Emotion Recognition System using IOT and Machine Learning - A Healthcare Application

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Abstract—**Emotion is strong instinctive and intuitive feeling in humans that arise from one's situations, circumstances, mood and relationship with others. So, emotions are a mental state of person which cannot be stopped. Thus, Emotion Recognition is an important subject when talking about human-machine interaction and when it comes to doing the analysis and controlling of emotions. Emotions can be detected using many techniques like facial expressions, speech, body gesture and psychological signals. Certain physiological changes take place in human body for example, variation in heart rate, temperature, skin conductance, muscle tension and brain waves (ECG). This paper considers temperature and heart beat values (in bpm- beats per minute) extracted from temperature sensor, pulse sensor as well as ECG sensor and use them to train a machine learning algorithm. Naive Bayes Classifier algorithm, a classification problem which is based on conditional probability model and assumes that each feature is independent of the other, the benefit of applying this algorithm lies in the fact that the every individual has different pattern in terms of heart beat and even sometimes the normal body temperature and heartbeat of individuals differ. Also same dataset is used to train K Nearest Neighbors model, another classification problem to help us do comparative analysis of two classification algorithms for instance, which is more accurate, which one is to be preferred when large samples are there, which one is to be preferred when high dimensional is available and so. So, applying Machine Learning will aid in correctly predicting the emotional state of every individual. So, this paper helps to detect emotion of a person and if at all he/ she remains in a sad state or angry state for longer period of time then this product alarms the person to go for consultation. The paper has reached an accuracy of about 84% on sample size of nearly 115 samples.**

I. INTRODUCTION

IOT has been greatly involved in healthcare applications such as personal healthcare, smart care, smart pills and real time health systems. Every human reacts differently in different situations, so there are no generalized parameters to detect mood swings. But there are some unique different features that provide accuracy towards emotion recognition. Regulating emotions is one of an important healthcare field. There are primarily four basic emotions considered in this paper which includes happy (excited), sad, relaxed (normal) and anger state. A lot of research has already been done in this field which focus on detecting emotions using psychological signals like ECG, sweat and skin conductance value etc. As already described above there are many different ways in which emotions are detected. Following are some of the ways:-

- Emotions using EEG: EEG signals are used to analyze the nervous system to provide information about different type of emotions.
- Emotions using facial expressions: Image processing techniques are used to detect the changes in facial expressions to provide information about various emotions
- Emotions using speech: Tone of speech is monitored using voice recognition systems and provide emotions information.
- Emotions using text: Based on words and sentences while communicating for example, chatting.

This paper focuses on Emotion Recognition using psychological signals. Machine Learning algorithm is applied on the data collected from the sensors. Since, our objective is to classify the emotion of a person into one of the four emotions taken into consideration, which makes our problem to be solved using Classification algorithm. Many classification algorithms can be implemented like Decision Tree, K Nearest Neighbors and Naïve Bayes Classifier. Here, we will be focusing on two important Classification algorithms i.e. Naïve Bayes Classifier and K Nearest Neighbors.

II. LITERATURE SURVEY

In order to achieve the objective, a literature review was conducted to analyze the different techniques and methods that are available for human emotion recognition:

Many researchers have been working in development of Health care systems using Internet of Things. One of the research paper "iPatient in Medical information Systems and Future of Internet of Health" present the results of Study iHealthCare Optimization, provided by Dell EMC External Research and Academic Alliances. Big Data analytics of Medical information system qMS records was implemented using cluster analysis in Python [1].

Smart Spaces Enabled Mobile Healthcare Services in Internet of Things Environments- another research by Dmitry G. Korzun, Alexander V. Borodin and Ilya V. Paramonov. This article studies the smart spaces approach applied for development of mobile healthcare (m-Health) services deploying in Internet of Things (IoT) environments. The authors consider a reference architecture model of the service ecosystem with focus on intelligent utilization of multi-source data originated from the IoT environment. Based on the architecture the authors introduce two reference scenarios: assistance in providing the first aid and communication with the hospital information system [2].

Human Recognition System using Smart Sensors -A research by Muhammad Tauseef Quazi states that emotion is a mental state that arises and is accompanied by physiological changes. He said studying these emotional changes is very important and can help in identifying at an early stage before they become serious [3]. Human Emotions Detection using brain wave signals - according to AlMejrad emotions play critical role in rational and intelligent behavior. When people are happy, their perception is based on selecting happy events, same in case of negative emotions. So, decisions taken by human beings are highly affected by their emotional states. He studied emotions using brain signals and classified emotions into three type's i.e. motivational, basic and social [4].

Automated Facial Expression Recognition System –here author studied emotions using facial expressions and classified emotions into 6 types i.e. happiness, sadness, fear, surprise, anger and disgust. He later expanded them into more types including relief, satisfaction, embarrassment etc. [5]. HERS is a real time system for emotion recognition through analysis of facial expression and speech features. The system simultaneously detects emotion from live video audio streams. The system splits the video stream into sequence of images, then detects the face of a person from the frames and extracts his/her emotion [6]. Facial expressions, a non-verbal communication plays a vital role in emotion recognition and classifies the human emotion into six basic facial expressions: happiness, sadness, surprise, fear, disgust and anger as researched by Monika dubey and Prof. Lokesh Singh [7]. Data Analysis by using ML Algorithm on Controller for Estimating Emotions - this paper targets GSR with BVP and temperature analysis to detect emotions. According to them, one can't avoid situation but can have awareness when body feel stress or any other emotion [8].

Similarly Damasio described emotions as an integral part of reasoning and decision making [9]. He found out that due to some damage in parts of their brains, they lost their ability to process emotion normally. Prinz when studying about emotions compared emotions and sneezing process [10]. Just like sneezing is out of human control, emotions are also outside voluntary control and are associated with certain body patterns. Recognition of Human Emotion from Heart Beat. This paper [11] targets body resistance and heartbeat to detect emotions. Body resistance is one of important parameter used for psychological and physical analysis of human body. For instance, Stress: increased blood flow to skin – low skin resistance-increased conductivity and for Calm mood: low blood flow to skin – high skin resistance- low conductivity

III. PROPOSED SYSTEM

Emotion Recognition system detects human emotions and helps analyze these emotions in order to control them at early stage before they can harm a person's health. The proposed system consists of wearable device that contains sensors which read body temperature and pulse rate continuously and sends it to Arduino board also present in the device. Arduino sends this data to gateway. From gateway, all this data is sent to cloud and gets stored in cloud. All computations and machine learning algorithms are executed on data collected. We used two classification algorithm i.e. naïve bayes and k nearest neighbors for machine learning and used data obtained to train our algorithm about various classes of emotions. We are primarily concerned with four different emotions here i.e. happy (excited), normal (relaxed), sad and anger.

IV. ARCHITECTURE OF PROPOSED SYSTEM

The IOT architecture for the proposed system is as follows: It starts from sensors (pulse, temperature sensor and ECG sensor) that collect the data and then send it to microcontroller unit (Arduino) using I2C communication protocol. The two lines are called Serial Clock (or SCL) and Serial Data (or SDA). The SCL line is the clock signal which synchronize the data transfer between the devices on the I2C bus and it's generated by the master device. The other line is the SDA line which carries the data. The data is directly sent through a Wi-Fi module interfaced to the microcontroller arduino under TCP IP protocol to cloud. The whole communication forms a mesh network. Data from Thing Speak (cloud) is then retrieved in csv format and proposed machine learning algorithm is the applied to analyze the data. The IoT architecture for the same is depicted at Fig. 1.

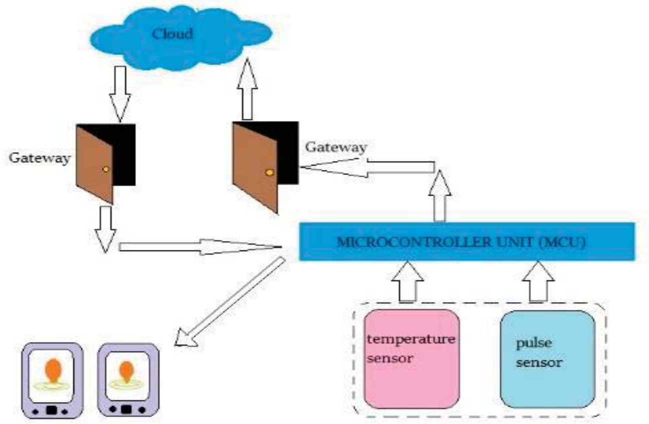

Fig. 1. Architecture of Proposed System

According to the IoT Reference Model published by the IoT World Forum, this paper sticks to the architecture and has following layers: Physical Devices & Controllers: The primary function of the sensors is to generate data and being capable of being queried or controlled over a network. Connectivity: This layer is required for communications between different sensors in Layer 1 and reliable delivery of information across the network. Wi-Fi module is used for connecting devices. Edge Computing: This layer is needed to evaluate and reformat data collected from the sensors for processing at higher levels and assessing the data. Data Accumulation: This layer captures the data and stores it so that it can be used by applications whenever necessary. Data Abstraction: This layer reconciles multiple data formats and ensures consistent semantics from various sources.

V. PROPOSED ALGORITHM

A. Machine Learning Algorithm

In this paper we have used supervised multiclass classification machine learning algorithm to predict the human emotion more accurately which is based on many parameters. Two classification problems are used and later comparative analysis is done to know which algorithm is best suitable for this application. As the training data was already prepared by using the sensor values generated by individual person and the emotion conditions were taken into account. This algorithm enabled us to predict the emotion on the basis of the data provided to it.

B. Multiclass Classification using Python

Multiclass Classification problem aims to predict the class of emotion given a set of independent variables. We have four classes of emotions considered, Class 1: Happy (Excited state), Class 2: Sad state, Class 3: Normal (Relaxed state) and Class 4: Anger state. Naive Bayes Classification is related to Bayes theorem of probability which uses the probabilistic model and finds the probability of an event occurring given the probability of another event that has already occurred. Posterior probability is calculated, as in (1).

$$P(a|b) = \frac{P(b|a) \times P(a)}{P(b)} \tag{1}$$

where P(a|b) is the posterior probability of class, P(a) – prior probability of class, P(b|a) – likelihood which is the probability of predictor given class and P(b) – prior probability of predictor.

C. Algorithms

Mathematical model for Naïve Bayes Classification for binary features is described in Algorithm 1.

Algorithm 1 Naïve Bayes Classifier for binary features

for $i = 1 : N$ do
  for $c = 1 : C$ do
    $L_{ic} = \log \hat{\pi}_c$;
    for $j = 1 : D$ do
      if $x_{ij} = 1$ then $L_{ic} := L_{ic} + \log \hat{\theta}_{jc}$ else $L_{ic} := L_{ic} + \log(1 - \hat{\theta}_{jc})$
  $p_{ic} = \exp(L_{ic} - \text{logsumexp}(L_{i,:}))$;
  $\hat{y}_i = \text{argmax}_c\, p_{ic}$;

Same logic can be applied when we have multiclass classification problem. There are three types of Naïve Bayes theorem i.e. Gaussian, Multinomial and Binomial. This paper deals with gaussian naive bayes algorithm. Gaussian naïve bayes is used because it provides a method to normalize the continuous data and it assumes the normal distribution of data. KNN algorithm is also implemented on given dataset which focuses on K nearest neighbors to predict the class to which an input variable belongs to. It is a non-parametric method where the input consists of the k closest training examples in the feature space. Algorithm 2 defines the mathematical model for KNN.

Algorithm 2 KNN Algorithm

```
1.) Load the data
2.) Initialise the value of k
3.) For getting the predicted class, iterate from 1 to N
        1.) Calculate the distance between test data and each
            row of training data.Here we will use Euclidean
            distance as our distance metric since it's the most
            popular method. The other metrics that can be used
        2.) Sort the calculated distances in ascending order
            based on distance values
        3.) Get top k rows from the sorted array
        4.) Get the most frequent class of these rows
        5.) Return the predicted class
```

Choice of k is very critical – A small value of k means that noise will have a higher influence on the result. A large value make it computationally expensive and defeats the basic philosophy behind KNN (that points that are near might have similar densities or classes). A simple approach to select k is set k = n^ (1/2), where n is the number of training samples in the data.

VI. EXPERIMENT AND SIMULATION SETUP

A. Hardware Components

Various hardware used for this research are as follows:

1) Arduino Uno: The Arduino can be programmed with the Arduino software. It has its own programming language which is very easy and also can be coded with C ++.

2) Temperature Sensor: We can measure the body temperature using various temperature sensors. For instance, LM35 series are precision integrated circuit sensors whose output voltage is linearly proportional to the Celsius temperature. It operates linearly +10.0mV/°C scale factor with 0.5°C accuracy. Human body temperature is of vital importance to maintain the health and therefore it is necessary to monitor it regularly.

3) Pulse Rate Sensor: Heart beat sensor gives digital output of heart beat. When heart beat detector is working the led flashes for every heartbeat. This digital output will be connected to microcontroller directly to calculate the beats per minute (BPM) rate. It works on the principle of light modulation of networked satellites and are tracked to uplinks data for synchronization. The system uses four frequencies in the L band which ranges from 1.2 to 1.6 GHz [12].

4) ESP8266-12E: It also known as NodeMCU and Wi-Fi Module. It is an open source IoT platform. It includes the firmware which uses the scripting language called Lau. It is a low cost self-contained SOC with full TCP/IP stack that can give any microcontroller access to your Wi-Fi Network.

5) ECG Sensor AD8232: The electrocardiogram (ECG or EKG) is a diagnostic tool that is routinely used to assess the electrical and muscular functions of the heart. The electrocardiogram (ECG) has grown to be one of the most commonly used medical tests in modern medicine.

Assembled components are shown at Fig. 2. And Fig. 3.

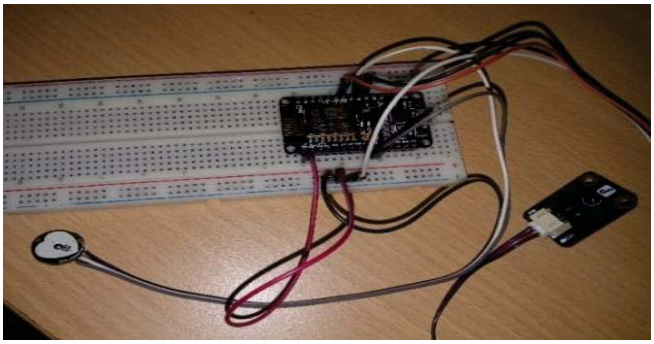

Fig. 2. Connections between sensors and Node MCU

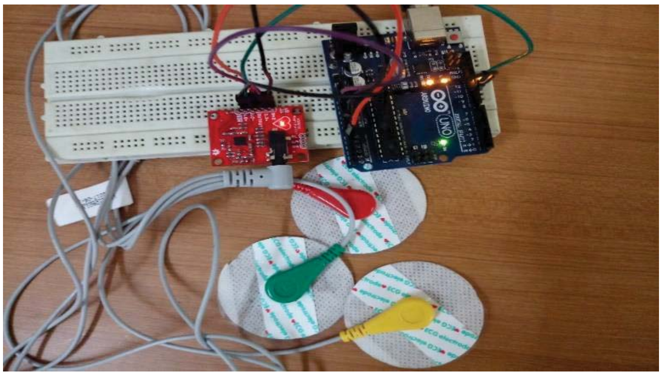

Fig. 3. Connections between ECG Sensor and Arduino

B. Collecting Dataset

Our Dataset includes two features taken into consideration i.e. body temperature and heart beat values. Body temperature is measured in degree Celsius and heart rate in beats per minute (bpm). This data is taken among individuals of age group 20-21 and assumption is taken into account about the gender of individual that it does not impact the emotion. We collected 115 data entries are shown in the Table I which were used in algorithm for training and testing.

TABLE I. TYPE OF DATA COLLECTED FOR TRAINING AND TESTING MACHINE LEARNING ALGORITHM

BODY TEMPERATURE (CELSIUS)	PULSE READING (BPM)	EMOTION CLASS
30.32	87.04	2
31.29	77.04	1
33.55	56.72	3
33.55	57.04	3
35.16	57.04	4

VII. RESULTS AND ANALYSIS

This system will predict emotion of an individual on the basis of his/her pulse rate and temperature. For prediction part, the paper used Machine learning classification algorithm i.e. naïve bayes classifier and K nearest neighbor classifier. The machine learning algorithm will take parameters like pulse rate and temperature from excel sheet which is directly linked with Arduino. For taking parameters from Arduino to excel, the paper have used Tera Term software. We have divided different ranges of temperature and heart beat value and assigned an emotion class to them. If a person's temperature lies in range of 37.5 to 38°C and bpm lies in range of 80 to 100 bpm, then he is happy (excited). If a person's temperature lies in range of 35–36°C and bpm lies in range of 80 to 100 bpm, then he is sad. If a person's temperature lies in range of 36.5–37.5°C and bpm lies in range of 50 to 80 bpm, then he is relaxed (normal) state. If a person's temperature lies in range of 37–38.5 °C and bpm lies in range of 95 to 120 bpm, then he is anger state.

Running python script, Fig. 4 shows the result to which class the input variable belongs to and what is the accuracy of the algorithm. There are about 113 samples in dataset out of which 25 percent is used for testing and rest 75 for training the algorithm. Input from user will be fed to algorithm which predicts the class to which emotion of the user belongs.

```
37.1
80
accuracy in %84.7
Happy(excited) state
```

Fig. 4. Results of Naïve Bayes Classifier

Pulse Rate Sensor's values are plotted on graph which is as shown in below Fig. 5. Through this graph it can be seen that each beat deviates the value by 400 on both the sides and the threshold for each beat can be kept a difference of 200 on any side.

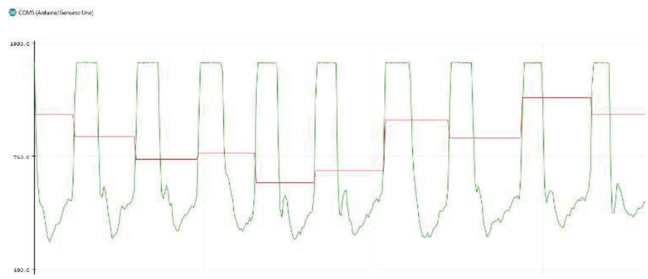

Fig. 5. Pulse Rate Sensor

Heart Rate is also measured using ECG sensor values Following Fig. 6 shows the different intervals and segments of an ECG wave. Atrial and ventricular depolarization and repolarization are represented on the ECG as a series of waves: the P wave followed by the QRS complex and the T wave [13]. The first deflection is a P wave associated with right and left atrial depolarization. Wave of atrial repolarization is invisible because of low amplitude. The second wave is the QRS complex. There are series of 3 deflections here. The first negative deflection is called Q wave. The first positive deflection is called R wave and a negative deflection after this positive deflection is called an S wave. ST segment follows the QRS segment which is followed by T wave.

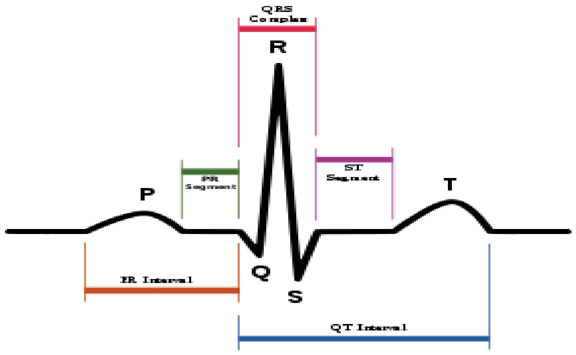

Fig. 6. Waves and Intervals on the ECG

Fig. 7. Depicts the series of ECG waves formed for a particular individual when measuring his/ her heartbeat using ECG Sensor. Our task was now after these waves to calculate the heartbeat of an individual. Normal range at rest is between 60-100 beats per minute (bpm). There are multiple ways to do that but the most basic way was to take the duration between two identical points of consecutive ECG waveforms such as the R-R duration divide it by 60, as in (2) [14]. The resulting equation would be:

$$Rate = 60/(R\text{-}R\ interval) \qquad (2)$$

Values from ECG sensor (heartbeat rate) and body temperature are then collected and K Nearest Neighbor algorithm is implemented to predict the class of emotion to which input variable belongs. K Nearest Neighbors takes k neighbors around an input variable and compute the distance from each of k neighbors. The most commonly distance used is Euclidean Distance which is special case of Minkowski Distance.

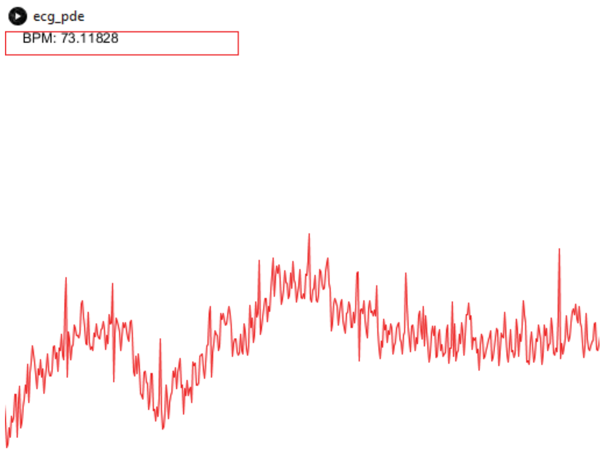

Fig. 7. ECG Sensor Wave Graph

K can be varied depending upon the number of samples and number of features in our dataset to get the most accurate prediction. Fig. 8 below shows the result of k nearest neighbor's algorithm. We have trained our dataset using 12 neighbors and as we can see from the Fig. 8 below decision boundaries are formed which separates samples belonging to one class from the samples belonging to another class. Red colored area belongs to samples with Happy Emotion class, Green color belongs to samples with Sad Emotion class, Blue color belongs to samples with Normal (relaxed) Emotion class and grey color belongs to samples with Anger Emotion class.

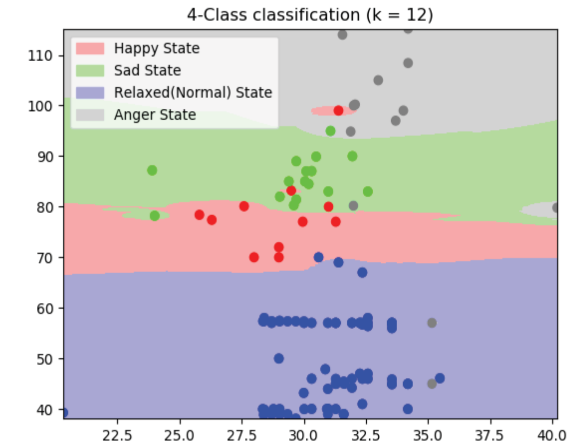

Fig. 8. Results of K nearest Neighbor

Thus by heart rate and body temp inputs the gadget starts learning about emotion pattern of each individual, and thus any divergence from the given pattern of emotion will help us find out the emotional state of human. So these data and graphs for an individual will act as first alarm. This paper also deals with analysing two different classification Algorithms. For k nearest neighbour, as k increases the score of the algorithm also increases and it fits the training model better and better to give more generalized decision boundaries as depicted in Fig. 9 and Fig. 10.

The figures clearly shows the deviation when k is set to 2 and when it is set to 15.

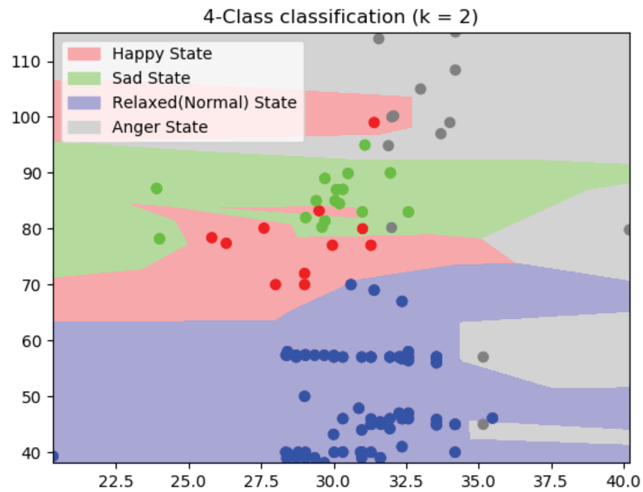

Fig. 9. No. of neighbor's k set to 2

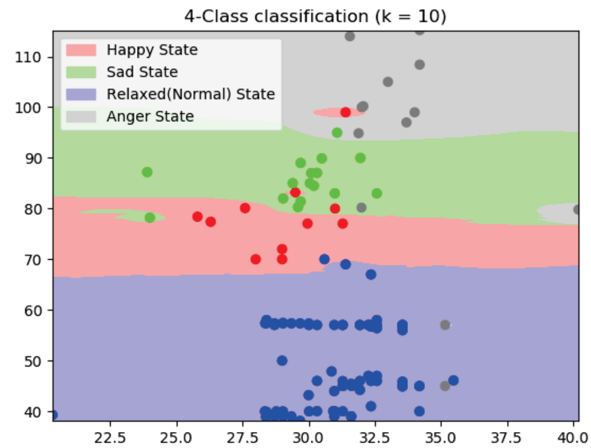

Fig. 10. No. of neighbor's k set to 10

As K changes from 2 to 10, our decision boundaries get more generalized and accurate. For our project, accuracy changes from 79% to 83% when k changes from 2 to 15. This change in accuracy will be more significant when we deal with larger datasets. Naïve Byes is based on independent probabilities whereas KNN is not a probabilistic model. Also, for small dataset like used in this paper, KNN gives better results as compared to Naïve Bayes. Comparing with respect to processing times, KNN is much slower as compared to KNN. These algorithms also depends on the number of features in the training sample and give different scores.

V. CONCLUSION AND FUTURE WORK

In this paper, we developed human emotion recognition system, based on data from the physiological sensors. Research helped us in providing the different ranges of these physiological parameters which were measured to predict different type of emotions. We have developed the embodiment of the concept by just taking into account two physiological parameters i.e. body temperature and heart rate. For future work, improvement and development of system can be done with use of additional parameters such as blood pressure, respiration, sweat and skin conductance value will help to predict the emotional state of an individual with higher accuracy. Also, as part of future work, wearable device can be designed which is personalized for an individual. It keeps a track of emotions for an individual and can be helpful in monitoring his/her health, alarms can be set up by setting a threshold value for a particular individual by learning his trend of emotions which will be different from another person. So, it will deal with the individual data and secondly the threshold for alarm is not preconfigured. It calculates the threshold for every individual by applying machine learning techniques. Also, this type of system can be modified to detect the stress levels along with emotions which further aids in managing the stress levels of an individual. Another thing which can be developed, for future improvement is to make lie detector system (Polygraph) as ECG sensor is used for that purpose.

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