



ML Final Project

PRESENTED BY
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Outline

- Introduction
- Preprocessing
- Models
 - Logistic regression
 - Support vector machine
 - Convolutional Neural Network
- Results and Analysis
- Conclusions and Recommendations

Overview

- Objective: Tune hyperparameters and evaluate performance of multiple models
- Models explored:
 - Logistic Regression
 - Support Vector Machines (SVM)
 - Convolutional Neural Networks (CNN)
- Metrics analyzed:
 - F1 Score (Macro and Micro)
 - Accuracy
 - Recall
 - Precision

Introduction to CIFAR-10

- CIFAR-10 is a widely used dataset for machine learning and computer vision tasks.
- It consists of:
 - 60,000 color images
 - 10 classes (e.g., airplane, automobile, bird, cat, deer, dog, frog, horse, ship, truck)
 - Image size: 32x32 pixels
- Dataset split:
 - 50,000 training images
 - 10,000 test images
- Commonly used for:
 - Image classification benchmarks
 - Evaluating convolutional neural networks (CNNs)

Unsupervised Analysis

- Motivation
 - Images have 32×32 resolutions with 3 channels
 - Total feature 3072, too high for directly analysis
- Approach:
 - Dimensionality reduction with Principal Component Analysis (PCA).
 - Variance retained analyzed for 1 to 100 components.
- Key Results

TABLE 1. Variance Captured by PCA Components

# Components	1	2	3	4	5	10	20	50	100
Variance Kept	0.291	0.403	0.470	0.507	0.543	0.655	0.745	0.843	0.901

Preprocessing Techniques

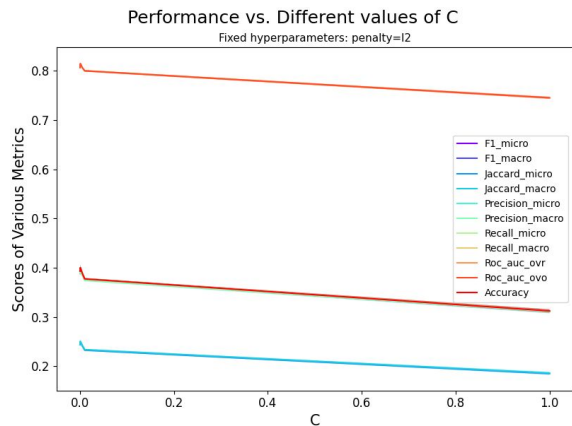
- Principal Component Analysis (PCA):
 - Reduced feature dimensions while retaining important variance.
- Polynomial Features:
 - Created interaction terms for better non-linear relationships.

Logistic Regression

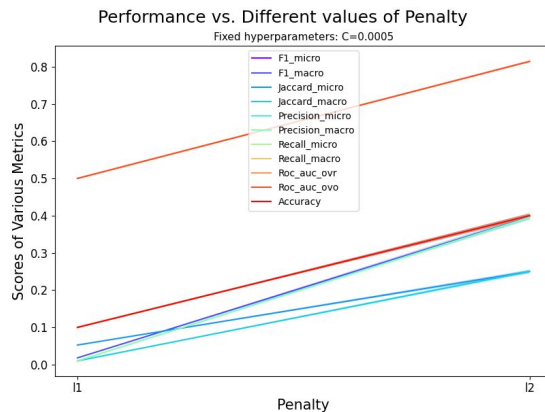
- Transformation
 - Radial Basis Function (RBF)
 - RBF and PCA
 - Polynomial transformation
- Penalties:
 - L1: Suitable for sparse datasets
 - L2: Assigns balanced importance to all features
- Results:
 - Optimal param C lies in the moderate range (0.001–1.0)
 - L2 performs better in balanced datasets

Comparison of Parameters

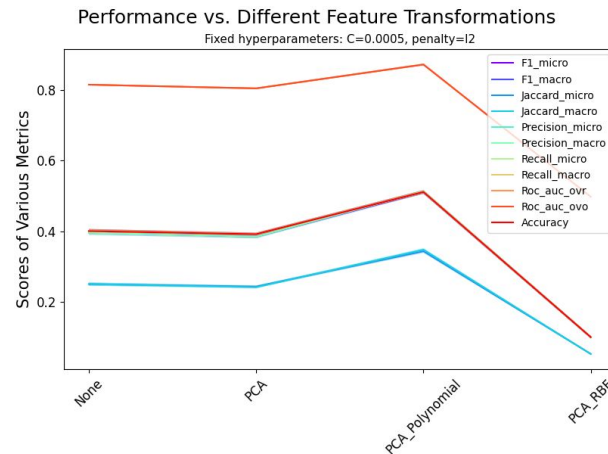
feature transformations	hyperparameters	mean_accuracy	mean_acccuracy_train	mean_precision_micro	mean_recall_micro	mean_f1_micro
PCA_Polynomial	C=0.0001, penalty=l2	0.51125	0.730025	0.51125	0.51125	0.51125
	C=0.0005, penalty=l2	0.4001	0.4596625	0.4001	0.4001	0.4001
	C=0.001, penalty=l2	0.3995	0.3963067919	0.2496161521	0.2501878884	0.3995
PCA	C=0.01, penalty=l2	0.39295	0.3887616971	0.2445260153	0.244300711	0.39295
PCA	C=1, penalty=l1	0.393	0.40640625	0.393	0.393	0.393
PCA_RBF	C=0.01, penalty=l1	0.10095	0.11394375	0.10095	0.10095	0.10095
PCA_RBF	C=0.0001, penalty=l1	0.1	0.1	0.1	0.1	0.1
PCA_Polynomial	C=0.0001, penalty=l1	0.1	0.1	0.1	0.1	0.1
PCA	C=0.0001, penalty=l1	0.1	0.1	0.1	0.1	0.1
	C=0.0001, penalty=l1	0.1	0.1	0.1	0.1	0.1



Performance vs. C



Performance vs. Penalty



Feature transformation

Best Results

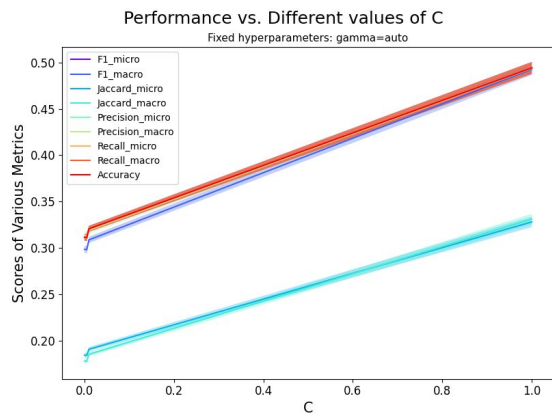
	Logistic_	Logistic_PCA	Logistic_PCA_Polynomial	Logistic_PCA_RBF
f1_micro	0.4153	0.2494	0.2614	0.1001
f1_macro	0.4112770228	0.2449428034	0.2553107377	0.09105211754
jaccard_micro	0.2620685303	0.1424654404	0.150350857	0.05268698353
jaccard_macro	0.262227003	0.1432901369	0.1486988309	0.04807267742
precision_micro	0.4153	0.2494	0.2614	0.1001
precision_macro	0.4104284466	0.242102908	0.2589800105	0.09995613946
recall_micro	0.4153	0.2494	0.2614	0.1001
recall_macro	0.4153	0.2494	0.2614	0.1001
roc_auc_ovr	0.8205815333	0.6887226444	0.6894341556	0.4979451667
roc_auc_ovo	0.8205815333	0.6887226444	0.6894341556	0.4979451667
accuracy	0.4153	0.2494	0.2614	0.1001

Support Vector Machines

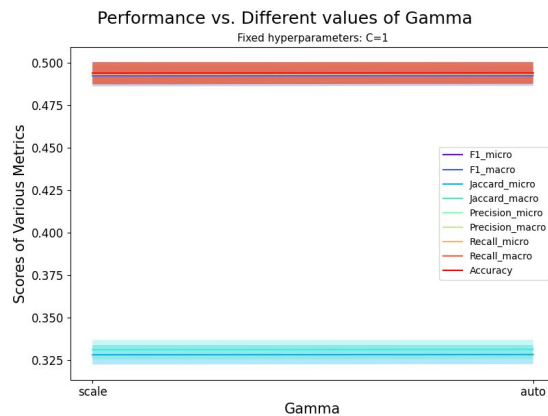
- Transformation
 - Radial Basis Function (RBF)
 - RBF and PCA
 - Polynomial transformation
- Hyperparameters:
 - param C: Regularization strength
 - param gamma: Kernel coefficient
- Results:
 - param C effects model complexity:
 - Low values: Underfitting
 - High values: Overfitting
 - param gamma controls feature interactions: Theoretically, moderate values yield best results

Comparison of Parameters

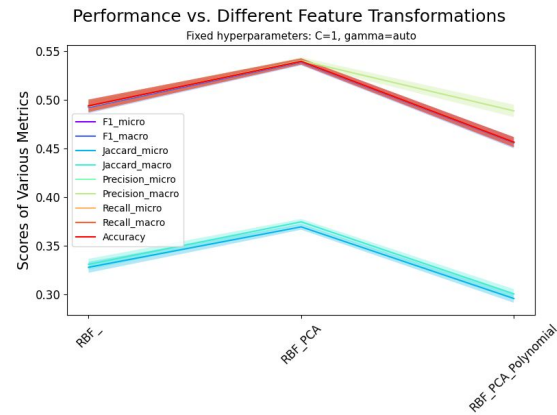
Transformation	parameters	mean_accuracy	mean_accuracy train	mean_precision_ micro	mean_recall_mic ro	mean_f1_micro
RBF_PCA	C=1, gamma=scale	0.539825	0.8067875	0.539825	0.539825	0.539825
RBF	C=1, gamma=auto	0.4941	0.7158	0.4941	0.4941	0.4941
RBF_PCA_Polyn omial	C=1, gamma=auto	0.4568	0.8824875	0.4568	0.4568	0.4568
RBF	C=0.005, gamma=scale	0.3113	0.318275	0.3113	0.3113	0.3113
RBF_PCA_Polyn omial	C=0.005, gamma=scale	0.1703	0.2044375	0.1703	0.1703	0.1703
RBF_PCA	C=0.0001, gamma=scale	0.28005	0.291325	0.28005	0.28005	0.28005



Performance vs. C



Performance vs. Gamma

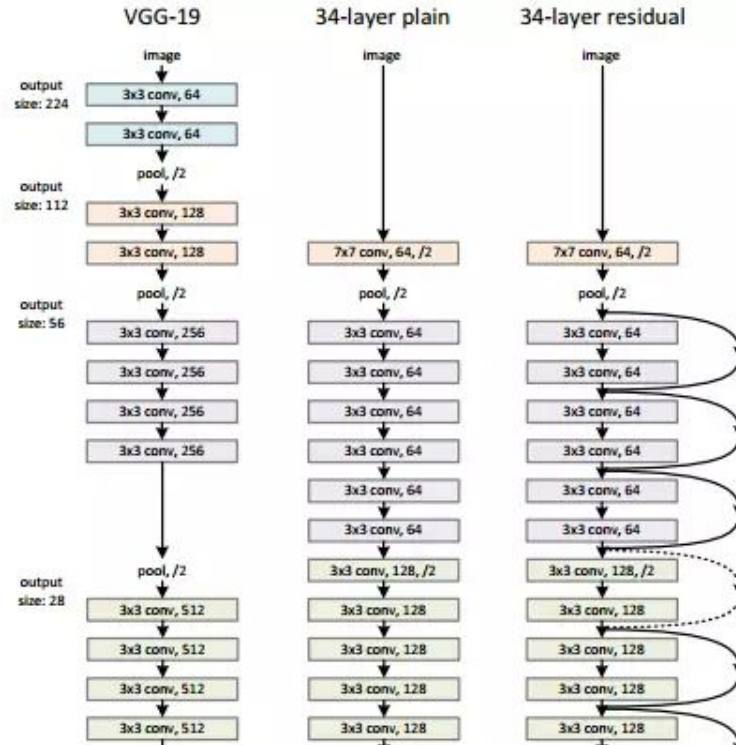


Feature transformation

Best Results

	SVM_RBF_	SVM_RBF_PCA	SVM_RBF_PCA_Polynomial
f1_micro	0.5381	0.2661	0.2416
f1_macro	0.5362570961	0.2636083625	0.2320019935
jaccard_micro	0.3680826322	0.1534690582	0.1373976342
jaccard_macro	0.3728279189	0.1545184775	0.133744542
precision_micro	0.5381	0.2661	0.2416
precision_macro	0.5365176717	0.2656052785	0.2577149449
recall_micro	0.5381	0.2661	0.2416
recall_macro	0.5381	0.2661	0.2416
accuracy	0.5381	0.2661	0.2416

ResNet Architecture



Convolutional Neural Networks

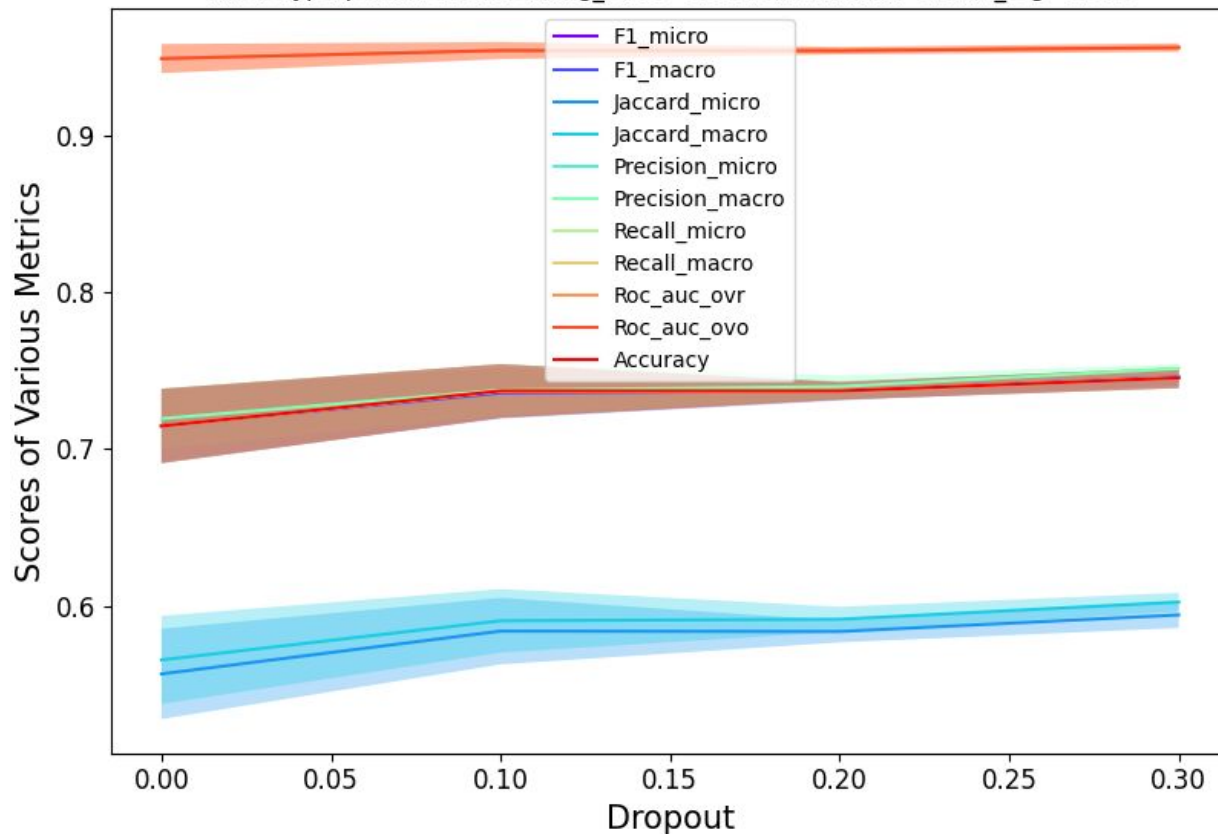
- Architectures:
 - ResNet18
 - ResNet34
 - ResNet50
- Hyperparameters:
 - Learning rate
 - Dropout rate
 - Weight decay
- Results:
 - Learning rate: Optimal range (0.001–0.01)
 - Dropout: Moderate rates (0.2–0.5) prevent overfitting
 - Weight decay: Controls generalization; high values underfit

feature				mean_precision_micro		
transformations	hyperparameters	mean_accuracy	mean_accuracy_train	o	mean_recall_micro	mean_f1_micro
resnet34	learning_rates=0.005, dropout=0.3, momentum=0.9, l2_reg=0.005	0.74536	0.9465066667	0.74536	0.74536	0.74536
resnet18	learning_rates=0.005, dropout=0.3, momentum=0.9, l2_reg=0.005	0.73328	0.93156	0.73328	0.73328	0.73328
resnet50	learning_rates=0.005, dropout=0.2, momentum=0.9, l2_reg=0.005	0.72496	0.8851066667	0.72496	0.72496	0.72496
resnet34	learning_rates=0.005, dropout=0, momentum=0, l2_reg=0.001	0.4852	0.5798666667	0.4852	0.4852	0.4852
resnet50	learning_rates=0.005, dropout=0, momentum=0, l2_reg=0	0.48632	0.5812533333	0.48632	0.48632	0.48632
	learning_rates=0.005, dropout=0,					

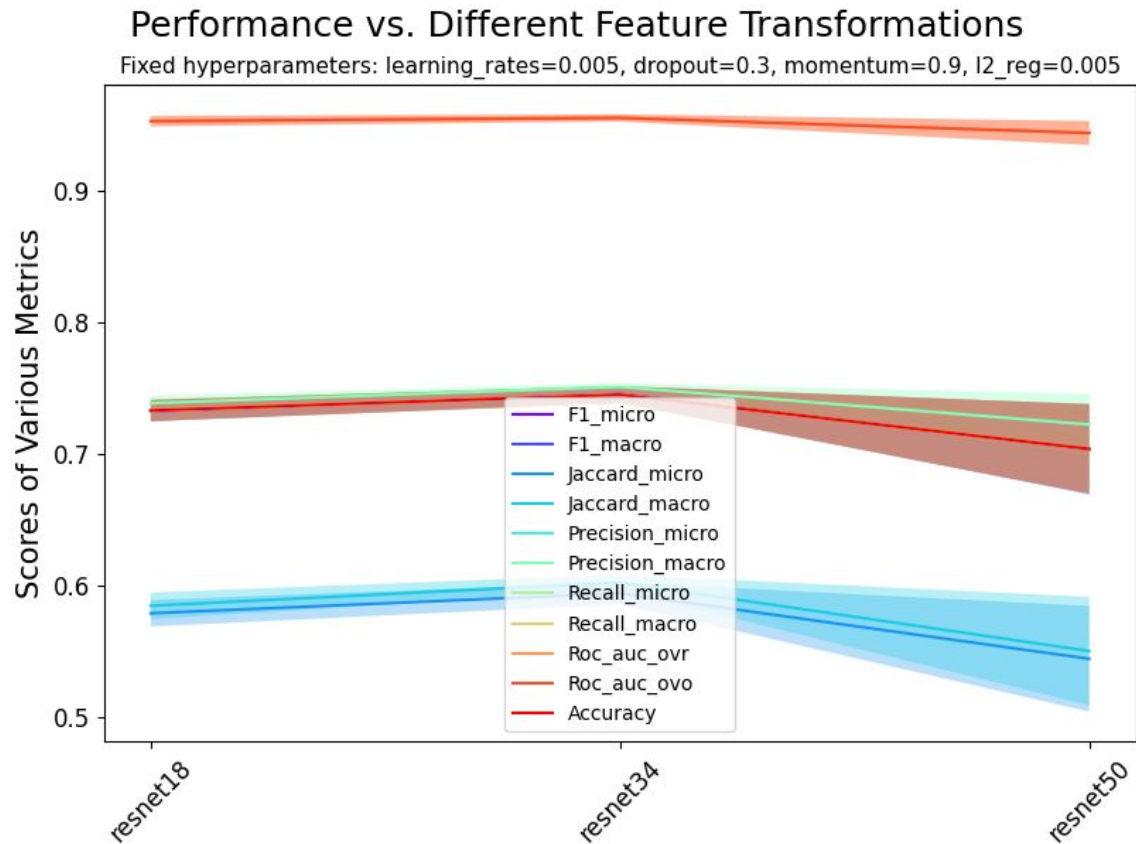
Dropout Analysis

Performance vs. Different values of Dropout

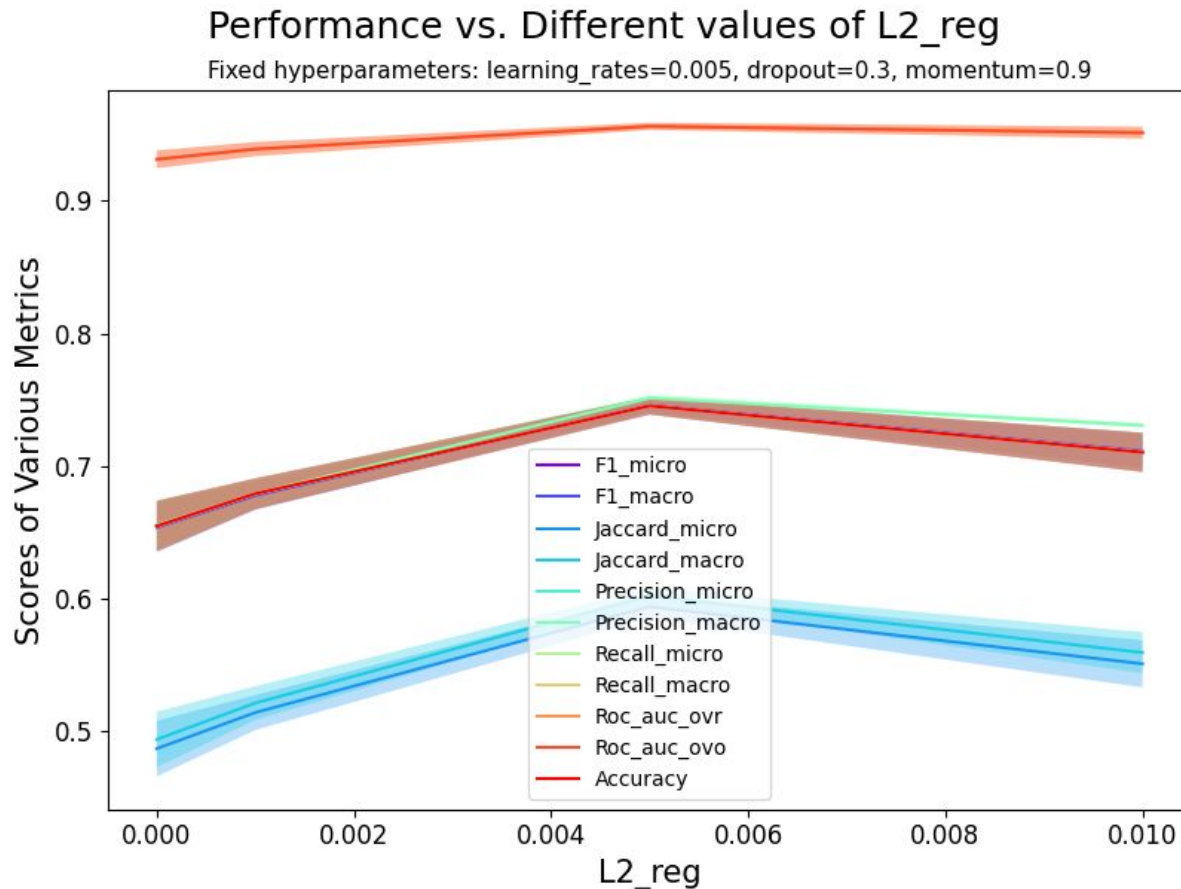
Fixed hyperparameters: learning_rates=0.005, momentum=0.9, l2_reg=0.005



Feature Transformation Analysis



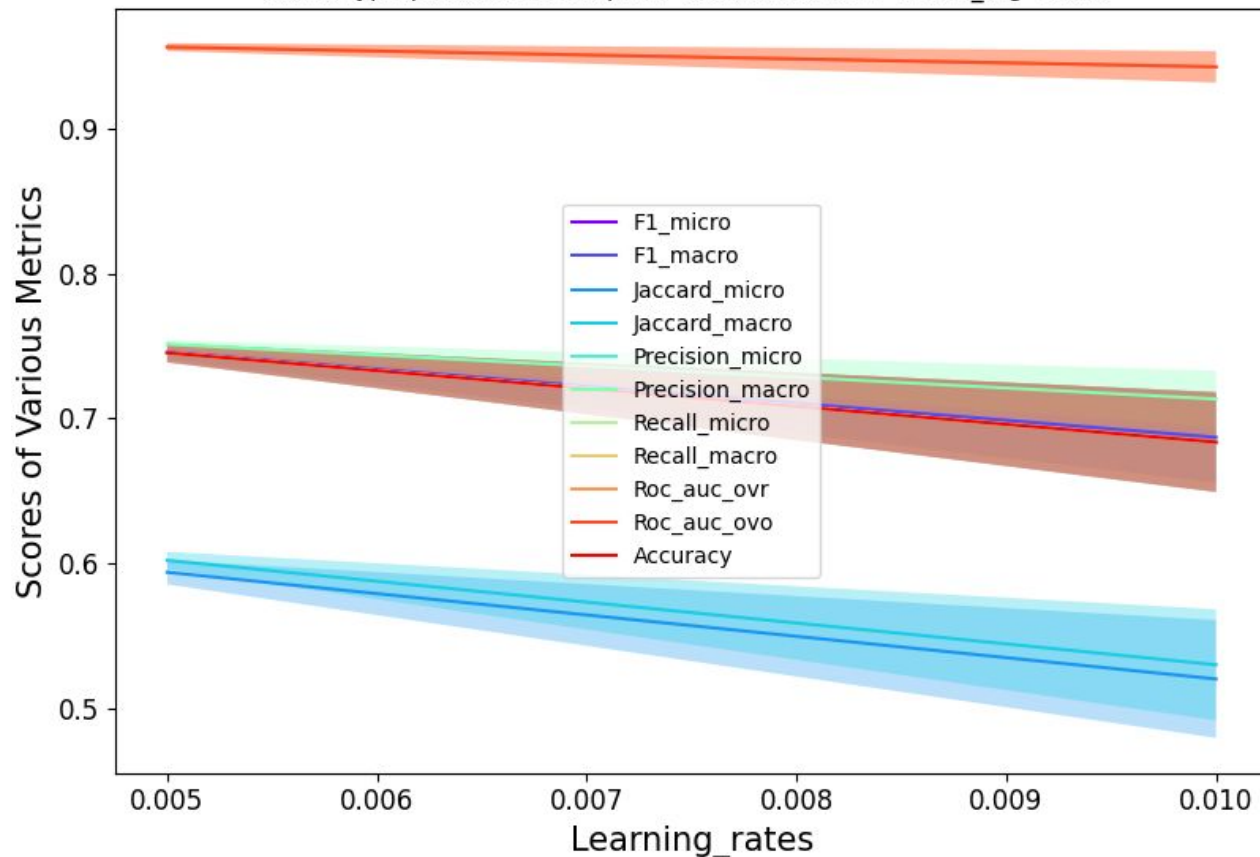
L2 Regularization Analysis



Learning Rate Analysis

Performance vs. Different values of Learning_rates

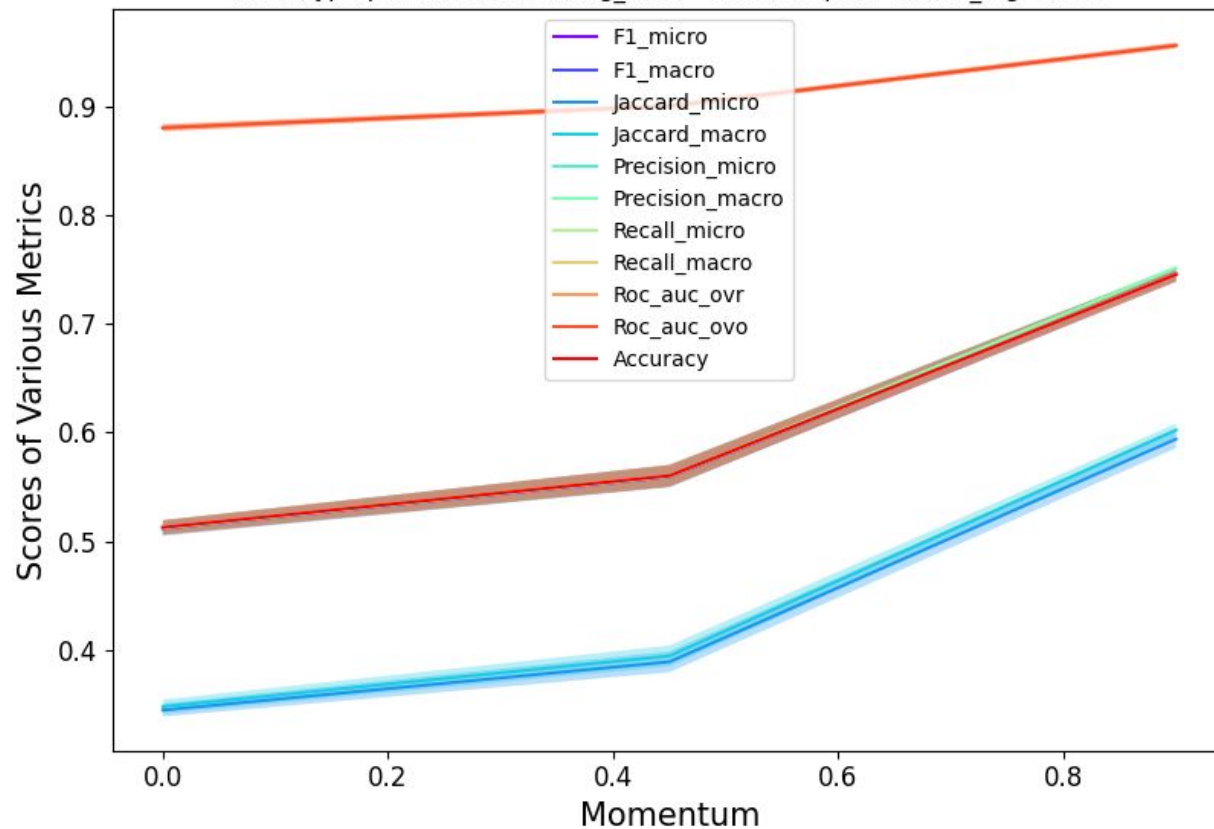
Fixed hyperparameters: dropout=0.3, momentum=0.9, l2_reg=0.005



Momentum Analysis

Performance vs. Different values of Momentum

Fixed hyperparameters: learning_rates=0.005, dropout=0.3, l2_reg=0.005

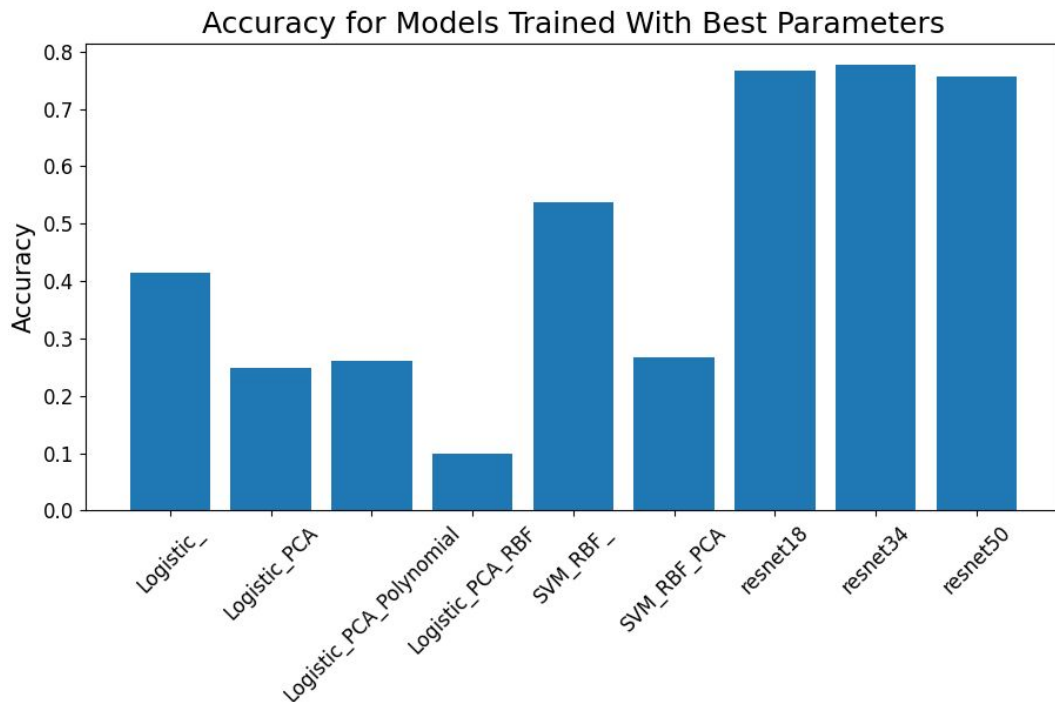


Best Results

	resnet18	resnet34	resnet50
f1_micro	0.7666	0.7761	0.7561
f1_macro	0.7634146766	0.77719182	0.7546764394
jaccard_micro	0.6215339711	0.6341204347	0.6078462899
jaccard_macro	0.6249020499	0.6422917504	0.6138521371
precision_micro	0.7666	0.7761	0.7561
precision_macro	0.7663285414	0.7833279756	0.7648182968
recall_micro	0.7666	0.7761	0.7561
recall_macro	0.7666	0.7761	0.7561
roc_auc_ovr	0.9715057111	0.9720813889	0.9698609833
roc_auc_ovo	0.9715057111	0.9720813889	0.9698609833
accuracy	0.7666	0.7761	0.7561

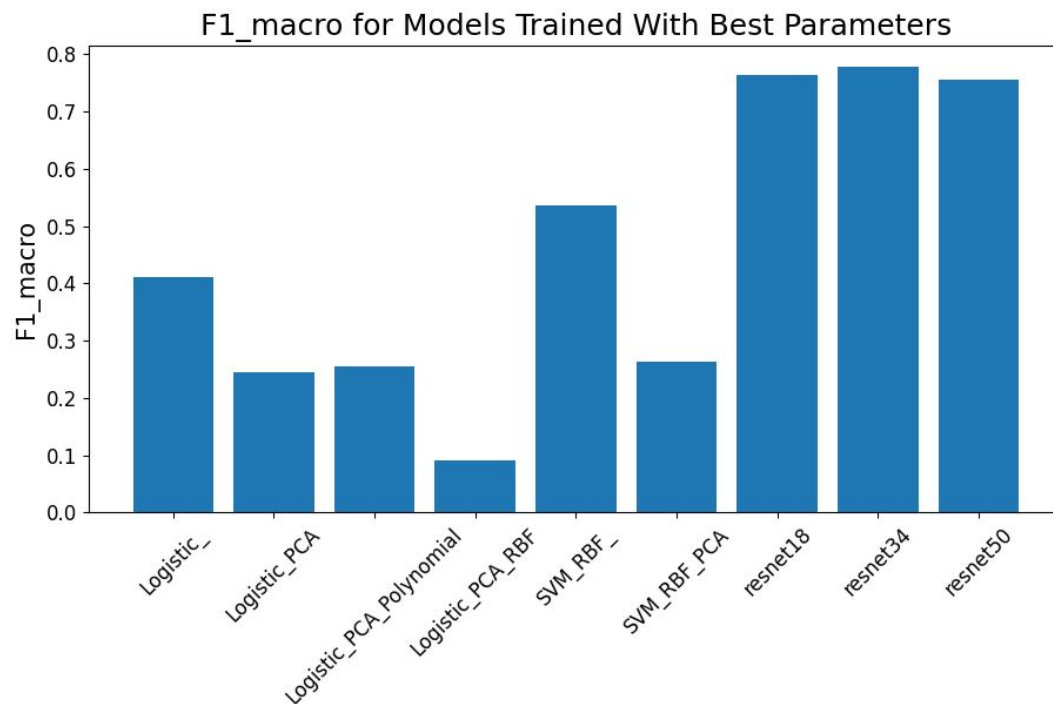
Accuracy Analysis

- Accuracy is one of the primary indicators of model performance.
- ResNet models consistently outperform other models in terms of accuracy.



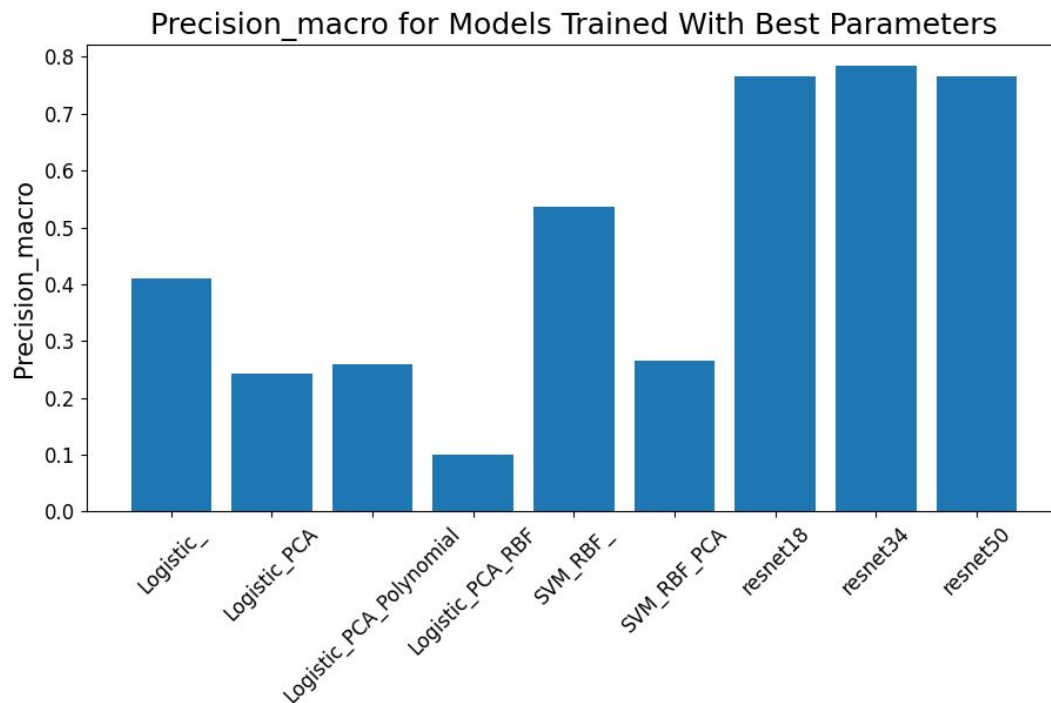
F1 Score Analysis

- F1 score (macro) measures the balance between precision and recall across all classes
- ResNet models achieve the highest F1 scores, indicating superior class balance.



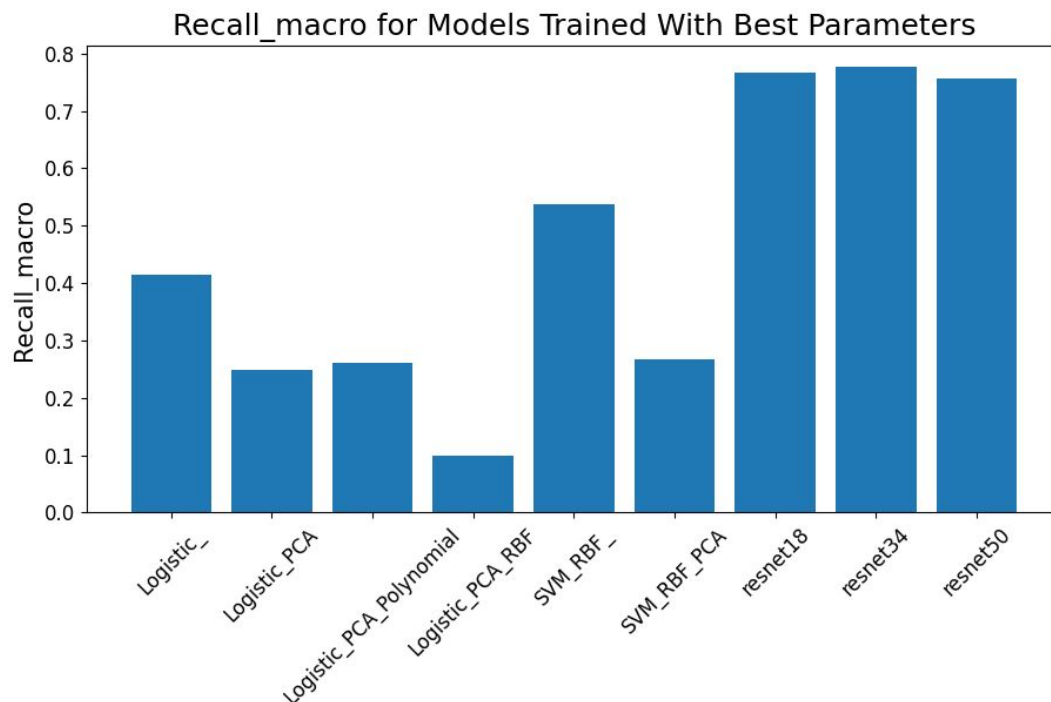
Precision Analysis

- Precision indicates the ability of the model to avoid false positives across all classes.
- ResNet models dominate in this metric, followed by SVM.



Recall Analysis

- Recall evaluates the model's ability to detect true positives across all classes.
- ResNet models maintain the highest recall, indicating robustness in detecting all classes.



ROC-AUC Analysis

- ROC-AUC reflects the model's ability to distinguish between classes.
- ResNet models achieve near-perfect ROC-AUC scores, confirming their superior classification capabilities.



Chart of result

	Logistic_	Logistic_PCA	Logistic_PCA_Polyn	Logistic_PCA_RBF	SVM_RBF_	SVM_RBF_PCA	SVM_RBF_PCA_Pol	resnet18	resnet34	resnet50
f1_micro	0.4153	0.2494	0.2614	0.1001	0.5381	0.2661	0.2416	0.7666	0.7761	0.7561
f1_macro	0.4112770228	0.2449428034	0.2553107377	0.09105211754	0.5362570961	0.2636083625	0.2320019935	0.7634146766	0.77719182	0.7546764394
jaccard_micro	0.2620685303	0.1424654404	0.150350857	0.05268698353	0.3680826322	0.1534690582	0.1373976342	0.6215339711	0.6341204347	0.6078462899
jaccard_macro	0.262227003	0.1432901369	0.1486988309	0.04807267742	0.3728279189	0.1545184775	0.133744542	0.6249020499	0.6422917504	0.6138521371
precision_micro	0.4153	0.2494	0.2614	0.1001	0.5381	0.2661	0.2416	0.7666	0.7761	0.7561
precision_macro	0.4104284466	0.242102908	0.2589800105	0.09995613946	0.5365176717	0.2656052785	0.2577149449	0.7663285414	0.7833279756	0.7648182968
recall_micro	0.4153	0.2494	0.2614	0.1001	0.5381	0.2661	0.2416	0.7666	0.7761	0.7561
recall_macro	0.4153	0.2494	0.2614	0.1001	0.5381	0.2661	0.2416	0.7666	0.7761	0.7561
roc_auc_ovr	0.8205815333	0.6887226444	0.6894341556	0.4979451667				0.9715057111	0.9720813889	0.9698609833
roc_auc_ovo	0.8205815333	0.6887226444	0.6894341556	0.4979451667				0.9715057111	0.9720813889	0.9698609833
accuracy	0.4153	0.2494	0.2614	0.1001	0.5381	0.2661	0.2416	0.7666	0.7761	0.7561

Thank You!