and 25 FPS(outlines each second)would have a size of 8.7 GB.This is the clarification video pressure is significant for sharing video data on a more prominent degree.Present day standard video pressure computations like H.264 furthermore,H.265 are psycho-apparently improved and pack the video data to such an extent that quality and detail decline is,as far as could sensibly be expected,imperceptible to human recognition.This routinely consolidates concealing subsampling,diminished picture quality during brisk developments,and clearing and fifiltering of small concealing changes.

These streamlining steps help to diminish the video information to reasonable sizes so video spouting and chronicling is today possible with a high observed picture quality.The information decline applied in these figurings could firmly influence the PPG signal.This issue is consistently overlooked in the present writing.Most papers need subtleties concerning the used codecs,encoding parameters,and video holder groups.This impedes the connection and reproducibility of dispersed outcomes.Just two or three papers unequivocally address the issues of com pression and how to diminish fifile sizes without settling the PPG signal.McDuff attempted the effect of video pressure on PPG signals with 25 individuals secured in two 5min undertakings.

They attempted the x264 and x265 codecs with different relentless rate factor(CRF)values(clarified in Sec.II-A.2)and stood out the zenith signal-from disturbance proportion(SNR),bit rate and mean estimation mistake.They shut that recordings"with a piece pace of 10Mb/s notwithstanding everything held a BVP[blood volume pulse]with reasonable SNR and the beat rate estimation botch was 2.17 BPM"[12,p.69]and recommended that the x265 count may be more practical than x264 on accounts with progressively unmistakable movement.While McDuffetal.[12]proposed an immaterial stuffed piece rate,which is dependent upon the image size and substance,they didn't endorse which parameters to choose for the video encoding to guarantee a fair PPG signal quality.

Blackford et altried the effect of diminished edge rate and objectives on beat estimation with 25 subjects.They varied the edge rate from 120 to 60 and 30 FPS and diminished the image objectives from 658x492 to 329x246 using bilinear and zero-demand down sampling.They contemplated that"there is insignificant detectable qualification in mean preeminent misstep or then again botch transports coming about due to diminished edge rates or picture goals".The paper of Sun et al.[14]additionally confifirms the effect of the picked packaging rate by communicating that,"Factual results presented no signifificant differentiate among the distinctive model rates,which was with respect to the self-governing connection between the assortments of[pulse rate variability]measurements and test recurrence[20-200 FPS].

"A good diagram as for the issues in the momentum writing,particularly about the nonattendance of information on record weight and recoding setting was done by Spetl'ıketal[15].This paper contemplated that a higher weight rate also,bi-straight objectives downscaling reduces the SNR and diminishing the video size grows the negative effect of weight on the SNR.The makers don't recommend the use of H.264 pressure for camera based heartbeat estimation.In the test part they decided and analyzed the sign to-fuss extent for different weight rates and goals.The results can't resist repudiating those of others:They neither show a consistent SNR decay as observed by McDuffetal.

Nor that changing the objectives has almost nothing conspicuous effect as uncovered by Blackford et al..This can be explained by the used video information.In general,just 10 accounts of 5 subjects each with 60 sec.runtime where recorded and used for the examination.

The game plan contained no or then again unimportant development,which probably made the video data less difficult to encode without beat information disasters due to the interframe pressure(see Section II-A.1)utilized by the encoder.The pressure impacts were simply researched using the SNR as a benchmark.The makers did neither report the genuine effect on the beat estimation,nor did they dismember which SNR is suffificient for achieving any specifific pulseestimation mistake.

We contribute right currently complete and reproducible examination to react to the subject of how to pack video without dealing the PPG signal.We dismember the effects of different video encoding parameters on the beat estimation and make encoding recommendations by proficiently surveying two transparently open datasets with all things considered 161 accounts and 50 members.Utilizing one of a kind parameters for the consistent rate factor,goals,shading subsampling and two present day video codecs,we inspected 13,084 chronicles with a general size of 1.2 TB.Four uncommon PPG signal extraction methodologies and two ROIs from the composing were realized to study the inflfluence of the encoding parameters on the beat estimation.Sec.II depicts the systems for the video encoding and heartbeat estimation.

**II.Implementation:**

A Video Encoding All videos for this paper have been generated using FFMPEG[16].The encoding methods compared in this paper are confined to a few important options,which have a big impact on the video data,quality and the evaluation used for the heart rate estimation.Many more options are available and possible in video encoding,but this paper is meant as a guide for the encoding and archiving options of future datasets for video based heart rate estimation and evaluates mostly the essential options which have to be chosen for the video encoding process.

1)**Codecs x264/x265:**We compared the inflfluence of two codecs on the target parameters.First the H.264 standard or Advanced Video Coding(AVC),which is widely used today in video streaming(e.g.YouTube,iTunes Store),HDTV

broadcasts or Blu-rays.Secondly the newer,more advanced H.265 standard or High Effificiency Video Coding(HEVC).This codec offers“approximately a 50%bit-rate savings for equivalent perceptual quality relative to the performance of prior standards[...].”[17,p.1667].We used the free x264 and x265 implementations of these codecs incorporated in FFMPEG.Both codecs are generally trying to find redundant parts in different areas of the video,in single frames(intraframe)and in previous or succeeding frames(interframe).While the intraframe compression should have little effect on most

heart rate estimation algorithms,due to the fact that the RGB values are usually averaged for every frame,the interframe compression could have a detrimental effect on the PPG signal quality by copying the same color information into different frames,which would result in resembling a multiframe smoothing fifilter

.

**2)Constant rate factor:**The used to set the overall perceived video quality.The value ranges from 0(lossless)to 51(highest compression).This mode encodes the video to achieve a constant perceived visual quality.The compression rate can vary throughout the video to optimize the encoding,like reducing the bitrate in high motion frames to reduce fifile size.This is possible due to the fact that the human eye does perceive less detail in moving objects and is used in modern video encoding methods.

**3)Pixel format**:Most of the cameras and screens used today have an RGB sensor or display.This means the data will be recorded and displayed in RGB.However,video data is typically encoded in the YUV color space.Two FFMPEG video color pixel formats are used in this paper,YUV444p and YUV420p.The YUV color encoding system separates the color information in an image into

the luminance part Y and the chrominance parts U and V,sometimes also known as Cb,Cr.We used only progressive pixel formats(p)which contain all pixel information forevery frame.While the YUV444 format(see Fig 1)saves the values of all three channels for every pixel,the YUV420

format implements chroma subsampling which results in a reduced resolution in the chrominance channels.In every 2x2 pixel block four Y values and only one U and one V value are saved for the whole block(see Fig 2).Due to the human visions higher acuity for achromatic than chromatic color components,a reduction of color information and fifile size is possible without visual degradation of

the image for the human perception.For this reason YUV420 is the default pixel format for most of the modern video streaming and storage that is used today.Important to note is that the color transformation from RGB to YUV is not reversible for all colors.The around 16.7 million RGB(8bit)colors are mapped to around 11 million YUV(8bit)colors when using the ITU recommendations in rec.601[18]or rec.709[19]defifined colorspaces.Besides these out-of-gamut colors,rounding errors in the quantization can happen as well during the encoding(RGB→YUV)and the decoding(YUV→RGB)color transformation.

4)Resolution:To reduce the fifile sizes we tested the impact of changing the image resolution on the heart rate estimation.The videos were downsampled during the encoding

*B.Heart rate estimaton*

Two different regions of interest(ROI)and four PPG signal extraction methods for RGB color data were used to test the impact of different compression levels on the heart

rate estimation accuracy.

***1)Region of Interest:***We used the Haar-Cascade classififier from *OpenCV* 2.4,to fifind the face in every image.In the nextstep the *DLib* facial landmark detector is used to calculate the pixel coordinates(*u*,*v*)of 68 points.Both steps were

implemented in C++.The landmark points are stabilized over several frames corresponding to 1/10 of the video frame rate by calculating the mean for each *u* and *v* coordinate.Based on face detection and landmarks,we extracted two ROIs

called FaceMid and Skin.While the FaceMid ROI is used in many approaches the Skin ROI has shown to generate the best results[20].

The **FaceMid** ROI was proposed in[3]and is a widely used ROI in the fifield of heart rate estimation.The Region uses the full height of the bounding box enclosing the facial landmarks,but trims the sides and utilizes only the middle 60%of the region(see Fig.3).This is supposed to improve the signal-noise-ratio(**SNR**)of the extracted PPG signal by removing non skin pixels at the

borders.The other ROI used is the **Skin** ROI approach proposed by Rapczynski et al.This is based on a lookup table approach from Jones and Rehg,using the implementation presented by Saxen and Al-Hamadi,which provides the skin probability for each color pixel.We used the skin probability *pi* for each pixel as a weighting factor

for the color value *ci* when calculating the pixel mean for the PPG signal,instead of a binary masking to skin/non-skin pixel.Fig.3.Example of

the **FaceMid** ROI **0 0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8**

Fig.4.Example of the **Skin** ROIs skin

probability *p.*

*2)***SIGNAL DETECTION***:*DeHaan and Jeanne[26] developed a chrominance based approach(**DeHaan**)to eliminate the effect of specular reflections produced by movement.Defining two orthogonal chrominance signals,the algorithm tries to separate the motion-induced noise,which should inflfluenceboth signals,from the blood volume change induced pulse signal,which should only inflfluence one chrominance signal.Adaptive Green-Red-Difference(**aGRD**)was presented by Feng et al.[27]and is based on the Green-Red-Difference(GRD)method from Hulsbusch et al.[28].The approach¨removes diffuse and scattered light in the green and redsignals to calculate a cPPG signal,with the blood pulse as highest amplitude.Wang et al.[29]presented a new signal extraction approach based on an inverse of the Fourier transformation(**IFFT**).The method decomposes the RGB signals in the frequency domain and extracts the pulse signal from every calculated frequency-band to suppress distortions.Normalized green(**normG**)was used by Stricker et al.and Rapczynski et al.as a signal extraction method.The green channel is normalized by the sum of all channels to compensate for different or changing spatial and temporal light intensity levels in the video.

*P P G*=*g r*+*g*+*b*

**ALGORITHM:**

We use a graph-based heart rate estimation algorithm presented by Rapczynski et al.[23].The PPG signal is fifirst fifiltered using an adaptive bandpass.In the initialization case,a wide(30-240 BPM)bandpass is used on a 30s long signal window.A shorter signal window(10s)of the PPG signal is filtered in the following time steps,if a previous heart rate value could be estimated,with a muchsmaller passband(*±*15 BPM)centering around the last heartrate estimation value to increase the SNR and enable a faster reaction to a changing heart rate.The signal peaks are then isolated and represent the possible blood pulse peaks.The algorithm then analyses the Inter-Beat-Intervals(IBI)of all detected peaks in the fifiltered PPG signal window by creating

a graph connecting all peaks with an IBI of 0.25s to 2s(corresponds to 30-240 BPM)between them.

In the initialization case several possible peak sequences are created by pairing peaks with similar IBI values at the start and the end of the estimation window and connecting them through the peaks in the graph while minimizing the shared mean error of the sequence.The sequence with the smallest mean squared error from their shared mean is selected and used to calculate the estimated heart rate from the mean of the IBIs of the selected peaks.If a heart rate value from the last time step is available the graph algorithm estimates the optimal continuation of the sequence by adding new peaks to the end of the sequence from the last time step.The heart rate estimation is calculated once per second.

*4)****IEC Error calculation****:*The ground truth heart rate was calculated by using a QRS heartbeat detection method described by Schmidt et al.followed by a manual check for missed or falsely classifified heartbeats.For every heart rate estimation the same window was analyzed in the

video(PPG)and ground truth(GT)data.The mean of the extracted ground truth inter-beat-intervals from the window is calculated and converted to the ground truth heart rate BPM value.The error for each heart rate estimation step is then calculated as *E*=*HRGT T HRP P G*.The error calculation described in the IEC standard 60601-

2-27 for medical ECG devices is used as validation benchmark for the heart rate estimation.Using the calculation above,an estimation is considered valid,if the absolute error

between the estimated and the ground truth heart rate is less then 10%of the ground truth or 5 BPM,whichever is higher.The percentage of measurements of a dataset which meet this

IEC standard is further referred to as the **IEC accuracy**(in%).

**RELATED WORK:**

Accuracy Enhancement of Doppler Radar-Based Heartbeat Rate Detection Using Chest-Wall Acceleration:(2018):The proposed idea was inspired by the field of seismo-cardiography, which is the measurement of local chest vibrations caused by the heartbeat, and can be sensed using miniature accelerometers placed on the chest. Seismo-cardiography has recently emerged as a promising technology for non-invasive wearable monitoring applications:Scale Selection Technique for Heartbeat Detection Algorithm (2017):Heart beat detection issue was approached in the literature several times and using multiple signal processing techniques. In fact, some attempts were performed to de-noise the ECG signal from motion artifact as a first step to obtain a clean ECG signal in order to make the heart beat detection operation easier using adaptive filtering , Blind Source Separation (BSS) or the Discrete Wavelet Transform (DWT)

**CONCLUSION:**

Our proposed framework shows the capacity of recognizing the pulses for various operational frequencies: 2.4, 5.8, 10, 16, and 60 GHz. Furthermore, for a steady recurrence (2.4 GHz), the proposed framework shows capacity in identifying the pulses at various force levels: - 2, - 7, - 12, 17, - 22, and - 27 dBm. In view of estimations got at 2.4 GHz, a model speaking to the cardiopulmonary exercises is displayed. A few preparing strategies are acted so as to extricate the heartbeat rate and to isolate the heartbeat and the breath signals. Applying FFT to the first cardiopulmonary sign shows precision in identifying the heartbeat rate at SNR more noteworthy than - 15 dB SNR. Be that as it may, utilizing Daubechies channels shows high location precision of the heartbeat rate at low SNR as - 20 dB. Likewise, utilizing wavelet channels.

**REFERENCES :** [1]Marek Malik,J Thomas Bigger,A John Camm,Robert E Kleiger,Alberto Malliani,Arthur JMoss,and Peter J Schwartz,“Heart rate variability:Standards of measurement,physiological interpretation,

and clinical use,”*European heart journal*,vol.17,no.3,pp.354–381,1996.

[2]Yu Sun,Sijung Hu,Vicente Azorin-Peris,Stephen Greenwald,Jonathon Chambers,and Yisheng Zhu,“Motion-compensated non

contact imaging photoplethysmography to monitor cardiorespiratorystatus during exercise,”*Journal of biomedical optics*,vol.16,no.7,

pp.077010–077010,2011.[3]Ming-Zher Poh,Daniel J McDuff,and Rosalind W Picard,“Noncontact,automated cardiac pulse measurements using video imagingand blind sourceseparation.,”*Optics express*,vol.18,no.10,pp.

10762–10774,2010.

1. Ming-Zher Poh,Daniel J McDuff,and Rosalind WPicard,“Advancementsinnoncontact,multiparameter physiological
2. measurements using a webcam,”*IEEE Transactions on Biomedical Engineering*,vol.

58,no.1,pp.7–11,2011.

[5]Hamed Monkaresi,Nigel Bosch,Rafael A Calvo,and Sidney K D’Mello,“Automated detection of engagement using video-based estimation of facial expressions and heart rate,”*IEEE Transactions on Affective Computing*,vol.8,no.1,pp.15–28,2017.

[6]Wim Verkruysse,Lars O.Svaasand,and J.Stuart Nelson,“Remote

plethysmographic imaging using ambient light,”*Optics express*,vol.

16,no.26,pp.21434–21445,2008.

[7]Magdalena Lewandowska,Jacek Ruminski,Tomasz Kocejko,and´

Jedrzej Nowak,“Measuring pulse rate with a webcam-a non-contact

method for evaluating cardiac activity,”in *Computer Science andInformation Systems(FedCSIS),2011 Federated Conference on*.IEEE,2011,pp.405–410.

[8]Timon Blocher,Johannes Schneider,Markus Schinle,and Wilhelm¨Stork,“An online ppgi approach for camera based heart rate monitor

ing using beat-to-beat detection,”in *Sensors Applications\_\_Symposium(SAS),2017 IEEE*.IEEE,2017,pp.1–6.

[9]Luca Iozzia,Luca Cerina,and Luca TMainardi,“Assessment of beat-to-beat heart rate detection method using a camera as contactless sensor,”in *Engineering in Medicine and Biology Society(EMBC),2016 IEEE 38th Annual International Conference of the*.IEEE,2016,pp.521–524.

[10]Humaira Nisar,Muhammad Burhan Khan,Wong Ting Yi,Yap Vooi

Voon,and Teoh Shen Khang,“Contactless heart rate monitor formultiple persons in a video,”in *Consumer Electronics-Taiwan(ICCE*

*TW),2016 IEEE International Conference on*.IEEE,2016,pp.1–2.

[11]Janis Spigulis,Dainis Jakovels,and Uldis Rubins,“Multi-spectral skin imaging by a consumer photo-camera,”in *Multimodal Biomedical Imaging V*.International Society for Optics and Photonics,2010,vol. 7557,p.75570M.

[12]Daniel J McDuff,Ethan B Blackford,and Justin R Estepp,“The impact of video compression on remote cardiac pulse measurement using imaging photoplethysmography,”in *Automatic Face&Gesture Recognition(FG 2017),2017 12th IEEE International Conference on*.IEEE,2017,pp.63–70.

[13]Ethan B Blackford and Justin R Estepp,“Effects of frame rateand image resolution on pulse rate measured using multiple camera imaging photoplethysmography,”in *Medical Imaging 2015:Biomedical Applications in Molecular,Structural,and Functional Imaging*.

International Society for Optics and Photonics,2015,vol.9417,p.94172D.

[14]Yu Sun,Sijung Hu,Vicente Azorin-Peris,Roy Kalawsky,and Stephen E Greenwald,“Noncontact imaging photoplethysmography to effectively access pulse rate variability,”*Journal of biomedical optics*,vol.18,no.6,pp.061205,2012.

[15]R.Spetl˘´ık,J.Cech,and J.Matas,“Non-contact reflectancephotoplethysmography:Progress,limitations,an myths,”in *2018 13th IEEE International Conference on Automatic Face Gesture Recognition(FG 2018)*,May 2018,pp.702–709.

[16]“Ffmpeg,”http://ffmpeg.org/,Accessed:October 18th 2018.

[17]Gary J Sullivan,Jens-Rainer Ohm,Woo-Jin Han,Thomas Wiegand,etal.,“Overview of the high effificiency video coding(hevc)standard,”*IEEE Transactions on circuits and systems for video technology*,vol.22,no.12,pp.1649–1668,2012.

[18]International--Telecommunication Union(ITU),“Recommendation bt.601,studio encoding parameters of digital television for standard 4:3 and wide screen 16:9 aspect ratios,”2011.

[19]InternationalTelecommunicationUnion(ITU),“Recommendation bt 709,parameter values for the hdtv standards for production andinternational programme exchange,,”2015.

[20]M.Rapczynski,P.Werner,F.Saxen,and A.Al-Hamadi,“How the region of interest impacts contact free heart rate estimation\_algorithms,”in *2018 25th IEEE International Conference on ImageProcessing(ICIP)*,Oct 2018,pp.2027–2031.

[21]Lan Wei,Yonghong Tian,Yaowei Wang,Touradj\_Ebrahimi,and\_Tiejun Huang,“Automatic webcam-based human heart rate measurements using laplacian eigenmap,”in *Asian Conference on Computer Vision*. Springer,2012,pp.281–292.

[22]Mohammad A.Haque,Kamal Nasrollahi,and Thomas B.Moeslund, “Heartbeat signal from facial video for biometric recognition,”in *Image Analysis*,Rasmus R.Paulsen and Kim S.Pedersen,Eds.,Cham, 2015,pp.165–174,Springer International Publishing.

[23]Michal Rapczynski,Philipp Werner,and Ayoub Al-Hamadi,“Continuous low latency heart rate estimation from painful faces in real time,”

in *23th International Conference on Pattern Recognition(ICPR)*,2016.

[24]Michael J Jones and James M Rehg,“Statistical color models with application to skin detection,”*International Journal of Computer*

*Vision*,vol.46,no.1,pp.81–96,2002.

[25]Frerk Saxen and Ayoub Al-Hamadi,“Color-based skin segmentation: an evaluation of the state of the art,”in *2014 IEEE International*

*ConferenceonImageProcessing(ICIP)*.IEEE,2014,pp.4467–4471.

[26]Gerard de Haan and Vincent Jeanne,“Robust pulse rate from chrominance-based rppg,”*IEEE Transactions onBiomedical Engineering*,vol.60,no.10,pp.2878–2886,2013.

[27]Litong Feng,Lai-Man Po,Xuyuan Xu,Yuming Li,and Ruiyi Ma, “Motion-resistant remote imaging photoplethysmography based on the

optical properties of skin,”*IEEE Transactions on Circuits and Systems for Video Technology*,vol.25,no.5,pp.879–891,2015.

[28]M Huelsbusch,“An image-based functional method for opto-electronic

detection of skin-perfusion,”*RWTH Aachen(in German)*,2008.

[29]Wenjin Wang,Albertus C den Brinker,Sander Stuijk,and Gerard de Haan,“Robust heart rate from fifitness videos,”*Physiological Measurement*,vol.38,no.6,pp.1023,2017.

[30]Ronny Stricker,Steffen Muller,and Horst-Michael Gross,“Non-¨ contact video-based pulse rate measurement on a mobile service

robot,”in *Robot and Human Interactive Communication,2014 ROMAN:The 23rd IEEE International Symposium on*.IEEE,2014,pp. 1056–1062.

[31]Marcus Schmidt,Johannes W Krug,Andreas Gierstorfer,and Georg Rose,“A real-time qrs detector based on higher-order statistics for ecg

gated cardiac mri,”in *Computing in Cardiology Conference(CinC), 2014*.IEEE,2014,pp.733–736.

[32]Zheng Zhang,Jeff M Girard,Yue Wu,Xing Zhang,Peng Liu,Umur Ciftci,Shaun Canavan,Michael Reale,Andy Horowitz,Huiyuan Yang, et al.,“Multimodal spontaneous emotion corpus for human behavior analysis,”in *Proceedings of the IEEE Conference on Computer Vision and Pattern Recognition*,2016,pp.3438–3446.

[33]“Ffmpeg h.264 video encoding guide,”

2018.