

## Experimental Results and Analysis

### 5.1 Preamble

This chapter details the experiments conducted on the proposed framework for real-time yoga hand mudra classification using a Random Forest classifier. The section covers the environmental conditions, experimental setup, and the applied constraints. Initially, we describe the hand mudra dataset, including its collection, the number of mudras classified, and the total number of images per class. Following that, the preprocessing techniques, such as data augmentation, are explained to ensure diverse training examples. Next, we present the feature extraction process using MediaPipe, which captures 21 keypoints of the hand for classification. Finally, the results of the experiments are analyzed and presented, demonstrating the effectiveness of the proposed method on the yoga hand mudra dataset.

### 5.2 Dataset Distribution

The training and testing datasets were split to ensure balanced representation across all six mudras. The training set had a slight imbalance, with 87 instances of Vayu Mudra compared to 96 instances of the other mudras. The testing set maintained proportional distributions, with Vayu Mudra having 22 samples, while the remaining mudras had 24 samples each. Below is the class distribution:

### 5.2.1 Training set

- Gyan Mudra: 96
- Prithvi Mudra: 96
- Shunya Mudra: 96
- Surya Mudra: 96
- Varuna Mudra: 96
- Vayu Mudra: 87

### 5.2.2 Testing set

- Gyan Mudra: 24
- Prithvi Mudra: 24
- Shunya Mudra: 24
- Surya Mudra: 24
- Varuna Mudra: 24
- Vayu Mudra: 22

## 5.3 Model Performance

### 5.2.1. Training Performance

The Random Forest classifier achieved perfect accuracy on the training set, with an accuracy of **1.0**. The confusion matrix below shows that all 567 samples were correctly classified without any errors.

**Training Confusion Matrix**

Actual	Gyan_mudra -	96	0	0	0	0	0
	Prithvi_mudra -	0	96	0	0	0	0
	Shunya_mudra -	0	0	87	0	0	0
	Surya_mudra -	0	0	0	96	0	0
	Varuna_mudra -	0	0	0	0	96	0
	Vayu_mudra -	0	0	0	0	0	96
		Gyan_mudra -	Prithvi_mudra -	Shunya_mudra -	Surya_mudra -	Varuna_mudra -	Vayu_mudra -
		Predicted					

**Fig 5.1 Training Confusion Matrix**

The classification report for the training set shows a precision, recall, and F1-score of 1.00 for all classes, confirming that the model fully captured the characteristics of each mudra:

- Precision: 1.00 for all classes
- Recall: 1.00 for all classes
- F1-score: 1.00 for all classes

### 5.2.2. Testing Performance

The model performed exceptionally well on the testing set, achieving an overall accuracy of **99.3%**. Out of 142 test samples, only one sample from the Prithvi Mudra class was misclassified as Surya Mudra.

**Test Confusion Matrix**

Actual	Gyan_mudra	24	0	0	0	0	0
	Prithvi_mudra	0	23	0	1	0	0
	Shunya_mudra	0	0	22	0	0	0
	Surya_mudra	0	0	0	24	0	0
	Varuna_mudra	0	0	0	0	24	0
	Vayu_mudra	0	0	0	0	0	24
		Gyan_mudra	Prithvi_mudra	Shunya_mudra	Surya_mudra	Varuna_mudra	Vayu_mudra
		Predicted					

**Fig 5.2 Testing Confusion Matrix**

The classification report for the test set highlights the model's strong performance across all mudra classes:

- Precision: 1.00 for all classes except Surya Mudra, which had a precision of 0.96.
- Recall: 1.00 for all classes except Prithvi Mudra, which had a recall of 0.96.
- F1-score: Ranges from 0.98 to 1.00.

Class	Precision	Recall	F1-score	Support
Gyan Mudra	1.00	1.00	1.00	24
Prithvi Mudra	1.00	0.96	0.98	24
Shunya Mudra	1.00	1.00	1.00	22
Surya Mudra	0.96	1.00	0.98	24
Varuna Mudra	1.00	1.00	1.00	24
Vayu Mudra	1.00	1.00	1.00	24

Table 5.1 Classification Report

## 5.4 Analysis of Results

The results indicate that the Random Forest classifier is highly effective at classifying the six yoga hand mudras, with both training and test accuracies close to perfection. The slight misclassification of *Prithvi Mudra* in the test set suggests that while the model generalizes well, subtle similarities between certain mudras could occasionally lead to errors. The overall precision, recall, and F1-scores further confirm the robustness of the model.

## 5.5 Conclusion

The experimental results demonstrate the Random Forest classifier's ability to accurately distinguish between different yoga hand mudras using keypoint features extracted by MediaPipe. The near-perfect test accuracy indicates that the proposed approach is effective and reliable for real-time hand mudra classification.