Emotion Recognition
"An Optimized Approach using RF Signals"

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***Abstract*—** For a better human computer interaction Emotion recognition has become an emerging field and has attracted much interest from both research and industry. Emotions are expressed by a person's speech, facial expressions and written text also known as speech respectively. The goal of this research is to show the comparison of various recognition systems and concluding one in terms of efficiency, complexity and accuracy. In this paper we also present a new technology to understand individual's emotion using RF signals. Radio transmitter transmits the RF signal and analysis of its reflections off a human's body is done at the receiver end for emotion recognition. Individual's heartbeat is extracted using RF signals and then it is used to calculate emotion-dependent features to recognize emotions.

Keywords*—emotion recognition, RF signals, facial expressions, speech recognition, EQ-Radio.*

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I. INTRODUCTION

Emotion recognition has attracted both industry and research community to sense a person's emotion so that we can build such machines or devices that can sense our emotions in a manner similar to how we interact with each other. Existing approaches are based on audio, images and texts and in physiological approach a person need to wear sensors like ECG monitor to measure heartbeats and correlate these changes to emotions like anger, joy, etc. In audiovisual based approach a person may hide his emotions for example, the person may be happy but he is not smiling or he may be smiling but not happy inside. Therefore these approaches are able to recognize outward expression of emotions but cannot measure inner feelings. In physiological approach person need to wear on-body-sensors which is cumbersome and it also interfere with user activity and emotions, thus not suitable for regular usage. RF based emotion recognition do not require user to carry any sensor and directly measures the physiological signals like a person's breathing and average heart rate without body contact.

II. VARIOUS EMOTION RECOGNITION TECHNIQUES

A. Emotion recognition using facial expressions

Human face plays a very important in communication and can express feelings through emotions. Various facial recognition techniques are used to extract features from the images to recognize emotions:

1. Principal component analysis (PCA)

In PCA data is expressed to highlight similarities and differences to identify patterns in data. Features are extracted using eigen faces. Training dataset is created and pre-processed input image is compared with the training data set to recognize emotion like Happy, Sad, Disgust, Surprise, Fear, Anger [10].

2. Local binary pattern (LBP)

LBP based feature extraction is method is having low computational complexity. In this method neighbourhood values are threshold by centre value as a binary number. If neighbour's value is less than centre value then write 1 otherwise 0. It is an easy and efficient method [11].

3. Active appearance model (AAM)

It is an statistical approach that have been extensively used in computer vision applications. This technique is used for feature extraction, shape and texture modelling [12].

4. Facial action coding system (FACS)

FACS is based on the analysis of relation between changes in face appearance due to muscle contraction. Face is divided into lower face action units and upper face action units. Changes in these units are caused by one or more muscles contraction. 46 action units represent changes in facial

expressions and 12 action units are connected with head orientation and eye gaze direction [13].

5. Haar Classifier

This process is having high detection accuracy and real time performance It consists of black and white connected rectangles and value of feature is calculated as the difference of sum of pixel values in black and white regions [11].

B. Emotion recognition using speech signals

Identification of emotional state of a person from his voice. It consists of four main modules: Speech input signal, feature extraction, classification and emotion output.

a) Speech input signal is given to a speech processing system to extract information such as pitch and energy.
b) This information is then reduced to a set of features.
c) Classifier associates these set of features to the emotion to provide an emotional output.

1. Feature Extraction

a) Energy and related features

In speech signal energy is a most important and basic parameter. Short-term function is used to extract the value of energy in each frame and then energy in whole is calculated using max value, variance, mean, contour of energy and variation range.

b) Pitch and related features

Pitch frequency is vibration rate of vocal. It depends on the vocal folds tension and sub glottal air pressure that gives the information about emotion because mean of pitch, variation range, contour and variance is different for basic emotional statuses.

c) MFCC features

MFCC (Mel-frequency cepstral coefficient) is an effective method for voice recognition. It is an important feature of speech with good frequency resolution in low frequency region, anti noise properties with good ability of distinction.

d) MEDC features

MEDC is similar to MFCC with the only difference that in MEDC logarithmic mean of energies is taken after MEL filter bank and frequency wrapping and in MFCC logarithmic value is taken after MEL filter bank and frequency wrapping and after that first and second difference about this feature is computed.

e) Linear prediction cepstrum coefficient

Extraction of feature coefficients from different channel characteristics is done to identify the emotions contained in a speech. LPCC is computed by the recurrence of linear prediction coefficients (LPC).

2. Classifiers

Classification algorithm is applied to extract features from emotional speech.

a) Support vector machine (SVM)

As compared to other classifiers it has a very good classification performance under limited training data and is widely used for pattern recognition. It converts input set to a high dimensional feature space by using kernel function.

b) Hidden Markov Model (HMM)

In HMM internal behaviour of model remain hidden from the observer. For emotion recognition data is sorted and features are extracted from input waveform then a database is created. Transition and emission matrix are made and random sequences of states and emissions are generated. Finally using Viterbi algorithm state sequence probability is estimated.

c) Gaussian Mixture Model (GMM)

GMM is a special case of continuous HMM based on the probabilistic model for density estimation. It is very efficient in emotional recognition due to its lower requirements for training and testing.

d) K Nearest Neighbour

Nearest neighbour technique is one of the most traditional techniques under statistical pattern recognition. Distribution of training examples are considered rather than priori assumptions and training of all cases is involved. By calculating the distance to nearest training case, new sample is classified. Effect of noisy points is reduced with larger values of K.

C. Emotion recognition using Physiological devices

In this method physiological signals like Blood volume pulse (BVP), Skin conductance (SC), Skin temperature (SKT), Electromyography (EMG), Respiration (RESP) are extracted using various sensors to extract features for recognition. These signals are provided as input to the classifiers such as Two pattern classification method, SVM and Fisher discriminant to compute the emotional state of the person.

D. Emotion recognition using RF signals

This method directly measures the emotions including physiological signals, in this technique user do not require to carry sensors on his body. It uses RF signals which are transmitted by EQ-Radio to sense emotion. These RF signals reflect off the human body, get modulated by body motion and are used to measure person's breathing rate and average heart

rate without any body contact. Classification of emotional state is based on arousal-valence model. The algorithm consists of three components: FMCW Radio, Heart-beat extraction algorithm takes and an Emotion classifier. [5]

FWCW Radio is used that transmits the RF signals and captures their reflections off the human body. Beat extraction algorithm captures takes these captured reflections and provides a series of signal segments that corresponds to individual's heartbeat. Emotion classification sub-system computes relevant features and use them to recognize person's emotional state. [5]

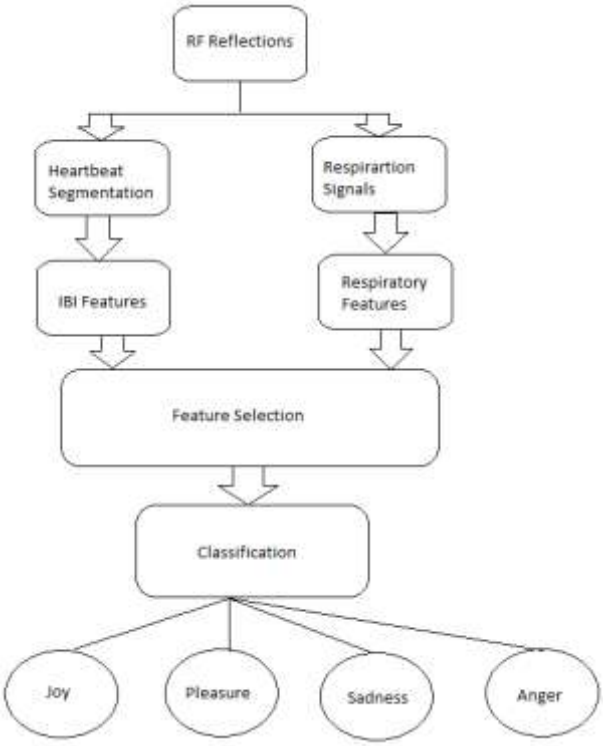

Fig. 1. *Overview: Three components of emotion recognition using RF signals, Radio for capturing RF reflections, heartbeat extraction algorithm and classification sub-system.*

TABLE I. Emotion recognition using RF signals vs Speech and Physiological Method

Method	Accuracy (%)
GMM	73.86 [1]
HMM	72.65 [2]
SVM	62 [3]
KNN	62 [4]
Physiological devices (ECG-Based)	88.2 [5]
EQ-Radio	87 [5]

Facial expressions techniques can recognize emotions only when a person explicitly expresses his emotions on his face and it cannot detect innermost emotions. Positive emotions, (eg. Happiness) are more visible as compared to negative emotions as these are visually closer to neutral state. From Table I we can also conclude that the efficiency of emotion recognition using RF signals is more as compared to speech signals and also RF method achieves comparable accuracy to emotion detection that uses physiological devices like, on-body sensors. Therefore, elimination of on-body sensors is possible without jeopardizing the accuracy.

Conclusion

In this study, the overview of different emotion recognition methods is discussed. Emotion recognition using facial expressions is not an efficient way to recognize person's emotions since it cannot detect inner feelings. Emotion recognition using speech is better than emotion recognition using facial expressions but here also emotions can be easily controlled or suppressed. Emotion recognition using physiological devices provides better results but it can also interfere with the person's emotions since he'she has to wear sensors on their bodies. In this growing era of wireless technology we believe that RF technology is capable of recognizing person's emotions without interfering with them. The accuracy of such systems will improve with improvement in wireless sensing technologies, advanced machine learning mechanisms for sensing purposes for emotion recognition, health monitoring and diagnosis.

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