Kathakali face expression detection using deep learning techniques

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Abstract. To develop a Deep Learning algorithm that detects the Kathakali face expression (or Navarasas) from a given image of a person who performs Kathakali. One of India's major classical dance forms is Kathakali. It is a "story play" genre of art, but one distinguished by the traditional male-actor-dancers costumes, face masks and makeup they wear. In the Southern region of India, Kathakali is a Hindu performance art in Malayalam speaking. Most of the plays are epic scenes of Mahabhharata and Ramayana. A lot of foreigners visiting India are inspired by this art form and have been curious about the culture. It is still used for entertainment as a part of tourism and temple rituals. An understanding of facial expressions are essential so as to enjoy the play. The scope of the paper is to identify the facial expressions of Kathakali to have a better understanding of the art play. In this paper, Machine Learning and Image Processing techniques are used to decode the expressions. Kathakali face expressions are nine types namely- Adhbutam (wonder), Hasyam (comic), Sringaram(love), Bheebatsam(repulsion), Bhayanakam(fear), Roudram(anger), Veeram(pride), Karunam(sympathy) and Shantham (peace). These Expressions are mapped to real world human emotions for better classification through face detection and extraction to achieve the same. Similarly a lot of research in terms of Preprocessing and Classification is done to achieve the maximum accuracy. Using CNN algorithm 90% of the accuracy was achieved. In order to conserve the pixel distribution and as no preprocessing was used for better object recognition and analysis Fuzzy algorithm is taken into consideration. Using this preprocessing technique 93% accuracy was achieved.

1. Introduction
In India ideas are expressed using synthesized music, choreography ,vocal performers, hand and facial gestures which are together shown in the classical dance art form of Kathakali. The main attraction that differs Kathakali from all other artforms is the facial expression. However, Kathakali incorporates movements from ancient Indian martial arts and athletic traditions of South India Kathakali differs in that aspect. Around the same time as Shakespeare , In the 16th and 17th centuries, Kathakali originated in Kerala. At the Kathakali school(non-functioning at present ) at Olappamanna Mana in Vellinezhi, almost 200 years ago ,The Kalluvazhi Chitta style being performed by these dancers was born on the stage.
In figure 1, each of the nine expressions are explained in detail below:

1.1. Shantham (peace):
Nose and mouth of this expression is in its relaxed shape. Eyes are pointed upwards slightly to the left side. Eyebrows here are very close to the eyeline with equivalent distance. This shows the calm posture of the face. (Figure 1: row 1, 1st image)

1.2. Bhibatsam (unpleasant):
In this expression, eyebrows are shrunk toward the nose. Mouth here is in the shape of an inverted parabola. The eyes are reduced to 3/4th of the original size. Nose is compressed in length. Something really awful is depicted in the expression here (repulsion). (Figure 1: row 1, 2nd image)

1.3. Veeram (heroism):
Mouth and eyebrows in this expression are moved almost straight. It is mostly connected with a king's face and his act of pride. The eyes are made to a little elongated shape. Nose is moved sideways. (Figure 1: row 1, 3rd image)

1.4. Karunam (pity):
In this expression, eyes are too hard to be found out in size. Mouth is shaped like an inverted parabola but the length is too small. This expression shows feeling sympathy for someone. (Figure 1: row 2, 1st image)

1.5. Raudram (angry):
Here, eyes are pointed downwards. Nose is elongated and eyebrows are in the shape of pointed inverted parabola. The mouth length depicted is very less. This expression shows the anger emotion. (Figure 1: row 2, 2nd image)

1.6. Adhbutam (surprise):
In this expression, eyes are almost circular and completely open. Nose is little projected outward and the mouth part is a little shrunk. The expression shows unexpected happiness here. (Figure 1: row 2, 3rd image)

1.7. Sringaram (amour or love):
A very pleasant smile is expressed on the face. The eyebrows are perfectly parallel to the eyes and the original size of mouth is retained here. The eyes are almost half of its actual size. Nose is in its original shape and usually depicts a face of love. (Figure 1: row 3, 1st image)
1.8. **Hasyam**(comic):
It is very similar to sringara but the difference is that eyes are opened to it’s normal size. The eyebrows are a little raised from their original position. Nose is in its original shape. It is used to show funny instances. (figure.1:- row:3,2nd image)

1.9. **Bhayanakam**(fear):
Mouth is shaped like an inverted parabola. Both eyes appear toward the center of the nose. It shows the facial expression of having fear of something.(figure.1:- row:3,3rd image)

A subcategory of machine learning is Deep Learning, which creates an “artificial neural network” by structuring the algorithms into layers that can learn and make intelligent decisions on its own. Convolutional neural networks(CNN) is one of the important categories in neural networks for image processing, classification, segmentation and also for other auto correlation data. So this is the one main reason to choose this method for Kathakali face expression detection.

CNN algorithms provide good accuracy when there is a large amount of data available for training. The computation cost is very high and the algorithm requires good GUI , otherwise a lot of time is required for training. There exists no previous dataset for Kathakali facial expressions to the best of the knowledge. The works that were previously done are concentrated on dance forms like kuchipudi, bharatanatyam, kathak, odissi, sattriya and Manipuri etc. Creating a dataset for all expressions from scratch was the main challenge. Guidance of kathakali artists in Kerala was taken for collection of data. 650 images of new dataset for Kathakali face expressions in which each nine expressions has around 50-60 images. Diversity of the dataset was taken into consideration. Factors considered are different positions by different people, background, some pictures with makeup and some without makeup etc., in creating the dataset.

Histogram normalisation is generally used in image preprocessing in order to remove noise from images. Due to this preprocessing as older pixels are being affected Fuzzy Algorithm is used for preprocessing as it enhances the images and retains the old pixels.

The intention of the work is due to the following reasons:

1. All the dance forms in India focus on hand gestures and body movement. Kathakali has given the utmost importance to face expressions compared to other art forms where very little importance was given to face expressions.

2. However, these facial expressions cannot be easily understood by a common man. Through this work it solves the issue of understanding facial expression can be resolved. This is the first work till date for exploring Kathakali face expression detection. Also, this work will be really useful in tourism for foreigners who love Indian culture and can now decode Kathakali art form.

There have been several works done for Bharatanatyam, Kuchipudi etc. Kathakali is very much similar to Bharatanatyam in terms of mudras and facial expressions. The techniques and methods used for prediction in Bharatanatyam is taken as a base for Kathakali work mainly due to the reason for accurate prediction of complex features.

2. **Literature Survey**

2.1. **From Bharatanatyam and Image Processing**
For the development of dance application, three aspects of dance need to be analysed:
1. To find the representative action elements for the Segmentation of the dance,
2. The action elements which are detected are matched.
3. Taking consideration into a huge number of action elements based on certain rules, recognition of the dance sequence is formed.
4. Using Machine Learning and Deep Learning Techniques recognizing the art forms and positions. Finally, the Hidden Markov Model (HMM) is used to recognize the dance sequence.

The multi-modal data of Bharatanatyam is captured using Kinect and built into an annotated data set.

Figure 2. CNN Training process

2.2. Survey
The article [1] introduced the Cauchy Naive Bayes classifier. The model used here is Cauchy distribution. Here Cauchy provided more accurate results in both person dependent and independent images. The reported accuracy is 80%. More scope was there for improvement in distribution, and provides a framework for selection of best model distribution assumptions. Some more correctness in feature extraction was required.

The paper [2] gives a description of automated recognition of live facial emotion through Artificial Intelligence (AI) and Image Processing techniques. Based on the categories of emotion like happy, sad, angry, surprise, neutral, disgust, and fear modeling of data is done by allotting 34,488 images for training dataset and 1,250 images for testing dataset. The main objectives of CNN used are Image Recognition and Image Classification. The outcome of the paper is for every individual input the model displays emotion classifier percentage. i.e., The accuracy achieved is 66%.

The survey [3] proposed a model using the exact working of CNN with levels using the steps of max pooling and flattening. Having the CNN model trained using a huge image dataset, it was made to an ideal model to classify the emotions of a person by his facial image. The reported accuracy is 85.23%. Multiple layers of 2D convolution layers, max pooling, back propagation, updation of filter matrix values and different types of filters like horizontal, vertical filters usage was applied.

The survey [4] proposed a model using publicly available databases which have AU’s Experimentation for performing spontaneous & posed facial emotion recognition. The reported accuracy for the intensity is 67.8% and preferred data and instant data was not accurate. Inference about Preprocessing techniques like masking, scaling, converting into grayscale, and noise reduction were analysed from paper.
The survey [5] proposed a model that demonstrates a new technology that can infer a person’s emotions from RF signals reflected off his body. EQ-Radio transmits an RF signal and analyzes its reflections off a person’s body to recognize his emotional state (happy, sad, etc.). The survey [6] proposed a model that automates the recognition of live facial emotion using Image processing and AI techniques. The survey [7] proposed a model for Face Detection and Recognition using Machine Learning Algorithms and Deep Learning Techniques. The survey [8] proposed a model to detect emotion by image scanning. Features extraction like nose, mouth, and eyes are done for face detection.

The Convolutional Neural Network (CNN) algorithm model is used for image detection. The paper [9] gives a description about major approaches to multimodal human computer interaction from a Computer vision perspective. Focus is on body, gesture, gaze, and affective interaction. The survey[10] proposed a model that focuses on body, gesture, gaze and interaction. It gives a description of procedures to multimodal human computer interaction from a vision perspective. The survey [11] introduced the usage of algorithms Support Vector Machine (SVM) model and Convolutional Neural Network (CNN) model to identify the images into categories. Comparison of the performance of Machine learning algorithms and Deep learning algorithms is done. Achieved an accuracy of 74%.

This paper[13] gives a description about face detection algorithms. Techniques range from simple edge-based algorithms to composite high-level approaches utilizing advanced pattern recognition methods. Classification is done as either feature-based or image-based and are discussed in terms of their technical approach and performance. This survey[15] gives a description about major challenges faced during the processing of misaligned dental x-ray images. Processing dental x-ray images are root canal treatment, infection and other malignancy diagnosis are described in this survey.

This paper[18] gives an introduction about Fuzzy algorithms to enhance the colored images present in their dataset. They proposed the logic that was well suited for preprocessing of images with low contrast color. This survey is taken into consideration as Fuzzy algorithm removes noise better than traditional methods and enhances the images by retaining the pixels. This paper[19] introduces a method for improving the quality of images which have low resolution using Fuzzy Inference System. Comparison of traditional methods with Fuzzy Inference System is done to analyze the performance of the model. As Fuzzy algorithm is better than traditional Histogram Normalisation for preprocessing of images the survey is taken into consideration.

The above articles are being considered for classifying Kathakali Face Expressions. CNN deep learning technique is considered as better accuracy of identifying images is observed compared to other algorithms and preprocessing of images is done using Fuzzy Algorithm as in traditional methods there are no advanced preprocessing techniques used due to which pixels are being affected in the image and due to advanced preprocessing in Fuzzy, this algorithm is taken into consideration. This work has explored various papers as mentioned above to facilitate in the process of the work.

3. Proposed Architecture
   The workflow for the Kathakali Face Expression Detection is shown in figure 3.

3.1. Collecting Images and Building DataSet
   The challenging part of this work is to create a dataset for each and every expression from scratch. Guidance from a kathakali artist in Kerala was taken for collection of data. Uttermost care was taken while collecting images such that they can be differentiated from each expression. Images collected had different forms like some were with makeup and some were without. Images from all angles were
taken into consideration for different expressions to make sure that algorithm has better accuracy. The Dataset was built from scratch with the guidance of Kathakali artists from Kerala. Apart from this, online sources were used and some images were captured from real-time videos as well. Some images were also supported by the Kathakali artists as well. These images were made into JPG format and drive storage is used for storing and maintaining the dataset. A collection of 650 images were built where 50-60 images belonged to each of the nine expressions.

![Proposed Architecture](image)

**Figure 3. Proposed Architecture**

3.2. **Preprocessing**

In CNN, some basic preprocessing of images are included for an accurate prediction.

Some of these techniques are mentioned below:

1. Prewitt filters are applied to remove noise and also to get a clearer image. Grayscale of images is done for easy handling of images as RGB values would be complex for CNN to evaluate.
2. Resizing of images is done so as to have image size consistency and also to reduce the load for the CNN classifier.
3. The unfilled pixels or scattered pixels are replaced by using the nearest neighbour method—where it uses the pixel values of the nearest pixel.
4. Initially, rotation angle is fixed to 10-20% and the same for height, width, zoom and shear ratios. Shear ratios are used to measure the displacement of pixels on applying the shear functions to get insights on pixel distribution.

Since the dataset collected involves complex features, appropriate measures are required in order to achieve this. Preprocessing is also done using Fuzzy Algorithms. Fuzzy Enhancement is used and it is based on the Histogram Equalisation. In order to conserve the pixel distribution and for better object recognition and analysis this preprocessing technique was considered. The emphasis in this area is due to the past projects done in Bharatanatyam that used Histogram Equalisation for preprocessing of the images.
Steps followed for Fuzzy Algorithm:
1. Image is converted from RGB to CIELAB on L Channel. Average pixel intensity is calculated (M value).
2. In Fuzzification for each class the degree of membership is calculated using pixel intensity and M value.
3. In Defuzzification the centroid value of the Fuzzy set is calculated.
4. Output pixel intensity is normalized from [-50,305] to [0,255] and convert the output image from CIELAB to RGB.
5. Rule Set:
   A. IF input is VeryDark THEN output is ExtremelyDark.
   B. IF input is Dark THEN output is VeryDark.
   C. IF input is SlightlyDark THEN output is Dark.
   D. IF input is SlightlyBright THEN output is Bright.
   E. IF input is Bright THEN output is VeryBright.
   F. IF input is VeryBright THEN output is ExtremelyBright.

3.3. Training and Validation Set
As dataset [17] is composed of 650 images, in order to have better accuracy the chosen ratio of training to testing dataset is 70:30. 70% of the training data that is 388 images are equally distributed among 9 expressions. Each of the 9 expressions now contain 40 training images. 30% of the testing data that is 169 images are equally distributed among 9 expressions. Each of the 9 expressions now contain 20 testing images. This split is adopted because the data is redundant and inconsistent.

3.4. CNN classifier
An image Classifier Convolutional Neural Network (CNN) is a multilayered neural network that has been used in image recognition. The Classifier CNN also had a special architecture to detect complex features in data. CNNs are involved with many layers starting with an input layer followed by hidden layers usually consisting of convolutional layers, ReLU layers, pooling layers and an Output layer. Using a stack of convolution layers and max pooling for exact detection of images, a model was made and a dense layer was applied for detection of expressions using relu as activation function. Some text.

3.4.1. Convolution. Convolution is used for extracting features from the input data. The layer has an input image, a feature detector, and a feature map. The filter is applied for every pixel block of the input image. That is through matrices multiplication.

3.4.2. Apply Relu. The Rectified Linear Unit is one of the most commonly used activation functions in deep learning models. If the value is positive the linear function returns the input itself else the value 0 is returned. So it can be written as

\[
\text{RELU}(x) = \begin{cases} 
0 & \text{if } x < 0, \\
 x & \text{if } x \geq 0 
\end{cases}
\]  

(1)

3.4.3. Pooling. Pooling helps in reducing the amount of computation and number of essential parameters. It also helps to control overfitting of data points. Feature map is taken and then applied using a pooling layer, and then the result obtained is the pooled feature map. The most common example is that of max pooling. In max pooling, the input image is partitioned into a set of areas that don’t overlap. Max pooling is the maximum value at each spot present in the image. By this we can get rid of 75% of the information that is not the feature.

3.4.4. Dropout, Dense Layer and Batch Normalisation. Batch normalization is a technique used for training deep neural networks that standardizes the inputs to a layer for each mini-batch. It has the
effect of stabilizing the learning process and dramatically reducing the number of training epochs required to train deep networks. A dense layer represents a matrix vector multiplication. (assuming batch size is 1). The values in the matrix are the trainable parameters which get updated during back propagation.

\[ u^T \cdot W, W \in \mathbb{R}^{n \times m} \]  \hspace{1cm} (2)

Finally, a m dimensional vector is obtained as output. A dense layer is used to change the dimensions of the vector. It also applies rotation, scaling and translation transform to the vector.

A dropout layer is used for regularization where it randomly sets some of the dimensions of the input vector to be zero probability. A dropout layer does not have any trainable parameters and hence nothing gets updated during backward pass of backpropagation. To ensure that the expected sum of vectors are fed to this layer, the dimensions remain the same. If no dropout was applied, the remaining dimensions which are not set to zero are scaled by 1.

### 3.4.5. Full Connection.

![Figure 4. Full connection](image)

The feature map matrix obtained will be converted as a vector \((x_1, x_2, x_3, \ldots)\). Finally, with the help of these fully connected layers, these features are combined together to create a model. Then, an activation function such as Softmax or Relu functions are used to classify the outputs as the expressions of Kathakali. CNN Classifier is adopted for this method mainly because of the reason that CNN worked well on image datasets and gave high accuracies of above 90%. The image dataset chosen involves complex features of Kathakali Face expression which is way different from normal human emotion detection. OpenCV classifiers, filter based, boundary based and other normal methods were also tried to achieve the same. Since they were predefined on human face color, none of them couldn’t detect Kathakali face very well. Hence, the need to analyse the complex features were very essential and also found that CNN showed best results with the experimental datasets.

### 3.5. Performance Evaluation and Measures

In this work accuracy and loss is used as evaluation measures. Accuracy is the degree of closeness between a measurement and the true value. In CNN various accuracy measures like training accuracy, validation accuracy, training loss and validation loss is used.

1. Training accuracy: Accuracy obtained during the training of the dataset.
2. Validation accuracy: Accuracy obtained during the testing of the dataset.
3. Training loss: Training loss is the error on the training set of data.
4. Validation loss: Validation loss is the error after running the validation set of data through the trained network.
4. Result Analysis and Discussion
The stages of implementation are collecting data, Preprocessing using Fuzzy Algorithm, parameter tuning, applying CNN and classifying the expressions.

4.1. Dataset
Algorithm allows only jpg format for image dataset and so the images are all in jpg format. Also there are 9 classes of expressions dataset which are distributed in 70% and 30% ratio for training and testing respectively.

4.2. Tools or Techniques used
Packages used for general plotting of graphs and reading of dataset are matplotlib, numpy, seaborn, pandas, os, sys. The packages used for cnn training are keras, tensorflow and image data generator.

4.3. Preprocessing Techniques
Filters like Prewitt filter are used for removing noise in the data. Relu (Rectified linear unit) and SoftMax are the activation functions used for quick convergence and optimisation. Relu relies only on positive values of the outputs whereas Softmax considers negative values actual outputs. Resizing of input images was done to 160x120 and normalisation was done after max pooling with (2x2) kernels and convolution(2x2,32x32,64x64) layers to extract features of the images. Once this was completed these were flattened and took a dropout of 60% so as to prevent overfitting.

Fuzzy Algorithm is used to preprocess the images in order to achieve better accuracy for identifying Kathakali Face Expressions. Fuzzification and Defuzzification are done to calculate the output Fuzzy set from the intensity of input pixel.

The centroid value of its output Fuzzy is also set respectively. For Fuzzification, CLAHE(Contrast Limited Adaptive Histogram Equalisation) method is used and for Defuzzification, Mamdani’s method is chosen based on the results analysed from different methods and results given by research papers. CLAHE is chosen due to its high accuracy and retention of original features (3)

FCE:76.85879758770768
HE:76.31598178260732
CLAHE:76.7860190188342 (3)

4.4. Parameter tuning
For nine classes, the CNN model was compiled using Categorical cross entropy which is for compiling the methods that have more than two classes.

Certain parameters like fill mode (which takes the nearest pixel value to the neighboring one to make computation simpler), batch size, and category for classifying into classes were applied to training and testing images. For CNN the training steps per epoch was set to 47 and epoch for validation was set to 30 iterations. The number of validation steps was set to 8 in order to improve both the training accuracy and validation accuracy.

4.5. Prediction for validation dataset, evaluating the validation model, Collecting the class label
With the help of Kathakali Artist it is analysed how the 9 expressions can be different from each other. The dataset is classified accordingly into 9 expressions and was split into training and testing dataset. CNN predefined model has tested for accuracy using confusion matrix. Evaluation was done for a few testing samples to identify the expression.
Figure 5. Training samples(T-Training Data,e-Testing Data)

Figure 8 shows the number of training (blue) and testing (orange) images sent to the CNN model for nine expressions respectively. Figure 6 compares the training (blue) and validation (orange) accuracy for each epoch over 50 iterations. Similarly, Figure 7 compares the training (blue line) and validation (orange line) loss for each epoch over 50 iterations. The peaks show the frequency of the accuracy obtained. Figure 5 shows the model performance on sending the dataset to CNN model. Towards the end of this paper, histograms related to image pixel intensity for each of the nine expressions are added. Also, results or outputs based on user input images are also added. Three images for adbhutam, sringaram and hasyam were sent to CNN. It showed 100%, 99% and 73% probabilities as output to these expressions. The decrease in the probability indicates the similarity of an image with one or more expressions. Also Figure 6 shows the improvement in training accuracy to 92% on working on Fuzzy Preprocessed dataset. The detailed results are appended in the final section.

Figure 6. Training and validation accuracy for 50 iterations (a-training and v-validation)

90% of training accuracy and 100% of validation accuracy is achieved on a dataset of 650 images. Mean training accuracy is around 87% and mean validation accuracy is around 83%.
4.6. Emotion Detection
The given input is classified into one of the 9 expressions using the techniques mentioned above and the correct expression is given as output. Around 650 images of each 9 expressions were collected from different sources under the guidance of the Kathakali artist. During dataset construction, the training and testing data is in 70:30 ratio. The training of CNN is done using keras and the result is mentioned in figure 9. After training the class labels were collected for 9 facial expressions and at last the emotion for a particular expression was detected.

5. Conclusion and Future Work
In this paper, the dataset is created for 9 Kathakali facial expressions from scratch with the help of Kathakali artists in Kerala. The accuracy for identification was compared with different algorithms and CNN gave the best accuracy. The dataset consists of 650 images with seventy percent of training images and thirty percent of testing images. The features were extracted from the designed Kathakali Facial Expressions dataset using max pooling layers and achieved an accuracy of 90%. This is the first attempt of this kind to create a dataset for facial expressions and classifying the expressions using deep learning techniques. However, the process of tuning the right parameters could only make the model...
successful. A lot of research is required in this aspect. Another drawback is that Kathakali expressions have similar expressions. This makes the model not predict well. Hence, this issue can be resolved only if more samples of the dataset are available. Another method of solving this issue can be done using more preprocessing on the dataset. For this Fuzzy technique was chosen as it gives enhanced images due to which it can predict accurate results. The scope of this paperwork can be extended to real time Kathakali Face Expression Detection in Kerala Tourism. After application of Fuzzy Algorithm as pre-processing technique a accuracy of 93% is achieved.

6. Other Results

6.1. Training image pixel distribution
The Kathakali Face expression dataset which consists of training dataset and testing dataset is divided in the ratio 70:30. 70% of 650 images were allocated for training. Each training set and testing set consists of images from nine expressions. Following graphs show the histogram of the pixel distribution of each of the nine expressions considering all images present in each expression. Pixel distribution is less for expressions like Bhayanakam, Hasyam, Raudram and Veeram because of less images in the training dataset under these expressions. X-Axis shows the pixel range from 0-255 and Y-Axis shows the frequency of pixel occurrence.

6.2. Testing image pixel distribution
70% of 650 images were allocated for testing. Pixel distribution is less for expressions like Bhayanakam, Hasyam, Raudram and Veeram because of less images in the training dataset under these expressions. X-Axis shows the pixel range from 0-255 and Y-Axis shows the frequency of pixel occurrence.
6.3. Testing results before application of Fuzzy Algorithm

Using the normal preprocessing techniques inbuilt in Neural Networks the following are the results obtained for images belonging to its specific expression. The percentage shows the similarity percentage of that image with the predicted expression. For an image of Adbhutam it shows 100% similarity and for an image of Sringaram it shows 99.83%.
6.4. Testing results after application of Fuzzy Algorithm

Using Fuzzy preprocessing techniques exact similarity of the image to each of the expressions can be observed. The image shown below belongs to Hasyam with a percentage upto 73.7%. But it also shows slight similarities with expressions like Adbhutam which is 25.87%.

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