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# Face Detection and Expression Recognition Using Fuzzy Rule Interpolation

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***Abstract* -** humans make use of facial expression to communicate in their day to day interactions with each other, which comes naturally without much effort. Facial expression is essentially a communication and interaction between humans and where other information like speech is not available; it becomes what one can depend on to transmit emotion or reactions of an individual. Hence, human expression recognition with high recognition is still an interesting task. This study is aimed at implementing face detection and expression recognition using fuzzy rule interpolation (FRI) technique. This follows through a development of specifications for fuzzy rule interpolation in emotion recognition using the viola jones algorithm as the detection algorithm and local binary pattern (LBP) algorithm for the feature extraction. The extended Cohn Kanade (CK+) face database was used for the experimentation of the system. The classification of the various expressions was achieved by the image category classifier of Matlab.

***Keywords* -** Fuzzy Rule Interpolation, Viola Jones Algorithm, Local Binary Pattern, Human Computer Interaction, Region of Interest, emotions, Compositional Rule of Inference, Sparse Rule.

## I. INTRODUCTION

Face detection and expression recognition has been around for a while now and lots of researchers have toed this area of research in recent times; in a bid to increase interaction speed. According to [1] face is the most important focus of attention in social intercourse, playing a foremost role in conveying identity and emotions and the ability for humans to recognize faces is outstanding. Verbal and nonverbal communications are two main aspects humans transmit messages and facial expression is one of the primary units in nonverbal communication [2],[3]. In other to make possible the interactions between humans and machine, it is important to develop automated facial recognition systems [4],[5]. They attest that Charles Darwin was the first to make discussions on the universality of emotions which he said are mental reaction embossed in the nervous system. Before Paul Ekman in the 1970s categorized the facial expressions into six senses where each sense symbolizes a given emotions like happy, anger, sad, disgust, surprise and fear. The American psychologist Robert Plutchik created an emotion wheel were he introduces eight basic emotions divided into four pairs which are acceptance – disgust; joy – sadness; anger – fear; surprise – anticipation. Ekman and his team developed the Facial Action Coding System (FACS) that describes human facial expressions based on some action units (AUs) [6],[7].

Expression recognition system follows a step by step procedure that comprises of face detection, feature extraction and expression recognition or classification [8]. This paper is aimed at increasing the interaction between humans and computers in transmitting emotions with high recognition [2],[9] using fuzzy rule interpolation (FRI). Fuzzy Rule Interpolation is used to produce inferences and in handling situations where there are sparse rule to drawing conclusions [10],[11]. This was achieved by the acquisition of facial image, detection of the face with the Viola Jones Algorithm, extracting the features with Local Binary Pattern and recognizing the expression using Fuzzy Rule Interpolation. A specification is to be developed for the FRI using the Cohn Kanade facial expression image dataset for the experimentation.

The rest of the paper is organized as followed: section I contains introduction of expression recognition, Section II contains the Related Work of different expression recognition techniques, section III contains the architectural and the essential steps of the expression recognition system, section IV explains the methodologies and use case diagram of the system, section V describes the result and discussion

 

system are presented, section VI concludes the research work and give recommendations for further studies

## II. RELATED WORKS

Ioannou et al, presented expression recognition through facial expression analysis using Neurofuzzy Network. The neurofuzzy system allows for further learning and adaptation to specific users' facial expression characteristics. They combine psychological findings about emotion representation with analysis and evaluation of facial expression and a neurofuzzy rule based system was created and used to classify facial expressions [12]. The Multiple Adaptive Neuro Fuzzy Inference System (MANFIS) model was used by the authors, in this paper; they proposed neuro-fuzzy based automatic facial expression recognition system to recognize the human facial expressions of the seven principal expressions [13]. Neural Network was also used to design an automatic facial feature extraction and expression recognition system. Feed forward back propagation neural network was used as the classifier for classifying the expressions of supplied face into seven basic categories [8]. Emotion recognition was carried out based on fuzzy rule system. The extracted data fed into a fuzzy rule – based system was used to classify 6 facial expressions [14]. Emotion recognition through facial expression analysis in merged images was used to classify 6 facial expressions only that he used Artificial Neural Network with concentration on the eyes and mouth regions [15]. A dynamic facial expression was approached with Atlas Construction and Sparse Representation. The Dynamic facial expression recognition was formulated as a longitudinal GroupWise registration problem. Their method was of two stages, atlas construction and recognition stage [16]. Facial expression was recognized using fuzzy art. This was done by segmenting and localizing the individual frames into regions of interest [17]. These authors explored this expression recognition in real time using the geometrical feature extraction method that was able to recognize emotions in real time [2]. An effectual approach for facial expression recognition was proposed and Adaptive Neuro-fuzzy classifier was also used to classify five principal expressions [9]. These authors classify and recognized facial expression on static images, classifying four basic emotions which are neutral, happiness, sadness and surprise [18]. Viola Jones Algorithms VJA and local binary pattern histogram (LBPH) were also applied for detection and feature extraction of a face for facial recognition system. They were able to detect facial image with side views using the Viola Jones algorithm [19].

## III. ARCHITECTURE OF THE SYSTEM

The architecture of the expression recognition system is captured in figure 1 which shows structurally the implementation part of the system and its subsystems determining the logical structure of particular modules and how they interact with other modules.

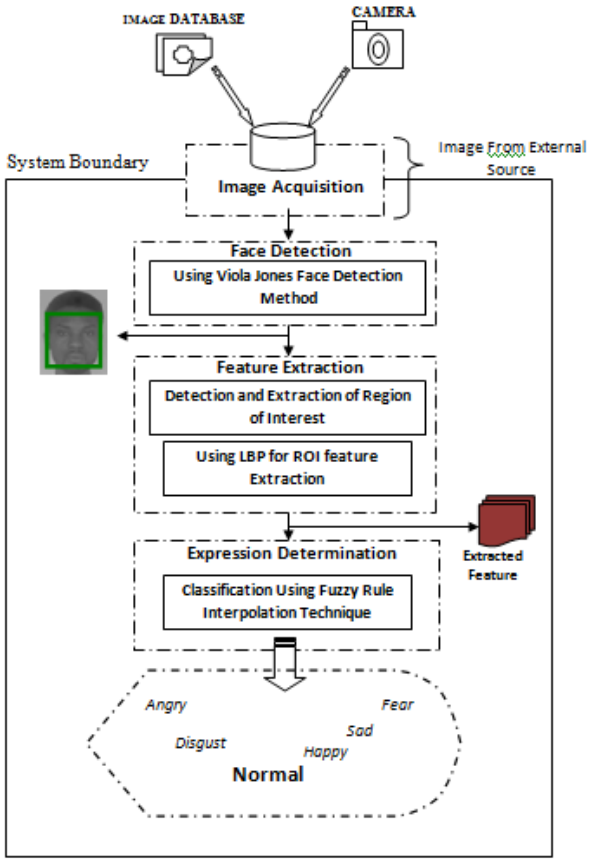


Figure 1 Architecture design of the proposed system.

### A. *Face Acquisition*

This is the initial stage for any facial image processing. The image is captured through sources such as camera or any standard database of images. It is regarded as the external part of the system since it is not in the main block of the system. For the system to perform its design functions, the acquisition of images is required. During acquisition, images that haven't been pre-processed are automatically pre-processed.

### B. *Face Detection*

Face detection is an essential step towards expression recognition: without which there won't be any classification of expressions. For the purpose of this research, the Viola Jones Algorithm is used. The Viola Jones Algorithm follows four main steps for detection, they are: Haar like features, Integral image, Adaboost and Cascade classifier [20]. It is fast and robust and separates face and its features from image accurately. Its principle is that, it scans the sub-window of an input image with the intent of detecting a face. This is done

 

using the invariant detector to rescale the input image as many times no matter the size of the image [21],[22],[23].

*C Feature Extraction*

To classify the image for the different expressions, some features are extracted from the region of interest of the given facial image. To achieve this, the Local Binary Pattern (LBP) technique is used. Local Binary Pattern is a technique used to extract textural image local information particular about the specific image. It is a proficient descriptor used for pattern recognition and classifications which has proven to be powerful and is robust [24],[25],[26].

*D. Expression Classification Using the Proposed Technique*

In this research work, the Fuzzy Rule Interpolation technique was used to implement the expression recognition and classification. This technique uses a sparse situation where the given observation does not overlap with the antecedent values of the rules. In which case, the compositional rule of inference (CRI) would not be able to draw conclusion, but with fuzzy rule interpolation, some conclusion may still be obtained [27],[10]. This technique has some other Matlab functions embedded in it that implement the interpolation with its foundation on fuzzy inference system. These techniques are up to nine of them but this research used the fuzzy interpolation in vague environment (FIVE) method that was developed to meet the speed requirements [16]. Below is the algorithm for the (FIVE) method for the expression classification.

*FIVE Algorithm for expression classification***.**

**Input:** Sparse rule base ***R***, Observation O***** and Set of parameters *params.*

**Output:** Classical Interpolated Conclusion B*

1. For all the α – cut level in the antecedent universe
2. Calculate the vague distance of the rule universe to the scaling function of the set of input universe.
3. Derive the fuzzy membership function of the set of input universe which is :

   $Fmf_A(x) = 1 \text{ minus } \{|\delta_s(x1, x2)|, 1\}$
4. Calculate the vague distance of the parameters universe (a, b) to 1 minus the alpha – cut level. Where α = 1/(xˆw), 1; $\delta_s = 1 - \alpha$.
5. Calculate the Scaling Function of the input universe

   W = NLS * abs (S(n + 1) – S(n))

   SCF(x) = w.*(((d + 1) . / (x + 1)) . ˆw – 1) . / ((d + 1) . ˆ w – 1)
6. Approximate the scaling function of the input universe
7. Return B*.

The Fuzzy Interpolation in Vague Environment (FIVE) algorithm is one of the methods in the fuzzy rule interpolation that uses fuzzy inference system as one of its input parameter; The IF-THEN rules are the knowledge base for approaching the fuzzy paradigm reasoning. For this work, the IF – THEN rule is as followed:

$$R_i = A_{i1} \wedge A_{i2} \wedge \dots \wedge A_{in} \text{ Then } B_i \quad - \quad - \quad (1)$$

Where the antecedent $A_{ij} \in F(X_j)$ which is the input universe and the consequents Bi $\in F(Y)$ as the output [28]. In a rule base coverage, by definition we can say: Let R = {R*i* | *i* = 1… *r*} be a rule base. Using the rule form in (1). If:

$$\forall A^* \in F(x): \omega(R) \geq \varepsilon > 0 \quad - \quad - \quad - \quad (2)$$

Then *R* forms Exelon (ε) coverage of the input universe (*x*). While *A** is the Observation, ω is the activation degree (i.e. degree of matching) and ε is the minimal confidence value of the conclusion. Therefore, the ε coverage rule base guarantees that the rule – base activation degree is at a minimal confidence conclusion for an arbitrary observation. Hence, from the equation (1) and (2), the facial expressions will be classified based on the following rules excerpts given here:

R1 = Lip Tightened ∧ Lip pressor ∨ Upper lip raiser ∧ Brow lowerer **Then** *Angry*

R2 = Nose wrinkler ∨ Upper lip raiser ∧ Inner brow raiser **Then** *Disgust*

R3 = Lip Tightener ∧ Outer brow raiser ∧ Inner brow raiser **Then** *Fear*

R4 = Lip corner puller ∧ Lips part **Then** *Happy*

R5 = Outer brow raiser ∧ Upper lips raiser ∧ Lips part ∧ Mouth stretched **Then** *Surprised*

The observation O*, is an input to the system which depicts the fuzzy set of an input for each dimensions which means the same thing as the rule base of the system. The parameters are the shepherd interpolation of the method FIVE. This is by default the antecedent dimension of the rule base.

*E. Expression Display*

This is the last module in figure 1 of the proposed system. It displays the result of the classified expression, showing any of the seven (7) expressions that best match the antecedents of the rule base. This means that the consequence of the antecedent would be either: angry, fear, sad, happy, disgust, surprised and or neutral showing also the percentages of closeness and the histogram of the subject.

## IV. METHODOLOGY

To successfully achieve this task, constructive research method and Object-Oriented Analysis and Design were used.

 

The constructive research method is characterized with its applications resulting in the introduction of new knowledge [29]. Object – Oriented Analysis and Design (OOAD) leads to object oriented decomposition. Applying this design methodology, software that is flexible to change is created and a greater level of confidence in correctness is being achieved [30]. This design approach, models a system as a group of interacting object that represents some of the interesting entity in the system being modelled. The unified modelling language (UML) is used as a notation for representing these models [31]. This design approach helps in the finding, organizing, describing scenario, behaviours and object interactions and it reveals the significance of clearly capturing both class and object hierarchies of the proposed system.

### *A. Use Case Diagram*

This shows the interactions between users of the system (i.e. actors) and the system during the execution process. It represents the different use cases the user is involve with and captures graphically the system functionalities and interactions between the user (referred to as actor) and the system. Figure 2 shows the categorized interactions of the execution process of the system.

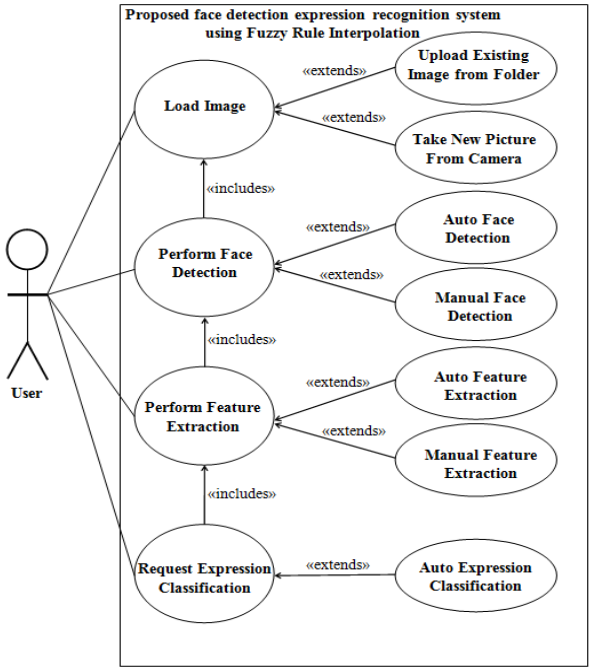


Figure 2 Use case diagrams for the proposed system

The use case in figure 2 presents the functions of the user (actor) who is the major player in the system. The user is responsible for caring out the actions of the system: first, the user initiates image upload "Load Image" which in-turn extends uploading image from the image dataset or from a camera and next he performs a detection operation "Face Detection" which can be Automated or manual face detection. The "feature extraction" is performed to get the features of the detected face before requesting for the classification using the proposed technique.

## V. RESULT AND DISCUSSION

The result for the implementation of the proposed system is presented in figure 3. The output is shown in a simple GUI which highlights the different modules in a button that is being manipulated by the user of the system. The result display of the face detection and expression recognition system is shown in figure 3

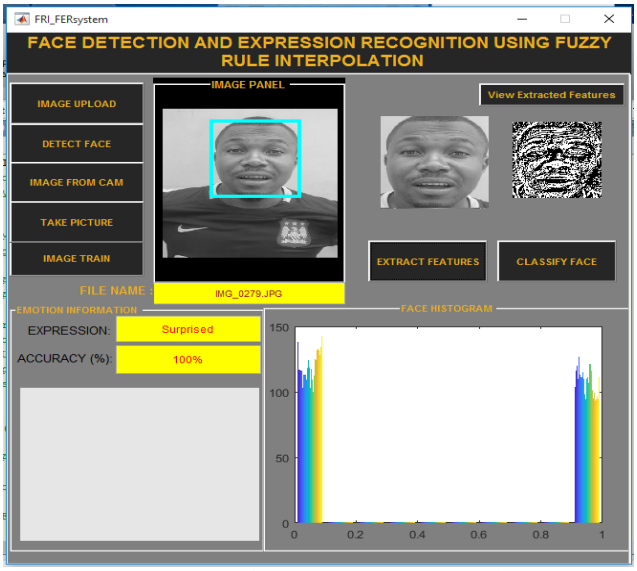


Figure 3 Expression classification and display output of the proposed system.

### *A. Result Evaluation*

The application worked correctly for all cases tested except for the classification. However, the classification of expressions was achieved using image category classification, a Matlab function. After classifying for few faces, it produces irregular outputs. The system was evaluated using 50% training set and 50% test set producing 71% average accuracy of the total system. Table 1 displays the percentage accuracy achieved for the different categories of expressions.

Table 1 Expression evaluation for proposed system

| Expressions | Percentage Accuracy (%) |
|---|---|
| **Anger** | 67 |
| **Disgust** | 90 |
| **Fear** | 60 |
| **Happy** | 100 |
| **Normal** | 43 |
| **Sad** | 37 |
| **Surprise** | 100 |

 

The system achieved 100% classification for happy and surprise expression and 90% classification for disgust emotion. For anger and fear, the system achieved 67% and 60% respectively, and 43% and 37% recognitions for normal and sad expressions, giving an average accuracy of 71%. Below is a column chart representing the evaluation of table 1.

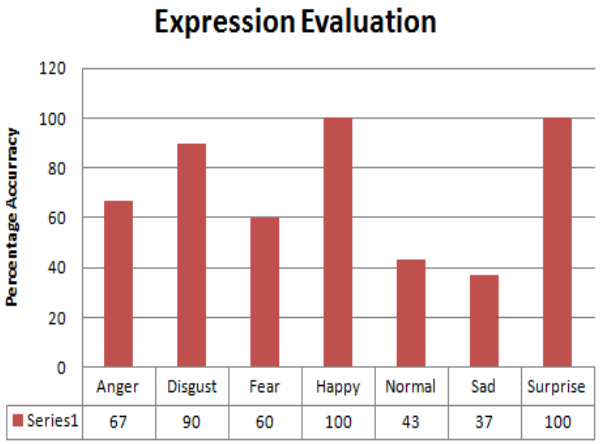


Figure 4 Graphical representation of expression evaluation of the proposed system.

## B. *Confusion Matrix*

The confusion matrix presents us with the percentage deviations and accuracy of the different expression after evaluation of the system using the test images. Evaluating the entire test sets, the confusion matrix gives the percentage of the confusion of an expression with another expression. Table 2 shows the confusion matrix of the test set of 50% images.

Table 2 Confusion matrix of the image classification.

| KNOWN | Anger | Disgust | Fear | Happy | Normal | Sad | Surprised |
|---|---|---|---|---|---|---|---|
| **Anger** | **0.67** | 0.00 | 0.00 | 0.00 | 0.23 | 0.10 | 0.00 |
| **Disgust** | 0.00 | **0.90** | 0.00 | 0.03 | 0.07 | 0.00 | 0.00 |
| **Fear** | 0.03 | 0.00 | **0.60** | 0.10 | 0.00 | 0.00 | 0.27 |
| **Happy** | 0.00 | 0.00 | 0.00 | **1.00** | 0.00 | 0.00 | 0.00 |
| **Normal** | 0.03 | 0.17 | 0.10 | 0.10 | **0.43** | 0.07 | 0.10 |
| **Sad** | 0.10 | 0.13 | 0.13 | 0.00 | 0.17 | **0.37** | 0.10 |
| **Surprised** | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | **1.00** |

From table 2, it shows that for 25% the system confuses normal with anger, for 10% the system confuses sad with anger. Another highly rated confusion is found in surprise being confused with fear with the 27% and for 17% normal is confused with sad. The column chart below shows the representation of table 2.

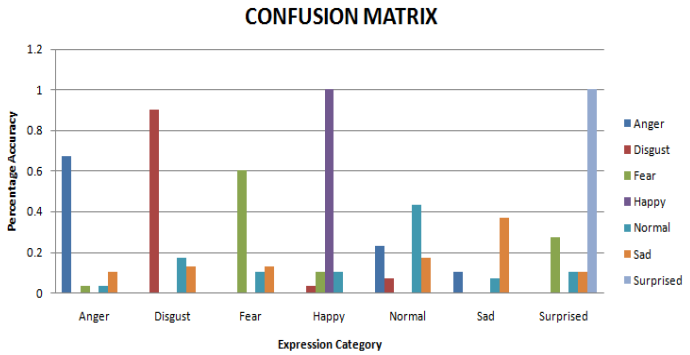


Figure 5 Graphical representations for confusion matrix of the proposed system

## C. *Discussion of Results*

The focus of this study is to detect a face from still image and to recognize the facial expression using the fuzzy rule interpolation technique. The system is to determine whether the facial expression in an image is Anger, Disgust, Fear, happy, normal/neutral, sad or surprised.

The figure 3 above is the display of the acquired image, a successfully detected face with Viola Jones Algorithm and extracted features with Local Binary Pattern and classification result. The system was not able to classify expressions using the fuzzy rule interpolation technique. The FRI Matlab toolbox were gotten, installed and analyzed with the finding that the feature extraction algorithm used was not able to provide accurate dimensions of the needed region of interest (ROI) for the classification hence the face was not classified with the technique. The technique has all it takes to perform the classification if the appropriate parameters are supplied.

Images from the Extended Cohn Kanade database were used in the experimentation to train and test the system. The Images were categorized with the different expressions and the smallest amount of images in a category was used as a benchmark to randomly make all categories the same amount of image. The images were trained using 50% of the total images in each category for training sample and 50% for testing, achieving an average accuracy of 71%.

Analysis from table 1 showed that the system performed distinguishingly in classifying two expressions Happy and Surprised precisely and expressions Anger and Disgust gives accuracy of 67% and 90% and others Fear, Normal and Sad gave the accuracy 60%, 43% and 37% respectively.

Analysis from table 2 shows the confusion matrix of the system after evaluation with the test images with image category classification. It shows that the expression, surprised is sometimes confused with fear and normal and also confused with anger. Disgust and fear were confused with sad and also anger was shown to be confused with sad.

 

From the results so far, the images in the categories need to be check and images that do not show clear expressions removed.

## VI. CONCLUSION AND FUTURE WORK

In conclusion, an expression recognition system using Fuzzy Rule Interpolation (FRI) technique to classify and recognize 7 categories of facial expression was developed. Experimentation result shows that FRI technique is a promising method and can perform better. The technique offers important tools that will enable expression recognition and the ability to make conclusion in situations where there are missing or sparse rule in the rule base. Face detection and expression recognition from facial images is a useful area of research that has its application in areas like the computer vision, human – computer interaction, robotics and security systems. The main stay of this research is to classify facial expression by first detecting a face (using Viola Jones Algorithm), extracting the features from the detected face with LBP and recognizing the expression using fuzzy rule interpolation technique. In this research, the seven different facial expressions from different image subjects were gotten from the Extended Cohn Kanade dataset and analyzed. The functionality of the developed system can be accessed easily by the user through a simple and a friendly GUI, which supply the user the ability of uploading an image, detecting the face, extracting the features and request classification.

In the future, Principal Component Analysis (PCA) and the graph based feature extraction technique that uses point location will be used to extract features for classification and Euclidean Distance used to calculate the distance and variation of the ROI in the facial features to help in the classification of the expression using fuzzy rule interpolation method. This system took advantage of the fuzzy interpolation in vague environment (FIVE), one of the methods from the fuzzy rule interpolation technique. Further research should be done using the other methods like the KH, IMUL, MACI, VKK etc and also a real time facial expression recognition should be tracked using the FRI technique.

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