# DATA ANALYSIS BY USING MACHINE LEARNING ALGORITHM ON CONTROLLER FOR ESTIMATING EMOTIONS

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## *ABSTRACT*

*Emotions are an unstoppable and uncontrollable aspect of mental state of human. Some bad situations give stress and leads to different sufferings. One can't avoid situation but can have awareness when body feel stress or any other emotion. It becomes easy for doctors whose patient is not in condition to speak. In that case person's physiological parameters are measured to decide emotional status. While experiencing different emotion, there are also physiological changes taking place in the human body, like variations in the heart rate (ECG/HRV), skin conductance (GSR), breathing rate(BR), blood volume pulse(BVP),brain waves (EEG), temperature and muscle tension. These were some of the metrics to sense emotive co-efficient. This research paper objective is to design and develop a portable, cost effective and low power embedded system that can predict different emotions by using Naïve Bayes classifiers which are based on probability models that incorporate class conditional independence assumptions. Inputs to this system are various physiological signals and are extracted by using different sensors. Portable microcontroller used in this embedded system is MSP430F2013 to automatically monitor the level of stress in computer. This paper reports on the hardware and software instrumentation development and signal processing approach used to detect the stress level of a subject.To check the device's performance, few experiments were done in which 20 adults (ten women and ten men) who completed different tests requiring a certain degree of effort, such as showing facing intense interviews in office.*

## *KEYWORDS*

*Emotions, Model, equation, Result, pattern, GSR, BVP, Temperature, Microcontroller*

## 1.INTRODUCTION

Human experiencing emotions in a higher magnitude differ from those who can regulate these emotional experiences; such type of factor is named as Emotional Intelligence (EI).Emotional intelligence has four aspects that are also known as branches. These branches perceive emotion to facilitate thoughts, understanding emotions and managing emotions[2].

This paper explains contribution to work in perceiving emotions. As perceiving emotion has ability to identify emotion in oneself and others. With this it also has ability to tell difference between honest and dishonest emotions. Recognizing emotions is not just dependent upon facial expressions rather many more kinds of cues are there now like: voice, gestures, actions and biofeedback modalities. Various biofeedback modalities which exist are electromyography (EMG) in which muscle contraction and relaxation is measured, temperature change is accessed via fingertip thermometers. Resistance of skin influenced by sweat is evaluated (GSR),

Cardiovascular activity is measured via heart rate [3]. Emotion depends upon ANS (autonomic nervous system) of the person. As emotion varies and it bring changes in sympathetic nerve of the ANS in excited condition, the sweat is secreted form the sweat gland and it decreases the GSR and heart rate is also under continuous control of autonomic nervous system which also increase heart rate [9].

This paper targets on the GSR with parallel work based upon BVP and temperature analysis. Measuring instrument was designed and developed by authors. It is based on low power consuming microcontroller(MSP430F2013).This measuring instrument can measure different biofeedback modalities and can also predict emotion of a person. In particular, popular learning algorithm was employed: Naïve Bayes Classifier. The Bayesian Classification represents a supervised learning method as well as a statistical method. It assumes a probabilistic model and it allows us to capture uncertainty about the model in a principled way by determining probabilities of the outcomes.

Through this healthcare application certain experiments was conducted on different people working in same office, by stimulating them with different scenarios like in meetings, before presentations, in breaks, people appearing for interview etc. Monitoring and analyzing emotions is important as it contains information that can help in improving human wellbeing. Emotions which were observer by system are joyful, anxiety, calm and will also reflect illness in case of high temperature. Twenty subjects were chosen to take part in this experiment with age from 23-55.This was carried out for 10 male and 10 female subjects with consistent experimental setup. When there is variation in ANS, it gives changes in biofeedback modalities as result emotions are observed. Table 1[4] gives an example of same.

Table I.Example of biofeedback modalities In autonomic activity

| **Emotions** | **GSR** | **BVP** | **Temperature** |
|---|---|---|---|
| Anxiety | Decreases | Decreases | Decreases |
| Joyful | Increases | Normal | Normal |
| Calm | Normal | Normal | Normal |
| Illness | Normal | Increases | Increases |

## 2.State of art

There exist different studies which try to detect with subject emotions in different manner. Study for blind people [5] Analyze autonomic nervous system activity is a subject. Estimation of emotion on one modality (GSR) [6] has shown possibilities to achieve outcome. Varying Heart Rate is another parameter used to measure different stress levels [7].Analysis of Emotion Recognition from GSR Based on PSO [8] is an application, which came up with different idea. A stress sensor has implemented different algorithm techniques on GSR [4].

## 3.Architecture of Emotion Estimation System

The architecture of emotion estimation monitoring system is shown (fig1), which has mechanism to measure different bio- modalities or bio-signals (GSR/BVP/Temperature). In this system validation of subject is done at priority. It sense biosignals from human and then sends it to

microcontroller (MSP430F2013). This is a new model which is solution to previous conventional models, with more portability low cost and more power efficient.

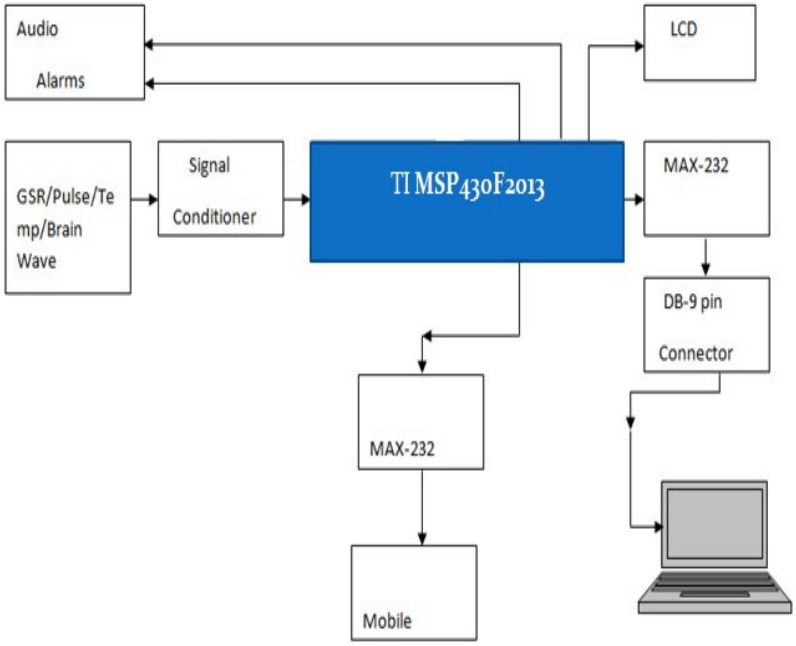
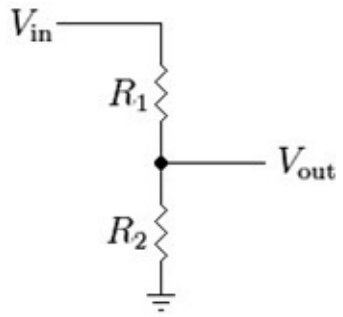



Fig.2.Biofeedback monitoring system which display different parameters connected to microcontroller [6]

Firstly system starts sensing galvanic skin response (GSR).GSR is based on sweat gland activity. The autonomic nervous system (ANS) controls eccrine sweating, with this skin conductance reflects arousal of the sympathetic ANS which accompanies different psychological processes. GSR is measured by passing a small current through a pair of electrodes placed on a surface of skin.

Fig. 2 Electrodes used as sensor for GSR

That measured value can be in form of conductance, resistance, current value or voltage value. By placing two fingers on the surface of electrodes Galvanic Skin Response (GSR) was measured. To have value, resistance was used. To voltage divider was formed to calculate resistance.




$$Vo = \frac{R2}{Rs + R2} Vcc \quad (1)$$

Fig. 3 GSR Input setup

Where, Rs/R1 is the resistance of the skin.

The GSR resistance oscillates between 10 kΩ and 10 MΩ[4].As ADC in MSP430 is 12 bits so it has been observed that ADC saturates at 2.30V and resolution is 0.570mv.A minimum tension level a human can have is 136mv, this helped to avoid operational amplifier and it was not included. By avoiding operational amplifier, efficiency of system got improved because it became less power consuming sensor system.

Blood volume pulse varies when heart rate variation is observed. It is due to the synergistic action of the two branches of the autonomic nervous system (ANS) - vagus nerve and sympathetic nerve. Vagus nerve: Vagal nerves innervate the S-A node, the atrioventricular node and the atrial muscle. The stimulation of the vagus nerve slows down the heart rate. Sympathetic nerve: Sympathetic nerve fibers innervate the entire heart, including the sinus node and A-V node. Increased activity of the sympathetic nerves results in the increase in heart rate of human body.BVP is recorded by technique known as a photoplethysmography.

Photoplethysmography (PPG) works by placing an individual's finger tip or ear-lobe between two parts of a transducer consisting of a light source and a light sensitive detector. A beam of infrared light is projected towards the detector. The blood in the finger or ear-lobe scatters the light in the infrared range, and the amount of light reaching the detector is inversely related to the volume of blood in the skin periphery. This is shown in fig 3.

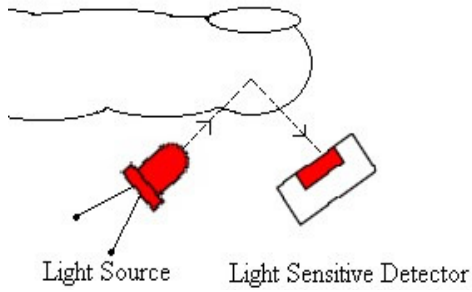



Fig 4 Arrangement of plethysmograph components

Heart rate is derived by measuring either the average or instantaneous time interval between two successive pulses. An average rate i.e. beats/min. is calculated by counting the number of pulses in a given time. The true picture of the heart's responds to exercise, stress and environment. This is done by measuring the time (T) in seconds, between the two consecutive pulses and converting this time into beats/min. [9]

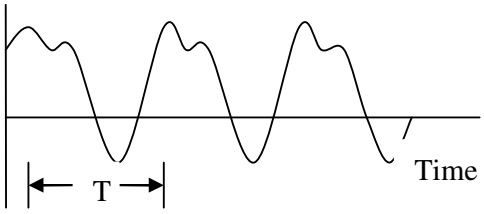



Fig .5 Beats/min. = 60/T, calculates beat per minute in human body

Heart rate reserve is the difference of the maximum heart rate and the resting heart rate. Heart Rate Reserve = Maximum HR – Resting HR.

(HR is Heart Rate of a human body) (2)

For temperature when we feel stress muscles get contracted (tense), with this temperature of body get reduced because of less blood reaches the fingers of the patient. This coldness can be experienced in our hands when we are stressed. An example for the same can be, when appearing for job interview that nervousness can be experienced by anyone. It is common for human temperature to have readings as low as 70 to 80 degrees Fahrenheit

The eZ430-F2013 is a complete MSP430 development tool providing all the hardware and software to evaluate the MSP430F2013 and complete an entire project in a convenient USB stick form factor. All 14-pins on the MSP430F2013 are accessible on the MSP-EZ430D target board for easy debugging and interfacing with peripherals. Using the integrated 16-bit SigmaDelta analog-to digital converter, the MSP430F2013 provides all the required elements for interfacing .Following algorithm help to prepare AD-converter:

```
SD16CTL = SD16REFON + SD16SSEL_1 + SD16XDIV_2 + SD16DIV_1; VREF=1.2V,
Clock=SMCLK, Clock-Divider2=16, Clock-Divider1=2  500kHz MF)
P1SEL |= BIT3;  (internal reference voltage at  P1.3 (Pin5) )
SD16INCTL0 = SD16INCH_4; (using input A4 (P1.1=A4+, P1.2=A4-))
SD16AE = SD16AE1 ;( negative inputs are internally connected to Vss (GND); P1.1 an A4+)
SD16CCTL0 = SD16IE + SD16UNI ;( Interrupt + unipolar Input, and continues mode)
SD16CCTL0 |= SD16XOSR; oversample rate
SD16CCTL0 |= SD16OSR_512; (over sample rate is 512)
SD16CCTL0 |= SD16SC; (start conversion)
_BIS_SR (GIE); (enter global interrupt)
```

The result sample rate is clock frequency divided by modulation frequency of the SD16, divided by the oversampling rate

### 3.1 Signals Processing

In GSR resistance calculation of Body is done using Voltage Divider Circuit with 10K variable resistance. That variable voltage according to the body resistance is fed into the msp430 microcontroller for analogue processing which is send to the 8051 microcontroller via 3 wire self designed protocol which is further send to the pc from serial port using UART Communication. In BVP Sensor it measure Blood Volume Pulse Rate we are using a sensor that gives us the high pulse in synchronization with the heart rate. A light is fed into the human finger using a LED which is reflected back from the amount of blood accordingly the phototransistor receives the amount of light and gives the output voltage that is fed into the msp430 microcontroller for analogue processing which is send to the 8051 microcontroller via 3 wire self designed protocol which is further send to the pc from serial port using UART Communication. In Temp Sensor (LM-35) MSP microcontroller has temperature sensor inbuilt with which temp is measured directly using the internal SD16 of MSP. The digital output value is send to the 8051 microcontroller via 3 wire self designed protocol which is further send to the pc from serial port using UART Communication.

The architecture of emotion estimation with Biofeedback (biosignals) monitoring system is given below (fig.1), which is having the mechanism of stimulation and measuring (with self designed instrument) and then finally the estimation of the emotional state (anger/happy etc) of person, which is the variation of the objective evaluation (experimental value) and ideal or expected values (subjective).

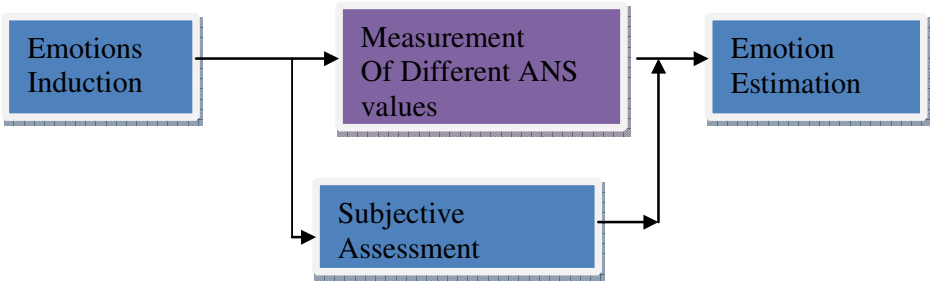



Fig 6 Emotion Estimation block diagram [6]

### 3.2Hardware/Software Requirements

To design and implement the actual device, main components used are listed below:

- Electrodes (silver)
- light emitting diode (LED)
- phototransistor
- LM35
- MSP430F2013
- Display (LCD )( 16 Character x 2 Line) /Personal Computer
- IAR/Code studio compiler

## 4.Mapping of emotion Model with Emotions

The main objective is this work was to design and develop real time monitoring system which is capable to estimate different emotions, specially for the people who all can't express their emotions like suffering from paralyzed body etc. This system will be user friendly as it will be following diagram shown in fig 5.

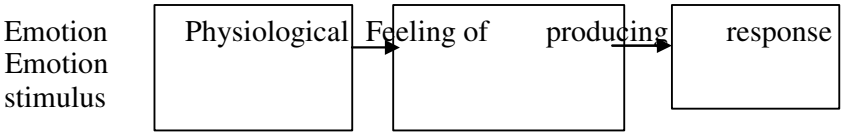



Fig 6 Sequence of emotion

The expected values of different biofeedback modalities are mapping with different ranges of emotions are as mentioned in the table given below [10].

TABLE II. values and emotions

| | Stressed | calm | Joy | Fear/ Aroused |
|---|---|---|---|---|
| GSR Amplitude | 0.28 | 0.15-0.25 | 0.15 | 0.29 |
| BVP | 63 | 72 | 73 | 85 |
| Temp | 98 | 98.2 | 98.4 | 96.4 |

Stress is seen as a state of emergency that is preceded by arousal due to an external stimulus. External stimulus can be considered anything which is creating distractions. After the factor causing stress (the stressor) disappears; the body relaxes get calm and returns to a normal state. Figure 6 shows the general case with more relationships between the four different states depicting the inner process of emotions. These states are interrelated by each other and are also associated by external stimuli. Emotion varies when input parameter GSR/TEM/BVP varies, depending upon input values result (emotions) are detected.

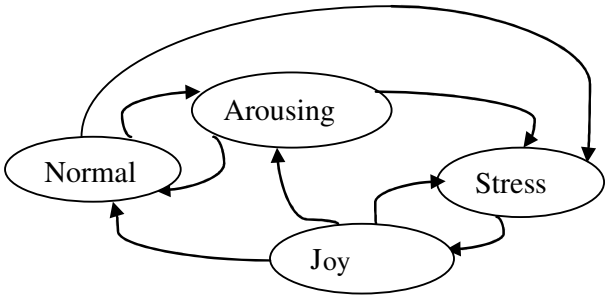



Fig.7 Relation between different states

In this paper we consider a simplified setting assuming that a person is either in the normal state or in a stressed state. The change between the two states can be sudden or incremental; typically, arousal is more rapid and relaxation takes considerably longer. [11] In following fig 3 we can see various emotions are categorized which are based upon the degree of arousal from low to high and valence i.e. positive to negative of emotions.[10]

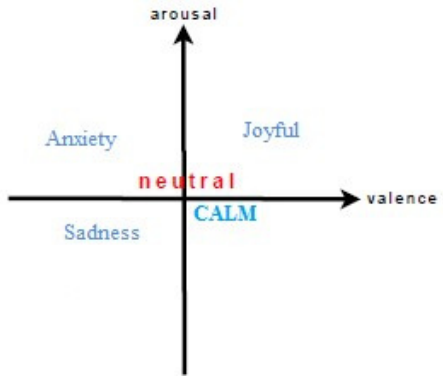



Fig. 8 Two dimensional emotion models with four quadrants

Following are observation from various Activities:

- when anxiety will increases then at same time with skin conductivity GSR will decreases and HR/BVP will increase
- When parson will be joyful then with skin conductivity GSR will increases and HR/BVP will (increase/decrease)
- When person is calm no change is observed

All features were extracted from experiment held by author, and then they were provided as input to learning systems, which were trained to differentiate the stress from the different state of a person.

Bayesian reasoning was applied to predict the emotional state. Bayesian is responsible for decision making and inferential statistics by using probabilities techniques [11].
Bayes Theorem:

$$P(h|D) = \frac{P(D|h)\,P(h)}{P(D)} \qquad (3)$$

Method above computes the conditional probabilities of the different classes given the values of attributes of an unknown sample and then the classifier will predict that the sample belongs to the class having the highest posterior probability in that case. Instance is represented by an ndimensional feature vector, (x1,x2,…,xn), sample is classified to a class c from a set of possible classes C according to the maximum a posteriori (MAP) decision rule:

$$\text{Classify}(x1,x2,\ldots.xn)=\text{argmax } p(C=c)\prod_{i=1}^{n} p(xi|C-c) \qquad (4)$$

D: Set of tuples

Each Tuple is an ‘n’ dimensional attribute vector

X : (x1,x2,x3,…. xn)

Let there be 'm' Classes : C1,C2,C3…Cm

Classifier predicts X belongs to Class Ci if

P (Ci/X) > P(Cj/X) for 1<= j <= m , j <> i

Maximum Posteriori Hypothesis

P(Ci/X) = P(X/Ci) P(Ci) / P(X)

Maximize P(X/Ci) P(Ci) as P(X) is constant With many attributes, computing of this is expensive to evaluate P(X/Ci).Naïve Assumption of "class conditional independence"

$$P(X|Ci)=\prod_{k=1}^{n} p(x_k \ |Ci) \qquad (5)$$

$$P(X/Ci) = P(x1/CI) * P(x2/CI) *\ldots* P(xn/ CI) \qquad (6)$$

The conditional probability in the given above formula is obtained from the estimates of the probability mass function using training data of that scenario. Moreover the independence assumption may not be a realistic model of the probabilities involved; it may still permit relatively accurate classification performance [6].

# 5.PROCEDURE FOR EXPERIMENTATION

Prerequisites to start the experiment are given below:

1. The author arrived with a setup to various areas of office where different activities were going on like meeting, interviews, lunch break, official work, tea time and official presentations.
2. Readings were taken three times before the task, within task and after task.
3. Experiment was done with age from 23-55.
4. As circuit is portable designed and was also helping with feature with low power supply, having 1.8V of power supply.
5. Before performing above experiment, permission was granted by officials.
6. Different emotions were detected, as it also helped in professional growth ( by building strong emotions).
7. While experiment, subject was not allowed to have water as it can change emotion.

## 5.1.The experiment

All the events or activities were found to trigger specific emotions. Both genders were considered 20 odd male and female. Sample was taken from various people were involved in different activities and reading were taken suddenly to avoid manipulated emotions. Person need to put their left and right fingers, one each on to the sensors and also check each parameter turn wise. Then according to the connections showed in diagram (fig.2,3) the GSR,BVP and temperature values are sensed by sensors , on the basis of these values emotions are predicted. Initially, the person', under neutral conditions is measured, that serves as the reference for us to

estimate the variance of the values, in different emotional states. Once the state is reached, person tends to be in that state for a finite amount of time. The total time of stimulus for each emotion is in between 5 to10 minutes and with a gap of 2-3 minutes is must between different emotions, so to full fill these criteria emotion was estimated thrice. This design is not suitable for people having Hyperhidrosis. This is disease of excessive sweating, which becomes drawback of system.

## 5.2Observations and Results

Values of GSR between < 5 K ohms indicates high level of brain arousal, and >25Kohms indicates low arousal (calm level).The normal heart rate of an adult varies between 60 to 90bpm.At rest, an adult has an average heart rate of 72bpm [7].

Table 3. Values of different people

| PERSON | GSR | BVP | TEMPERATURE | Emotions |
|---|---|---|---|---|
| Subject 1 | Low | Low | Low | Anxiety |
| Subject 2 | Low | High | Low | Anxiety |
| Subject 3 | High | Low | Low | RELAX |
| Subject 4 | High | High | Low | JOYFULL |
| Subject 5 | Normal | High | Low | RELAX |
| Subject 6 | Normal | Low | Low | RELAX |
| Subject 7 | High | Normal | Low | JOYPULL |
| Subject 8 | Low | Normal | Low | Anxiety |
| Subject 9 | High | High | Normal | JOYFULL |
| Subject 10 | High | Low | Normal | RELAX |
| Subject 11 | Normal | Normal | Normal | RELAX |
| Subject 12 | Low | Low | Low | Anxiety |
| Subject 13 | Normal | Normal | Normal | RELAX |
| Subject 14 | High | High | Low | JOYFULL |
| Subject 15 | Low | Low | Normal | Anxiety |
| Subject 16 | Low | High | Normal | Anxiety |
| Subject 17 | Normal | Normal | Normal | RELAX |
| Subject 18 | Low | Low | Low | Anxiety |

| | | | | |
|---|---|---|---|---|
| Subject 19 | High | High | Low | JOYFULL |
| Subject 20 | Normal | Normal | Normal | RELAX |

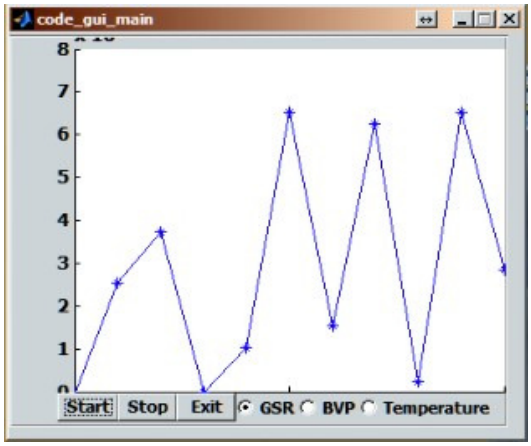



Fig 9 Variation in GSR

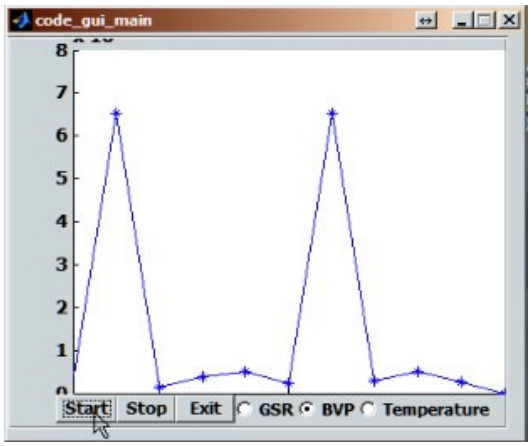



Fig 10 Variation in BVP

## 6.CONCLUSION

Emotion regulation is a capability of emotional Intelligence. The work finds its application in the domains for personnel usage especially for people who are paralyzed. Situations and emotions where there is great arousal like anger, fear, horror and melancholy could be easily identified, while lower arousal emotions like calm and sad were meagerly distinguishable. Research also talks of emotions like joy as high arousal emotions and hence easily distinguishable. The heart rate varies between individuals and gives different reading according to their emotions. The normal human heart rate at rest is 60 to 80 bpm. At rest, an adult has an average heart rate of 72bpm and GSR varies from 0 to 35 K ohms'. Further empirical studies need to be conducted to give a clearer picture on this aspect. However the present work is an attempt to such an end and hopes to find out methods and ways to achieve the goal of affective communication. Future working is also being done parallel by adding more input parameters to the same.

## 6.ACKNOWLEDGEMENTS

This research paper got possible through the help and support from: My guide, parents, family, friends, and god. Especially, I would like to acknowledge my gratitude toward the following significant advisor of my work:

Foremost, I would like to thank Dr. Bhanu Kapoor for his most support and encouragement. With this my sincere thank to my parents, family who provide all essential support. This research paper would not be successful without all support.

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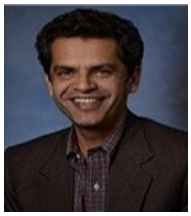

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