Study of the Changing Trends in Facial Expression Recognition

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ABSTRACT
Enrichment of knowledge becomes possible only through literature search on any topic of interest. It is true even in the case of 'Facial Expression Recognition'. So it is attempted to have a broad look into the origin and development of 'Facial Expression Recognition' in the recent past. It has been developed, into a topic of interest, only after the contributions made by Ekman and Friesen. Though there are many expressions yet to be recognized, significant contributions are made by many eminent scholars to identify the six primary emotions viz. happiness, sadness, fear, disgust, surprise and anger. In this paper, we attempted to bring to lime light some of the important contributions on the subject.

General Terms
Facial Expression Recognition, Facial Expression Measurements, Emotions.

Keywords
Action Units, Intensity Measurements, Image Ratio Features, Caricatures, Feature Points.

1. INTRODUCTION
Facial expressions are the means to convey emotions, feelings, warning signs of dangers, happiness, disappointments, confidence etc. of man. It is injected into the living things from the womb to tomb. Psychologists, Saints and Men of spirituality consider facial expressions as indications of hidden truth and exposition of sudden feelings, in the right way, at the right time without any reservations.

In man, facial expressions were well studied, since 1971 by the pioneers Ekman and Friesen [2]. Even in the theory of evolution of Darwin [1], there are reminiscence of the rule of automatic facial expression, to grab new shapes and intelligence in the transformation process of one animal into another. Ekman and Friesen [2] are acclaimed of their contributions to the postulation of six primary emotions - happiness, sadness, fear, disgust, surprise and anger. These six distinctive facial expressions are unique in their feature.

In India, the scope of facial expression had been recognized from the very past through variety of classical dance forms like Bharathanatyam, Kathak, Kuchipudi, Odissi, Manipuri, Kudiyattam, Kathakali and others. In all these art forms, the role of facial expression is well depicted to convey the emotions of characters, popularly known as Navarasa [36] [43] (Figure 1). 'Navarasa' means nine emotions, in which 'Nava' signifies nine and 'Rasa' signifies emotions. These nine emotions include Shringara (romance or love), Hasya (laughter or ridicule), Karuna (kind-heartedness or sorrow), Raudra (anger or wrath), Veera (courage or valour), Bhayanaka (fear or terror), Bheebhatsya (horror or disgust), Adbutha (surprise or wonder), and Shantha (peace or tranquillity). Out of these nine areas of facial expressions (emotions) that are depicted and enacted in these art forms, only six basic emotions — sadness, fear, disgust, surprise and anger were attempted by Suwa et. al. [4] and Mase and Pentland [9].

In the areas of research, lots of controversy still exist that 'Facial Expression Recognition' is distinct to 'Human Emotion Recognition' (B Fasel and J Luettin [25]). However, it appears that facial expression is a mirror image that is being reflected on the face, which gives scope for facial expression recognition to expose the hidden truth and feelings of human mind.

2. ORIGIN AND SCOPE OF FACIAL EXPRESSION ANALYSIS
Emotions often come out as gestures, postures and even body languages in human beings. It may attain different forms with or without voice modulation to convey different needs, feelings, and anticipation.

Initially, automatic facial expression was of great concern to psychologists but later it gained momentum due to its application for face detection, face tracking, face recognition, image understanding, facial nerve grading [23] in medicine etc. Now, around the globe researches are being conducted on different areas like facial image compression, synthetic animation [24], video-indexing, robotics and virtual reality in addition to psychological studies.

Various studies put forward many hypotheses, of which the most important one is that facial expression is a composite effect of mental state and physiological activities that attained exposition through verbal and non-verbal communications. Though mental state of the individual is of prime importance, it will be influenced by felt emotions, communication and cogitation. Similarly, physiological activities will be determined by manipulators, pain and tiredness. As a result of these composite influences and complexity, optimum accuracy still remains intricate. In fact, variety of facial expressions cannot be subjected to proper analysis and interpretation with the same type of facial expression measurements [20], [28], [29], [34].

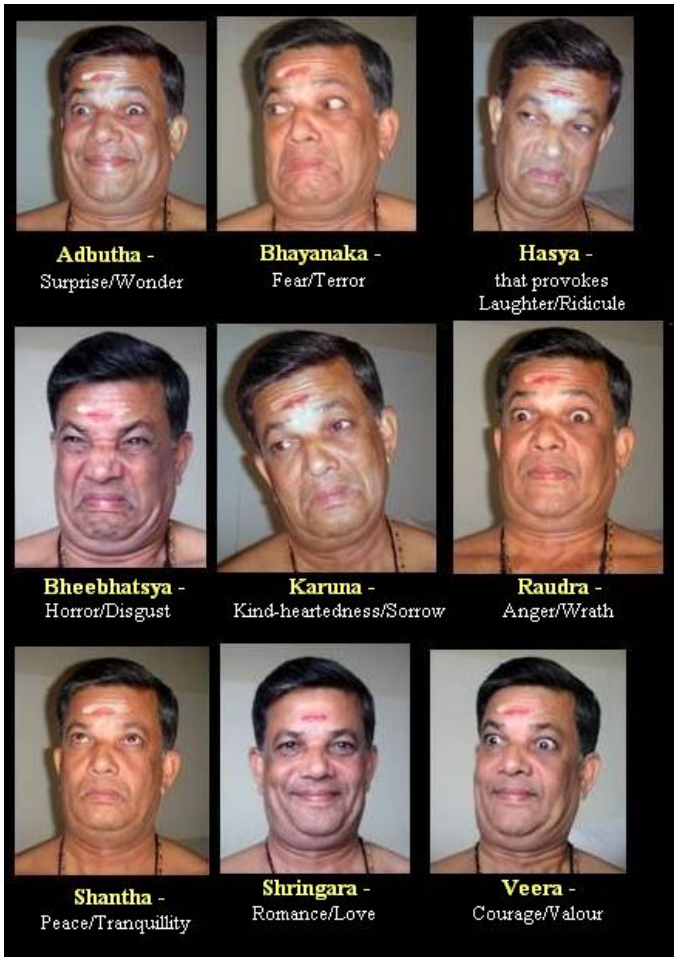

Fig 1: Navarasa – The Nine Emotions [43]

3. EVOLUTION OF FACIAL EXPRESSION MEASUREMENTS

The origin of Facial Expression Measurements can be traced back to simple observation of similarity and dissimilarity in facial expression with respect to various emotions like happiness, sadness, anger, surprise etc. It is primarily related to observation of face movements with respect to eyes, nose, lips [12] etc. Later, it gave way to real measurements of Facial Expressions. Then it started to measure the facial features such as eye lids, eye brows, nose etc. in comparison to vertical face.

It is further evolved into recording of duration of time, up to which a facial expression lasts. Also, there are certain measurement tools, came into picture for describing facial expressions. It was necessitated due to short time changes of muscular activities. At this stage, the facial expression measurement was primarily based on location of facial action, how much intensity was observed along with its dynamics etc. It was made possible through measuring geometric deformation of facial features or density of wrinkles appearing. The major challenges faced by the researchers at this juncture were the wide range of interpersonal variability in facial actions and expression intensities.

3.1 Expressive Expression Mapping with Ratio Images

In the paper [27], the authors Zichen Liu et. al. encountered with the illumination change of one person's expression by computing Expression Ratio Image (ERI) to generate more expressive facial expressions of any other person. Prior to this, T.F.Cootes [21] et. al. attempted to compare Active Shape Model (ASM) [11] with Active Appearance Model (AAM) [14] by means of MRI (Magnetic Resonance Imaging) brain sections. It was found that, ASM is faster and achieves more accuracy in feature point location than AAM, though it gives a better match to textures.

3.2 Facial Intensity Measurements

It was difficult to explain facial expressions by simple measurements of wrinkles or textures. So, facial expression intensity measurements were also started. Again, it was further evolved that simple static images do not clearly depict subtle changes in faces and hence accurate timings were also recorded as yet another facial expression parameter. Accordingly, three important temporal parameters viz. onset (attack), apex (sustain), offset (relaxation) were studied. The reliability of these facial measurements was often subjected to errors, since it was being done by human coders. The Facial EMG (electromyographic) [3] was extensively used for automatic computation of onset and offset of facial expression. Accordingly, two different methodological approaches came into existence viz. (i) Judgment based and (ii) Sign vehicle based [7].

'The Judgment-based assessment' of facial expression centered on specific pre-defined facial patterns of mental activities. This is generally coded by more than one coders and average of such coding patterns, is usually taken into account [2] for interpretation.

In sign-based approaches, facial motion and deformation are coded into visual classes [5]. In this method, location of facial action and intensity are given prime importance. Rather, it is appearance-based and mental stature has basically no role or only limited role. Thus in this case, a complete description of frame work with all possible perceptible signs on face, are recorded. To attain accuracy in sign based approaches, FACS (Facial Action Coding System) made use of 44 Action Units (AUs) for the description of facial actions and intensity. In this case the intensity is often assessed in 3 or 5 levels of magnitude. It can be modeled as single action units or action unit combinations. In order to attain compactness in interpretation Friesen and Ekman [8] later developed Facial Expression Dictionaries. Also, Ekman [15] et. al. was the pioneers in presenting a database called FACSAID (Facial Action Coding System Affect Interpretation Database).

3.3 Line Based Caricatures

Facial recognition often becomes difficult from a single static image. So Gao [30] et. al. demonstrated a simple method for facial expression recognition from line-based caricatures. In this method, structured and geometric features are drawn as line based caricatures. It is proved to be very effective in real time applications due to its cost-effectiveness. Here, line matching is attained through user sketched expression models over the Line Edge Map (LEM) [22] descriptor of the input face image.

3.4 Higher Order Singular Value Decomposition (HOSVD)

Higher Order Singular Value Decomposition (HOSVD) [26] is a simultaneous face and facial expression recognition algorithm. It is made possible by the development of expression sub-space and person sub-space images for seven basic facial expressions. Then, the facial expression that is to be recognized will be subjected to comparison with the expression sub-space model developed by Wang and Ahuja [31]. This method had the limitation that, the expressions of people with unforeseen characteristics such as beard were not synthesized.

3.5 Dynamics and Active Visual Information Fusion

Temporal behavior of facial expression is dealt with in 'Facial Expression Understanding in Image Sequences Using Dynamic and Active Visual Information Fusion'. This method of facial expression detection appears to be more accurate and robust. In this, the authors [32] demonstrated a probabilistic approach with Dynamic Bayesian Network (DBNs) Model. They used the Facial Action Units (AUs) [8] to provide a coherent and unified hierarchical probabilistic frame work. It represents spatial and temporal information on facial expressions. Then, the most informative visual cues are selected from the available information to minimize the confusion in recognition.

3.6 Feature Points Tracking

Feature Points Tracking [18] using RBF Neural Network and Fuzzy interface system (FIS) introduced by Seyedarabi [35] et. al. opened up new vistas of knowledge in recognizing the six universal facial expressions. In this study they suggested two entirely different systems for classifying expression using feature point tracking viz. RBF (Radial Basis Function) classifiers and FIS (Fuzzy Interface System) classifiers [33]. These innovations made the facial feature extraction possible from facial characteristic points in front image sequence of continuous video points. Ultimately, they tried to evaluate the comparative effectiveness of RBFN and FIS by deducing a feature vector from the feature points. In fact, RBFN classifier turns out to be superior to FIS in providing better recognition rate. Still, it needs more processing time and hence FIS classifier appears to be superior, for real time implementation.

3.7 3D Face Pose Recovery and Facial Expression

Zhiwei Zhu and Qiang [39] derived a technique based on Singular Value Decomposition (SVD) [13] which can recover 3D face pose and facial expression simultaneously from a monocular video sequence in real time. This is the concept envisaged in their paper on 'Robust Real Time Face Pose and Facial Expression Recovery'. This real time system is proved to be robust and accurate in extracting the face pose and facial expression parameters of a user, by simply posing to a camera without black make-ups or markers. In the mean time, yet another paper was published by J. Shi [37] et. al. to assess the effectiveness of landmarks and their geometry for face recognition.

3.8 Comparison of Biologically Inspired Encoding with Logic Encoding

Face is considered as an important communication medium in human beings. So M.F. Valstar and M. Pantic [40] attempted to compare the level of detection of emotions directly from features with those of a logic inspired encoding of facial actions and emotions video. Later, the authors attempted to understand the image sequence using dynamic and active visual information fusion [34]. Thereafter a real-time automated system for the recognition of Human Facial Experience was evolved by Keith Anderson and Peter W. McOwan [38]. This has been demonstrated in two simple affective computing applications that respond in real-time to the facial expressions of the user, in providing potential for improvements in the interaction between a computer user and technology.

3.9 Optimal Feature Selection

The movement of still photograph frames in continuum makes meaning in cinema. Like-wise the automatic facial expression frames in continuum make meaning to elicit truth, desires etc. in optimal feature selection, at times. A similar analogy has been described by Lajevardi and Lech [41] in their paper on facial expression recognition from image sequences. The procedure was fully automatic and the different frames were in sequence for face detection, maximum arousal detection, feature extraction, selection of optimal features and facial expression recognition. The authors centered on the selection of facial features and the classifier design. Proper facial feature selection envisages deriving a set of features from the original face images. It maximizes the 'between class variations' and minimizes the 'within class variations' of different frames. The classifiers are used to recognize the results accurately. Even the best classifier will be able to give better results, provided the adequate features are used.

In the facial recognition system the sequence of images are the pre-requisites. Such images are filtered for the selection of the optimal image using MIFS (Mutual Information Filter System) [10] for training and classification. The facial extraction is usually done either by geometric feature based method or appearance based method. Donato [20] et. al. demonstrated Gabor Wavelet appearance featuring that gives better results than geometric features [16]. It is computationally expensive to convolve the face images. Also, it has got the limitation that the maximum bandwidth of a Gabor filter is limited to approximately one octave and they are not optimal, when the objective is to achieve broad spectral information with the maximum spatial localization.

3.10 Image Ratio features for Facial Expression Recognition

Mingli Song [42] et. al. developed a new method for facial expression analysis. In this study, they attempted the facial expression recognition through video-based computer vision. They proposed a new texture feature to solve the problem, which is known as 'Image Ratio Feature'. Here, facial animation parameters [17] are designed to detect the subtle changes in facial features and image ratio features are used to capture the intensity changes. It is proved to be more robust in albedo and lighting variations and has gained improvement in facial expression recognition accuracy.

Table 1. Comparing methods for facial expression recognition

Reference	Method	Test Database	Accuracy
Irfan A. Essa and Alex P. Pentland[12]	Optimal optical flow method is used to sense the expressive articulations of face which is tied to a physical model which computes the muscle control variables. Using these control parameters facial pattern is recognized.	Own Database, Cohn–Kanade[44] and Japanese Female Facial Expression Database[45]	98.0%
Zhang Z [16] et. al.	A two - layer perceptron architecture is used to make a statistical decision in which, facial expression is to be associated for the geometric positions provided as input to the system. The geometric positions are extracted from a set of fiducial points identified from the face.	Own Database	73.3%
Zhang Z [16] et. al.	Set of multi-scale and multi-orientation Gabor wavelet coefficients are extracted from the face image at the fiducial points. These are provided as inputs to a two layer perceptron to further explore on the type of facial expression.	Own Database	92.2%
Zhang Z [16] et. al.	Combines geometric position of a set of fiducial points with a set of Gabor wavelet coefficients for better facial feature extraction. This is further fed into a two layer perceptron to efficiently recognize a facial expression.	Own Database	92.3%
Donato [20] et. al.	Facial motion identification using estimation of optical flow, holistic spatial analysis and performance evaluation using Gabor wavelet representations and local principal components.	FERET Database[19]	96.0%
Liu [27] et. al.	Expression ratio image is used to capture visually important details of facial expressions.	Own Database	-
Bartlett [28] et. al.	Gabor magnitude representation of images is used to train the Support Vector Machine (Linear or RBF kernels) or Adaboost or AdaSVM classifier to further classify the facial expressions.	Cohn–Kanade Database[44]	-
Cohen [29] et. al.	A new architecture based on Hidden Markov models (HMMs) was used for automatically segmenting and recognizing human facial expression from video sequences.	Own Database and Cohn–Kanade Database[44]	-
Gao [30] et. al.	Sketched expression models are line matched over LEM descriptors for expression recognition of still images.	AR Face Database[46]	86.6%
Wang and Ahuja[31]	HOSVD based facial expression decomposition is used to model the mapping between persons and expressions.	Pictures of Facial Affect Database[6]	84.9%
Zhang and Qiang[32]	Make use of a multisensory information fusion technique with Dynamic Bayesian networks (DBNs) for facial expression recognition.	Cohn–Kanade Database[44]	-
Seyedarabi [35] et. al.	Feature vectors formed from feature points were used to train the RBFN classifier to classify the facial expressions.	Cohn–Kanade Database[44]	91.6%
Seyedarabi [35] et. al.	Rule base is used in FIS classifier to classify input feature vectors into one of the six basic emotions.	Cohn–Kanade Database[44]	89.1%
K. Anderson and P. W. McOwan[38]	Motion averaging strategy is coupled with Support Vector Machine classifier to recognize the facial expressions in real time.	Cohn-Kanade Database[44]	81.8%
Zhu and Qiang[39]	N-SVD method (Normalized Singular Value Decomposition) is used to estimate the face pose and expression parameters.	Own Database	83.5%
M. F. Valstar and M. Pantic[40]	Emotions are detected from AUs by Artificial Neural Networks or using a rule base.	Cohn-Kanade Database[44]	93.2%
Lajevardi S.M and Lech. M[41]	Performs MIFS facial expression classification using the Naïve Bayesian classifier.	Cohn–Kanade Database[44]	79.5%
Mingli [42] et. al.	Facial expression recognition is carried out by combining image ratio features with facial animation parameters and classifying using Support Vector Machine.	Own Database, Cohn–Kanade[44] and Japanese Female Facial Expression Database[45]	85.2%

4. DISCUSSION

'Facial Expression Recognition' is a challenging research topic in recent years. It spreads its wings, not only in psychological domain but also in Medicine, Law, Criminology, etc. for corroborative evidence. It is attained by way of face detection, face tracking, face recognition, image understanding, facial nerve grading etc.

The present paper gives a comparative study and analysis of 'Facial Expression Recognition Technology' along with its progressive growth and developments. During the days of Ekman and Friesen, the major challenges were interpersonal variability in facial actions and expression intensities. Also, simple static images were not enough to describe subtle changes in faces. So the important temporal parameters — onset, apex and offset — were also taken into account. Then Facial EMG has come into picture. Also judgment based and sign vehicle based approaches find their way for accurate face detection. In sign based approaches, facial motion and deformation are coded into visual classes. Later, FACSAID came into existence.

In order to minimize the cost-effectiveness, line based caricatures were attempted. A simultaneous face and facial expression recognition algorithm replaced, the then existing system, which was developed through HOSVD. This algorithm gave prime importance to the neutral face expression in addition to the six basic facial expressions. Subsequently, the temporal behavior of facial expression was dealt with facial expression understanding in image sequences using dynamic and active visual information fusion. In this case, Bayesian Network model was experimented. In the meantime, Seyedarabi et. al. made a comparative study on RBF classifier and FIS classifier. They have identified the key features of both the classifiers, when used to classify facial expressions from continuous video sequence.

Zhiwei Zhu and Qiang developed a new technique to recover 3D face pose and facial expression simultaneously from a monocular video sequence in real time. Also, expressive expression mapping with radio images made its presence for facial expression recognition. Besides, Valstar and M. Pantic attempted to compare the level of detection through biologically inspired encoding and logic encoding.

In course of development, facial expression recognition from image sequences acquired importance. In this direction Mingli et. al. made significant contributions through their invention on image ratio features.

5. SUMMARY

Facial Expressions are the means to convey the emotions, feelings, happiness, descriptions etc. Initially, psychologists considered it as an important tool to study human behavior but later the automatic facial expression analysis gained momentum due to its application for face detection, face tracking, face recognition, image understanding etc. In course of time, facial expression turned out to be an important tool to measure the mental and physiological attainment of exposition through verbal and nonverbal communications. Though facial expression measurements started with simple observation at the outset, later it became an important measure of facial intensity. Also, significant focus was given to feature points and image ratio features. The important milestones in Facial Expression Recognition researches were judgment and sign based approaches, facial expression recognition from image sequences, expressive expression mapping with ratio images, selection of optimal image using MIFS, line based caricatures, higher order singular value decomposition, dynamics and active visual information fusion, facial feature point tracking, 3D face pose recovery and facial expression, comparison of biologically inspired encoding, image ratio features for facial expression recognition etc (Table 1).

6. CONCLUSION

Facial expressions are the basic instinct of human beings to express sudden feelings of spontaneous outburst of nine emotions illustrated in Indian art forms. Out of these nine emotions, researchers have succeeded in detecting six basic expressions only. The present study is an attempt to elicit the scope of some important developments in automatic facial expression recognition and its applications.

Initially, the facial expression measurement was provided on the basis of the location of facial expression. It was far from satisfactory due to its static nature and lack of intensity measurements. The facial EMG has made a revolutionary change in the computation of automatic change in onset and offset of facial expression. The inadequacy due to static nature has been rectified with the introduction of facial expression recognition through image sequence. The expressive expression mapping with ratio images made it possible to measure the change of one person's expression by computing expression ratio image to generate more expressive facial expressions of any other person. The defect due to expression measurement was rectified at a certain extent with the introduction of facial intensity measurement. A simple and useful method, then evolved for expression recognition, was based on line based caricatures. The invention of HOSVD was a revolution in facial expression recognition due to its earmarking of expression subspace and person subspace.

The lack of clarity in detecting temporal behavior of facial expression has been attempted through dynamics and active visual information fusion. Classifying facial expression based on RBF and FIS is yet another novel approach for facial expression recognition. RBFN classifier has been proved to be more effective in providing better recognition rate, but FIS classifier appears to be more successful for real time implementation. The innovation of 3D face recovery and facial expression method was yet another milestone in the facial expression recognition research. Also, the variation due to albedo and lighting has been taken care of, by the new invention of image ratio features. Facial Expression Recognition is a fast developing human computer interface. It can be developed into a vital tool to elicit hidden truth, level of understanding of lessons by students, level of capability assessment during interviews, severity of illness and diagnosis etc., provided the methodologies are refined and tuned up to cope up with the new requirements with maximum precision.

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