

Comparative Analysis: Classical vs Deep Learning

Video Classification

This notebook summarizes the performance comparison between classical feature-based models and deep learning approaches for video classification using a subset of the UCF-101 dataset.

Performance Comparison Table

```
! pip install pandas
```

```
Requirement already satisfied: pandas in /usr/local/lib/python3.12/dist-packages (2.2.2)
Requirement already satisfied: numpy>=1.26.0 in /usr/local/lib/python3.12/dist-packages (2.0.2)
Requirement already satisfied: python-dateutil>=2.8.2 in /usr/local/lib/python3.12/dist-packages (2.9.0)
Requirement already satisfied: pytz>=2020.1 in /usr/local/lib/python3.12/dist-packages (2024.1)
Requirement already satisfied: tzdata>=2022.7 in /usr/local/lib/python3.12/dist-packages (2024.1)
Requirement already satisfied: six>=1.5 in /usr/local/lib/python3.12/dist-packages (1.17.0)
```

```
import pandas as pd
```

```
data = {
    "Model": [
        "Logistic Regression",
        "SVM",
        "Random Forest",
        "CNN Temporal",
        "R(2+1)D"
    ],
    "Accuracy": [0.90, 0.85, 0.53, 0.875, 0.775],
    "Precision (macro)": [0.90, 0.85, 0.52, 0.88, 0.77],
    "Recall (macro)": [0.90, 0.85, 0.52, 0.88, 0.75],
    "F1-score (macro)": [0.90, 0.85, 0.52, 0.88, 0.75],
}
```

```
df = pd.DataFrame(data)
df
```

	Model	Accuracy	Precision (macro)	Recall (macro)	F1-score (macro)
0	Logistic Regression	0.900	0.90	0.90	0.90
1	SVM	0.850	0.85	0.85	0.85
2	Random Forest	0.530	0.52	0.52	0.52
3	CNN Temporal	0.875	0.88	0.88	0.88

Next steps: [Generate code with df](#) [New interactive sheet](#)

✓ Performance Interpretation

Logistic Regression achieved the highest overall accuracy (0.90), indicating that the hand-crafted feature representation is highly effective for this dataset.

The CNN temporal model achieved competitive performance (0.875), demonstrating that learned representations can approach classical feature-based performance even with a relatively small dataset.

SVM also performed well (0.85), confirming that histogram-based feature vectors are well suited for margin-based classifiers.

Random Forest performed significantly worse (0.53), suggesting that the feature space does not contain strongly separable axis-aligned decision boundaries.

The R(2+1)D model achieved moderate performance (0.775), indicating that 3D convolutional models require more data or longer training to fully capture spatiotemporal dynamics.

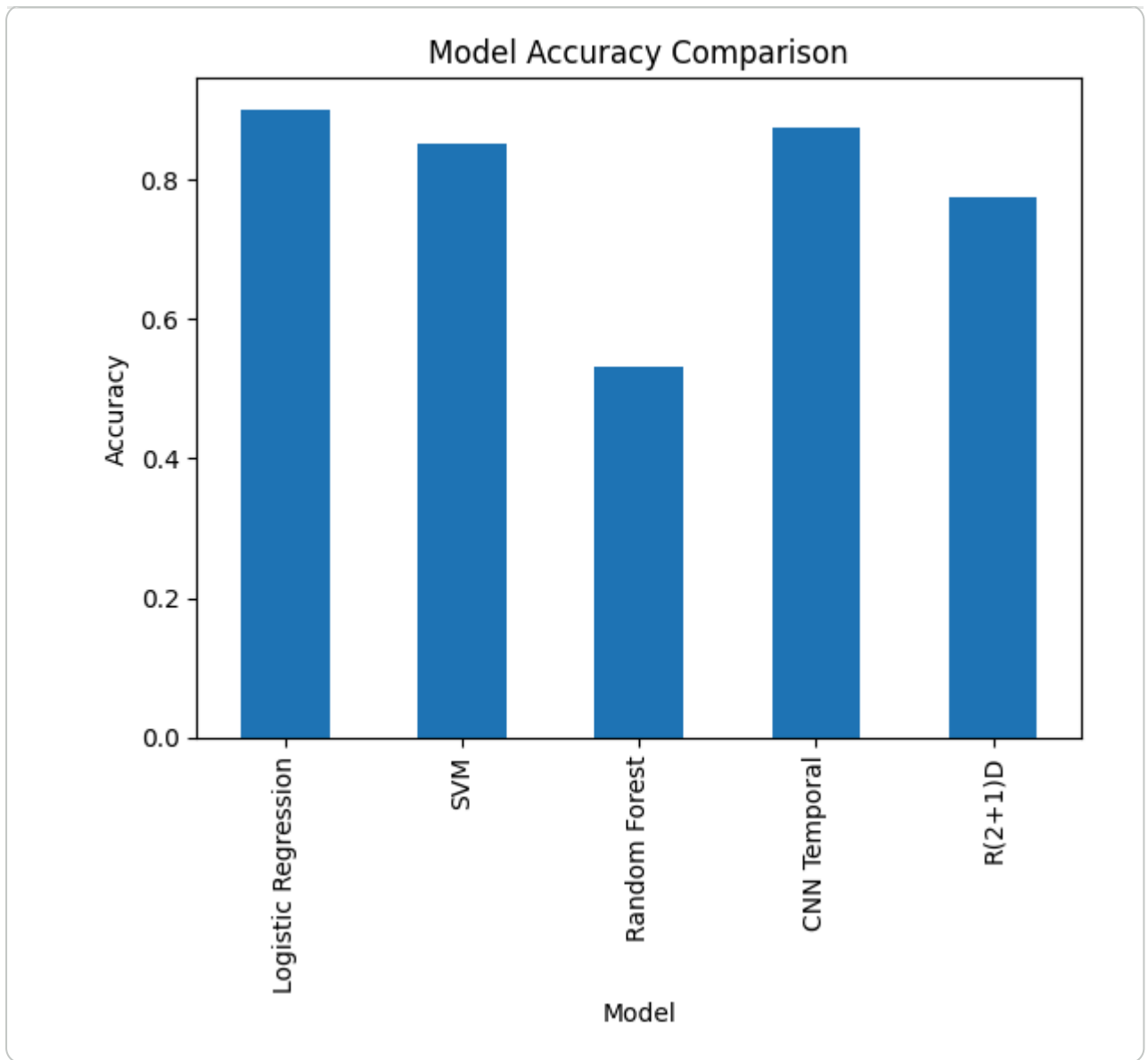
Best accuracy achieved: Logistic Regression (0.90)

Best deep learning model: CNN Temporal (0.875)

✓ Model Accuracy Comparison

```
import matplotlib.pyplot as plt

df.set_index("Model")["Accuracy"].plot(kind="bar")
plt.title("Model Accuracy Comparison")
plt.ylabel("Accuracy")
plt.show()
```



Error Analysis

From confusion matrix observations across all models:

Basketball is classified more reliably across models, while most misclassifications occur between JumpingJack and WalkingWithDog. These two classes contain repetitive motion patterns that produce similar motion features, leading to confusion across both classical and deep learning approaches.

- Classical models confuse motion-heavy actions such as JumpingJack and WalkingWithDog.
- Random Forest struggles due to distributed feature importance.
- CNN Temporal model reduces misclassification using learned features.
- R(2+1)D improves temporal understanding but requires more data.

Common failure reasons:

- Similar motion patterns across classes
- Limited dataset size

- Frame sampling limitations

Computational Analysis

Classical Pipeline:

- Feature extraction time is high.
- Model training is fast on CPU.
- Small model size.

Deep Learning:

- Requires GPU training.
- CNN Temporal trains faster than R(2+1)D.
- R(2+1)D requires more memory and compute.

Inference:

- Classical models are faster after feature extraction.
- Deep learning requires forward pass computation.

Computational Comparison

Approach	Training Cost	Inference Cost	Model Size	Hardware
Classical ML	Low	Very low	Small	CPU
CNN Temporal	Medium	Medium	Moderate	GPU
R(2+1)D	High	High	Large	GPU

Trade-off Analysis

Accuracy vs Computational Cost: Logistic Regression achieved the highest accuracy with minimal computational cost, showing the effectiveness of well-designed hand-crafted features. Deep learning models required significantly more computation while providing comparable performance.

Data Efficiency: Classical models performed strongly with only ~300 training videos. Deep learning models typically require larger datasets to outperform feature-based approaches.

Interpretability vs Performance: Classical features (color histogram, LBP, motion statistics) are interpretable, while deep learning models learn abstract representations.

Overall: Classical methods are efficient and reliable for small datasets, while deep learning models are more scalable for large video datasets.

Deployment Considerations

Edge deployment: Classical models are suitable due to low memory and CPU inference.

Cloud deployment: Deep learning models benefit from GPU infrastructure.

Real-time feasibility: CNN Temporal may support real-time inference with GPU. R(2+1)D requires optimization for real-time usage.

Maintenance: Classical pipelines require manual feature updates. Deep learning models can be fine-tuned with new data.

Conclusion

This project compared classical feature-based methods and deep learning approaches for video classification.

Logistic Regression achieved the highest accuracy among classical models. The CNN temporal model achieved strong performance among deep learning approaches.

The experiments demonstrate the trade-offs between computational efficiency, interpretability, and representation learning.

Representation Learning Insight

The strong performance of classical models suggests that low-level appearance and motion statistics are sufficient to distinguish the selected action classes. This indicates that dataset complexity is moderate and does not require deep hierarchical feature learning.