Estimation of Visual Heart Rate to Predict Depression

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Abstract — Depression is a common but a leading mental disorder impacting people of all ages globally. Depression can be predicted accurately by analyzing a Heart bit rate of a particular person for 24 hours. Heart Rate (HR) is very useful Physiological parameter which acts as indicator for physiological state of human being. Eulerian Video Magnification (EVM) helps for the development of the healthcare solutions by extracting physiological signals from inputted facial video. In this research paper the potential of inputted video is examined using EVM to extract physiological data, especially heart rate.
The person's heart rates who is suffering with depression is elevated during the night time, when it usually reduces. From the heart rate individual can be identified as mentally healthy or depressive. The dataset used in this paper is clinically evaluated on which proposed methodology is applied. Results indicate that visually calculated heart bit rate is efficient tool for predicting depression in an individual.

Index Terms—Heart Rate(HR), Spatial Filtering, Time Domain Filtering, Laplace Pyramid

1. INTRODUCTION

According to the WHO, globally the annual economic adverse effect of depression is approximately estimated as $1 trillion and is detected as the main reason of disability by 2020. For a person, depression can affect in several ways and that interferes with or attack on person's ability to perform many life activities. Its symptoms affect on person's emotional feeling, thinking, decision taking and daily routine activities like working, sleeping, or eating. To better predict, diagnose and treating depression, artificial intelligence is explored as a potential solution.[1]. The machine learning and deep learning algorithms are widely used and applied on many problems so that the solution can be obtained easily and accurately, facial emotion reorganization and facial detection is one of the mostly studied topics in this field [2]. To be diagnosed with depression, first it should be detected and by using predictive analytics activity of patient is monitored to prevent the mental health risk using facial expression. Research warns that depression is risky for patients who are suffering with heart disease [3]. HR is a tool, which guides to find the mental condition of a person. The expanding and aging world's population has increased a demand for automated, inexpensive and reliable healthcare solutions. EVM helps for the development of such solutions [4].

2. RELATED WORK

In the existing literature, mostly a person's face has been analyzed for Emotion Recognition. Using facial expressions, emotional behavior can be found. It is used to display emotional states [5]. As face is the index of mind by capturing face reading estimation of emotions can be done [6]. Face feelings are the impressions of the inner emotions of a human. The human expressions play an essential role in nonverbal communication. Emotion is acknowledged from facial expressions which plays vital role in non-verbal correspondence [7]. Research developed programmed framework based on outward appearance. It has many applications like understanding human behaviour and detecting any mental disorder.[8][9]. Face recognition and emotion recognition plays a vital role for authentication, robot interaction, active research region in the field of Human robot Interaction, Smart home, Smart Door Unlock[10], Healthcare applications.[11].
Further research is progressed by developing deep learning based architectures for video-based prediction of depression via facial expressions. [12]. It is useful in healthcare applications. Till now estimated HR has not used to monitor an individuals' mental health. Author in [13] calculated the heart bit rate by taking input as facial videos that are captured while watching different films and identified an individual as depressed or healthy. While author

in [14] explored the underlying connection between an individual's mental health and his personality , by combining observed facial behavior and self-reported scores based on personality. This combination is used for training the deep neural network to predicting depression.

3. PROPOSED TECHNIQUE

Given facial videos of a person are magnified using EVM algorithm & heart rate is computed.

3.1 Heart Rate Measurement

EVM estimates HR from variation in facial skin color that is caused due to blood circulation. Medical experts concluded that heart rate of patients with depression on the average was about 10-15 beats per minute higher than people who did not suffer from this disease [15].

The blood is pushed by heart to each body part and particularly to the head that is to the brain, which causes change in the color as well as opacity of the skin [4]. It is possible to detect such changes by the analysis of the average red or green component of the input frames, acquired from the camera. Various filters are necessary for the implementation of EVM algorithm. The required analysis is performed using the following specified approach :

1. Spatial filtering: It is Pyramid multiresolution decomposition of the inputted video sequence required to extract features/structures of which are interested, and also for attenuating the noise.
2. Time domain filtering: It performs time-domain bandpass filtering to obtain interested frequency bands, on the images of each scale by using Fourier transform.
3. Amplify the filtering result: Taylor series is used to approximate differentially the signal of each frequency band, as well as the result of linear amplification is also approximated. Hence study of Euler amplification is needed.
4. Composite image: The synthesis is performed on the amplified image. The temporal changes in a video are captured by processing spatial and temporal data. The sequence of video is decomposed into spatial frequency bands. The frequency bands may be magnified in different ways because of the difference in their corresponding Signal To Noise Ratio. The purpose of spatial processing is to improve the temporal ratio of signal-to-noise via pooling of many pixels [16]. Then for computational efficiency and spatial filtering, the low-pass filter is applied and then sampled by using Laplace Pyramid.

Laplace Pyramid

Gaussian kernel is used for convolution of original input image. The cut-off frequency is controlled with the use of σ that is standard variation.

Laplacian pyramid is calculated as the difference between the inputted image and the low pass image that is filtered. It is the difference between successive Gaussian pyramid levels. This whole process is repeated for obtaining a bunch of band-pass images which are filtered (every image is the difference between two levels of the Gaussian pyramid). Therefore the Laplacian pyramid means a bunch of bandpass filters [19].

Original image should be repeatedly filtered and subsampled for generating the sequence of images with reduced resolution. This contains copies of the original image as low pass filters with the decreased bandwidth in one-eighth steps.

On every spatial band temporal processing is performed. In a particular frequency range, time series for respective the pixel value is then passed through a bandpass filter for extracting the interested frequency bands. For detection of HR, frequency band is within 0.4–4Hz, which means 24–240 bpm for magnifing a pulse. For each spatial level as well as within level, the temporal processing is uniform for all pixels , hence the time series of each pixel can be passed through the same filter.

Spatial Filtering: It is performed to spatially filter the inputted video sequence for obtaining basebands with varying spatial frequencies. Perform spatial filtering to "spelt" many nearby pixels into one part, using a low pass filter. For multiresolution decomposition Laplacian pyramids or Gaussian pyramids is used by linear EVM.

Time Domain Filtering: After getting the bands having various spatial frequencies, bandpass filtering is performed in temporal domain for every baseband for extracting the the change in signal of interest. For example, to amplify the heart rate signal, we can choose bandpass filtering from 0.4 to 4 Hz (24 to 240 bpm). This band is the range of human heart rate.

For pulse detection, after computing Laplacian pyramid the magnification value or amplification factor α, are set to 0 for fine two levels. This setting causes down sampling by applying a spatial low pass filter for every frame which reduces quantization as well as noise for boosting the subtle pulse signal of interest [16]. The incoming video frame is then passed through bandpass filter with range of 0.83 to 1 Hz equivalent to 50 bpm to 60 bpm. In final step, a large value of $\alpha \approx 100$ (amplification factor) and $\lambda c \approx 1000$ (cutoff frequency, beyond which an attenuated version of α is used. Either take α as zero for all $\lambda < \lambda c$, or scale α to zero as it is important parameter in controlling noise) then used for spatially low pass signal to emphasiz the change observed in color to the maximum possible extent.

3.2 METHODOLOGY

To predict depression main program utilizes all the other modules to read in the input video, run Eulerian magnification on it, and to calculate heart rate. The purposes of the other modules are described below:

- Preprocessing module - Contains function to read in video from file and uses Haar cascade face detection to select an ROI on all frames.
- Pyramids module - Contains functions to generate and collapse image/video pyramids (Gaussian / Laplacian).
- Eulerian module - Contains function for a temporal bandpass filter that uses a Fast-Fourier Transform.
- Heartrate module - Contains function to calculate heart rate from FFT results.

Heart rate for different healthy individuals ranges from 60 to 85 bpm (beats per minute). For depressed patients HR is 10-15 beats more. If calculated HR is above the normal range then patient is predicted as depressed. This decision is taken using Decision Tree classifier.

3.3 DATA

For evaluation, real-world dataset which is clinically validated is used named as BAUM-1 [17]. The database BAUM-1, which has been released by EEE department, Bahcesehir University is used for evaluation of methodology. BAUM-1 database was collected as a part of a research project supported by the Turkish Scientific and Research Council (TUBİTAK).For testing Heart rate activity of 9 facial videos is analyzed. Facial videos are downloaded from website www.videvo.net, www.istockphoto.com,www.storyblocks.com.

3.4 ARCHITECTURE

Architecture of system is as shown in figure 1.

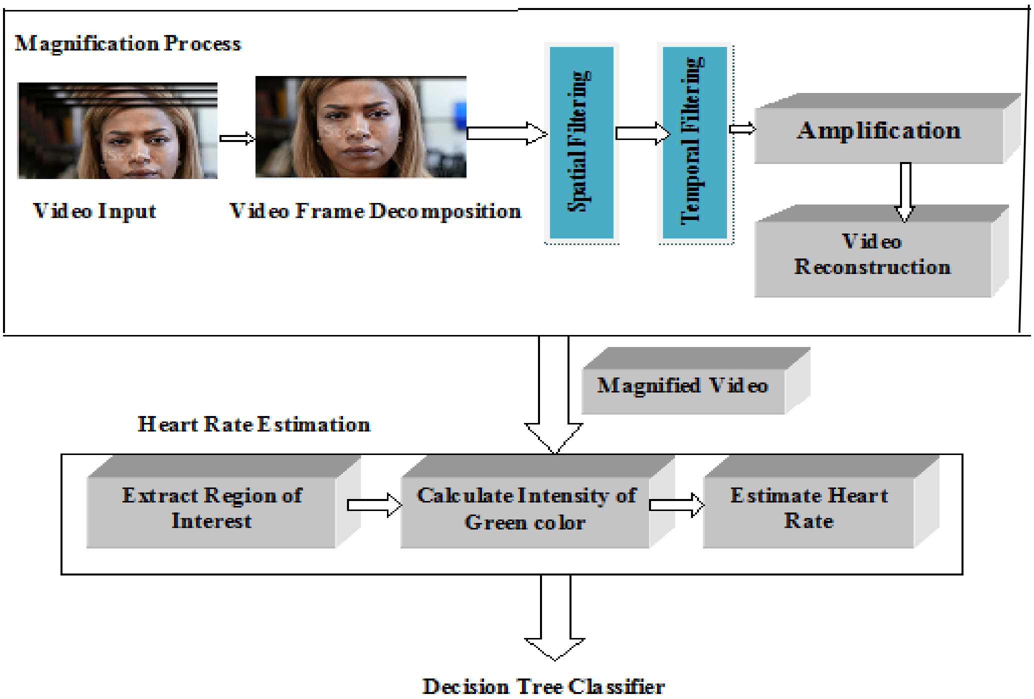

Fig. 1: Architecure of Predicitive Pipeline

4.

5. EXPERIMENTAL RESULTS

Fig. 2: Input facial videos

Videos used for prediction are shown in figure 2.

After application of EVM magnified video is as given in figure 3 which extracts heart rate from change in skin color of face caused due to circulation of blood [16]. Estimated heart rate is given as input to Decision Tree which acts as good Classifier. A decision tree is a tree like flowchart. In which non-terminal nodes indicates particular attribute and the edge indicates a rule based decision rule, while terminal node indicates final outcome. The top node that is root node. It gets trained to divide depending upon the value of attribute. It goes on partitioning the tree recursively. This flowchart-like decision tree structure helps in making decisions. Attribute used for partitioning is estimated heart rate.

Healthy person has heart rate range as 60 to 85 bpm. Depressed person has heart rate increased by 10-15 bpm. Based on this person can be classified as depressed or healthy.

After performing experiment on 27 facial videos from BAUM-1 dataset, only 3 videos got heart rate more than 85 bpm. While remaining videos heart rate is in normal range of 60-85 bpm. Hence it can be concluded that three persons are predicted as depressed while remained are healthy. Estimated HR value for each input facial video which helps for prediction is as shown in Table 1. Corresponding bar pot is shown in figure 4.

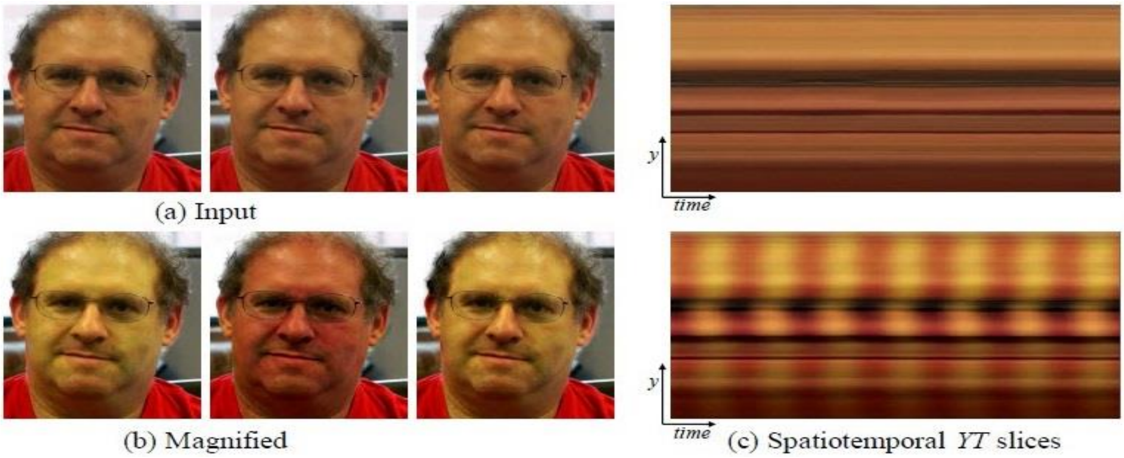

Fig.3: Use of EVM algorithm for estimating the heart rate. (a) Frames in the inputted video. (b) The frames but with amplified Heart rate signal. (c) From input indicated by top and output indicated by bottom videos, a vertical scan line which is plotted over time that showing amplification by EVM via variation in color. In the original input video, signal is imperceptible, but in the output magnified sequence the color variation is clear.

TABLE1. RESULTS: Prediction based on HR value

Index	Name	Estimated Heart Rate	Prediction	Index	Name	Estimated Heart Rate	Prediction	Index	Name	Estimated Heart Rate	Prediction
1	Video1	65.78073089700990	Not Depressed	10	Video10	77.76536312849160	Not Depressed	19	Video19	67.96875000000000	Not Depressed
2	Video2	88.47457627118640	Depressed	11	Video11	60.83916083916080	Not Depressed	20	Video20	62.14285714285710	Not Depressed
3	Video3	82.20472440944880	Not Depressed	12	Video12	76.90607734806630	Not Depressed	21	Video21	62.14285714285710	Not Depressed
4	Video4	72.07100591715970	Not Depressed	13	Video13	72.50000000000000	Not Depressed	22	Video22	70.16129032258060	Not Depressed
5	Video5	68.57142857142850	Not Depressed	14	Video14	74.04255319148930	Not Depressed	23	Video23	69.94974874371850	Not Depressed
6	Video6	63.43749999999990	Not Depressed	15	Video15	60.00000000000000	Not Depressed	24	Video24	79.09090909090910	Not Depressed
7	Video7	61.20603015075370	Not Depressed	16	Video16	85.29411764705880	Depressed	25	Video25	74.04255319148930	Not Depressed
8	Video8	72.50000000000000	Not Depressed	17	Video17	88.47457627118640	Depressed	26	Video26	62.70270270270270	Not Depressed
9	Video9	74.04255319148930	Not Depressed	18	Video18	73.10924369747900	Not Depressed	27	Video27	78.37837837837830	Not Depressed

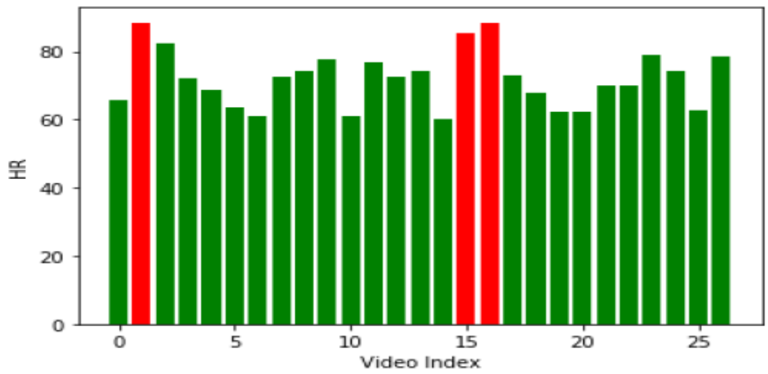

Fig. 4: Bar plot based on prediction in Table 1

Output scatter plot is shown in figure 5 in which red dots indicates depressed patients while healthy persons are indicated by green dots.

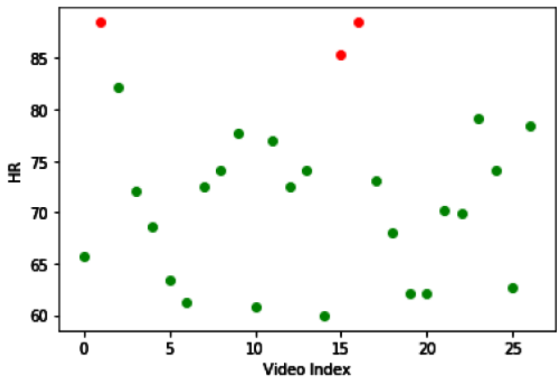

Fig.5 Scatter plot

Though naked eye observed emotion is sad , if person's estimated heart rate is in normal range 60-85 bpm then person is healthy. If heart rate is crossing 85 bpm then person has risk of depression. Hence heart rate gives correct prediction. For classification instead of just one classifier as linear SVM, decision tree is also used. When experiment is performed over 27 videos, Accuracy given by decision tree has proven upper hand over SVM. Accuracy given by Decision tree classifier is 1.0. For linear SVM obtained accuracy is 0.94.
Using linear SVM confusion matrix is shown in figure 6 & figure 7 indicates classification report.

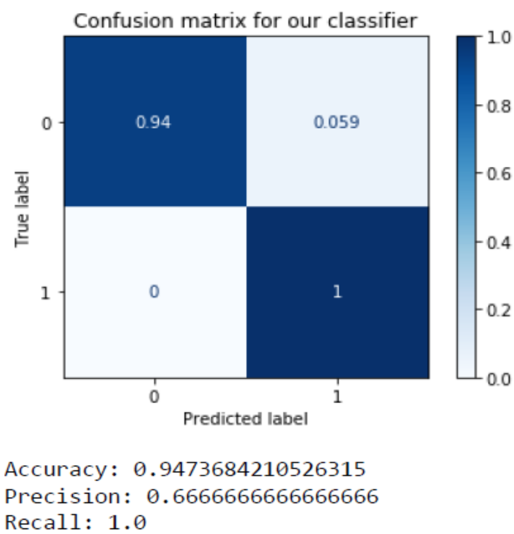

Fig. 6 Confusion Matrix

	precision	recall	f1-score	support
0	1.00	0.94	0.97	17
1	0.67	1.00	0.80	2
accuracy			0.95	19
macro avg	0.83	0.97	0.88	19
weighted avg	0.96	0.95	0.95	19

Fig. 7 Classification Report

6. CONCLUSION AND FUTURE SCOPE

In the research, architecture is introduced to predict depression from visual heart rate estimation. Inputted video is magnified using EVM & heart rate is calculated. Estimated heart rate is used as partitioning feature for classifying decision tree classifier. The methodology used performs Visual HR estimation very perfectly. It can be extensively used in healthcare applications to monitor the mental health of a person and predict the depression[18].

Experiments are performed on smaller dataset. In future same experiments can be performed on publicly available larger dataset and effectively predict depression.

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