Image Classification with Traditional Classifiers and Deep Neural Networks

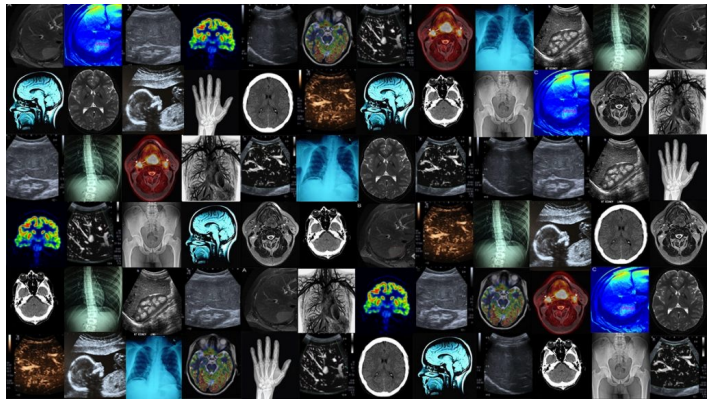
Daniele Montagnani

12 February 2024

Introduction

Image Classification and Computer Vision

Useful for a lot of fields: medical diagnosis, autonomous driving and automatic industrial quality control



Different Methods:

- Traditional Feature Extraction + Traditional Classifier
- Deep Learning

Dataset and Data Pre-processing

Two types of data preprocessing:

- For the traditional pipeline
- For the deeplearning pipeline

Noisy, High visual similarity
Fairly balanced dataset
Frameworks (torch, lightning)

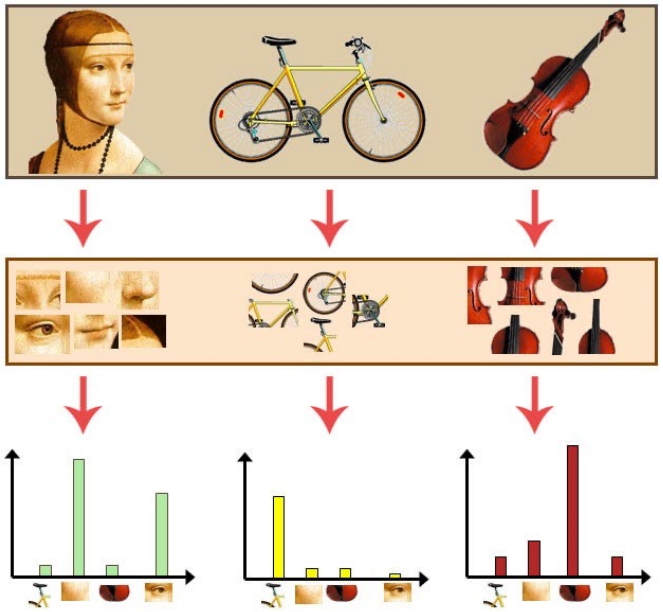
Traditional Feature Extraction

Scale Invariant Feature Transform:

- Keypoint Detection
- Descriptors Computation
- Bandpassing for Scale Invariance

Bag of Words:

- Compute prototypes
- Cluster features
- Describe Images



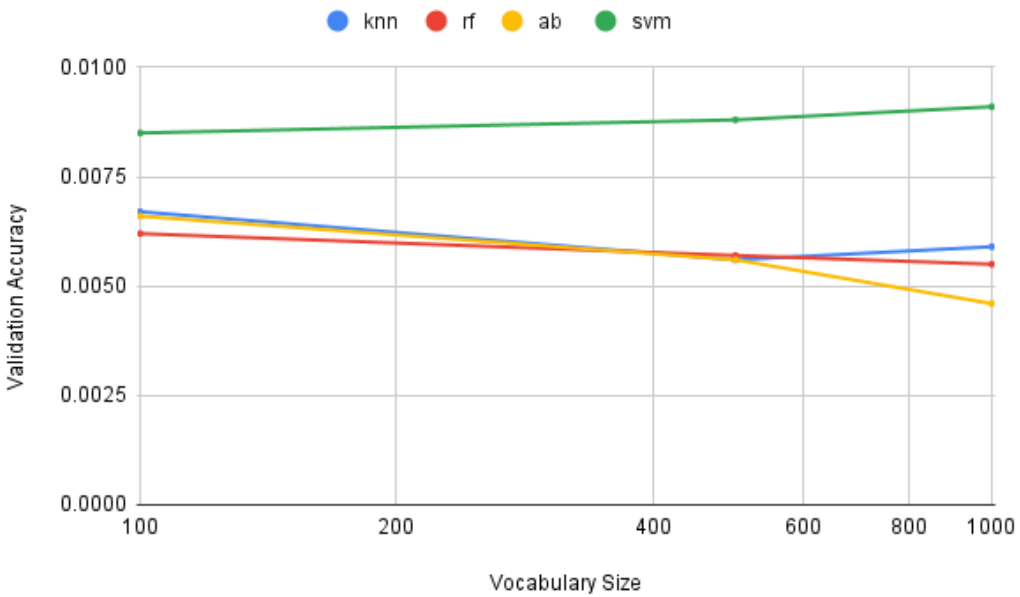
Traditional Classifiers

Different vocabulary sizes were not so determinant for performace
For computational Reasons, chose lowest size

Models Considered KNN, Random Forest, SVM, Naïve Bayes, Adaboost

For Every model:

- Computational considerations
- Interesting Hyperparameters
- Hyperparameter Space
- Exhaustive grid search



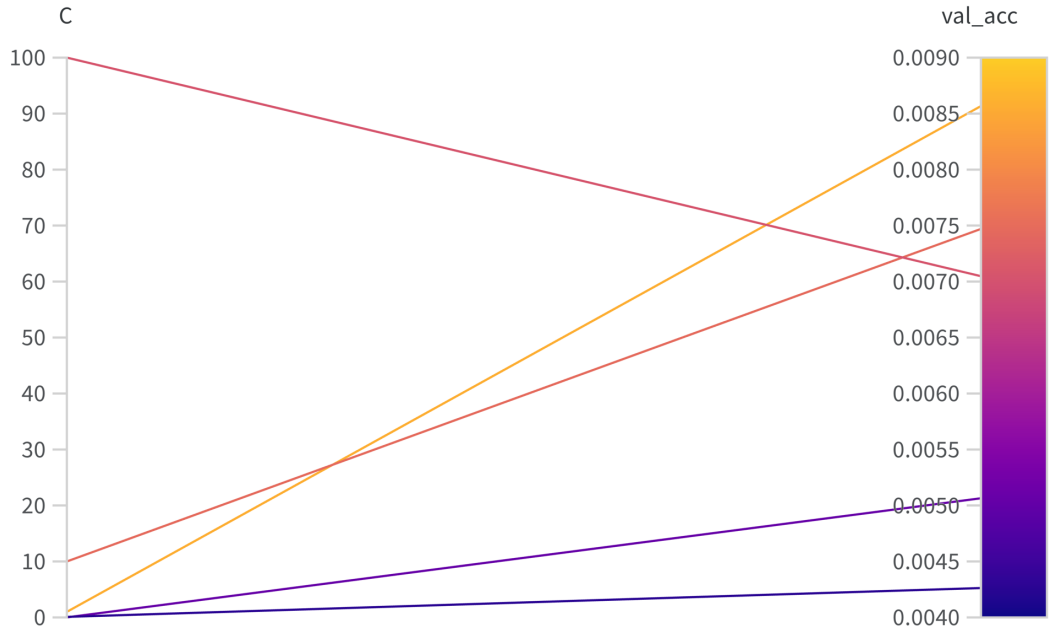
Traditional Classifiers - SVM

Time Intensive Training

Best Validation Accuracy 86 pips

Hyperparameter Space:

- C = [0.01,0.1,1,10,100]
- Gamma = “scale”
- Kernel = “RBF”
- Class = “balanced”



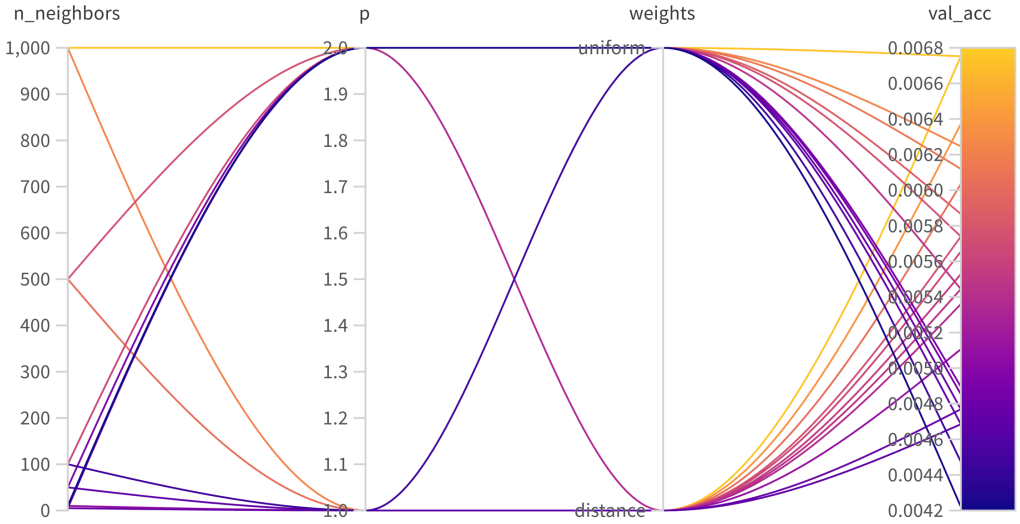
Traditional Classifiers - KNN

Fast Training

Best Validation Accuracy 68 pips

Hyperparameter Space:

- n_neighbors = [5,10,50,100,500,1000]
- Minkowski metric = [1,2]
- Weighting = [”uniform”, “distance”]



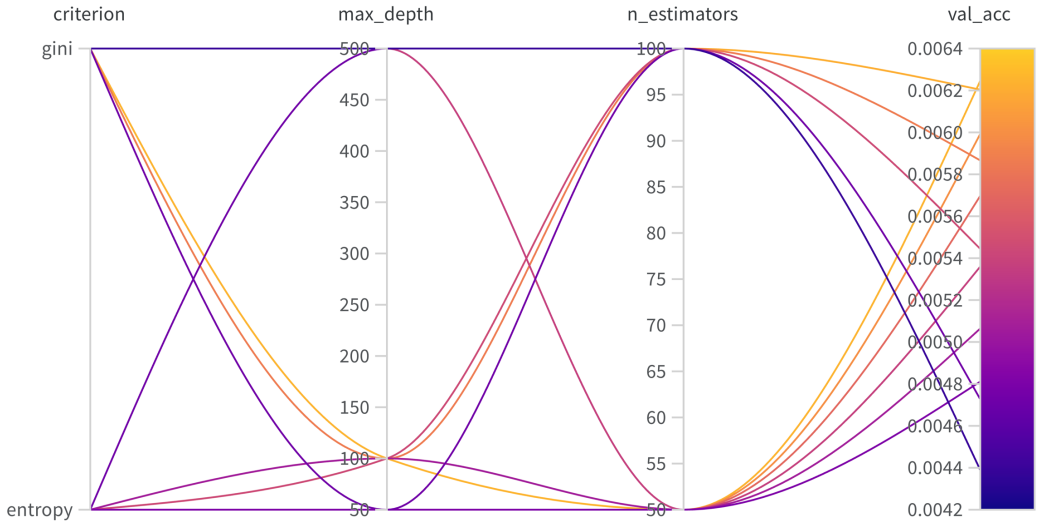
Traditional Classifiers – Random Forest

Expensive Training

Best Validation Accuracy 62 pips

Hyperparameter Space:

- Criterion = [“gini”, “entropy”]
- Number of Estimators = [50, 100]
- Max Depth= [50, 100, 500]



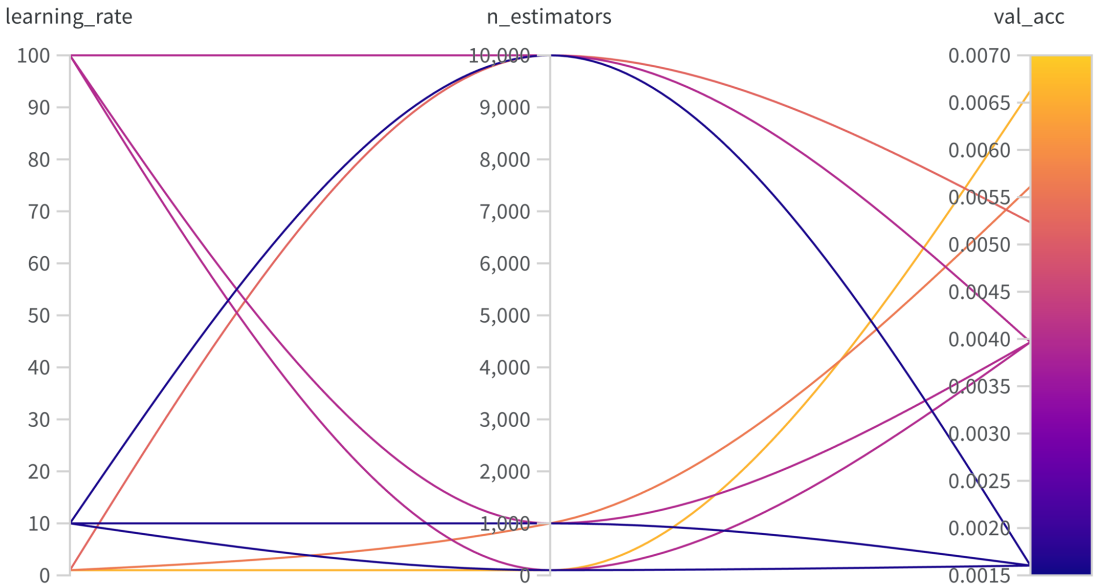
Traditional Classifiers - AdaBoost

Expensive Training

Best Validation Accuracy 66 pips

Hyperparameter Space:

- Learning Rate =[1, 10, 100]
- Number of Estimators = [100, 1000, 10000]



Traditional Classifiers – Final Evaluation

Very Low Performance Overall

KNN worst Algorithm
Curse of Dimensionality

Above Random Guessing Benchmark → Some Learning

Better Scores with training on the full training set

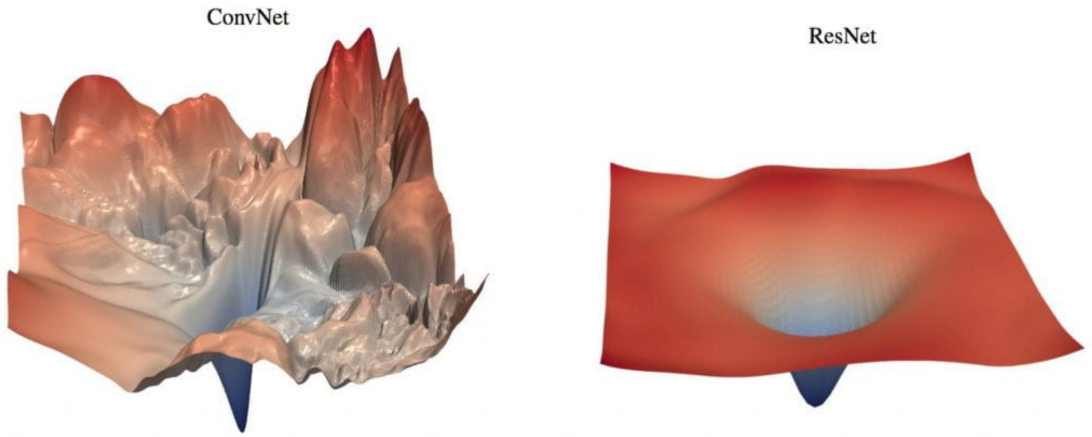
	Accuracy	Precision	Recall	F1-Score
Naïve Bayes	0.0097	0.0068	0.0097	0.0061
SVM	0.0099	0.0069	0.0099	0.0072
KNN	0.0043	0.0042	0.0043	0.0021
Random Forest	0.0051	0.0044	0.0051	0.0042
Adaboost	0.0091	0.0106	0.0091	0.0061

Deep Learning

End to End Training
Automatic Feature Extraction
Based On Optimisation Methods

Cnn → Leverage Geometry → Efficiency
Resnet's Skip connections → Better Optimisation Landscape → Deeper networks

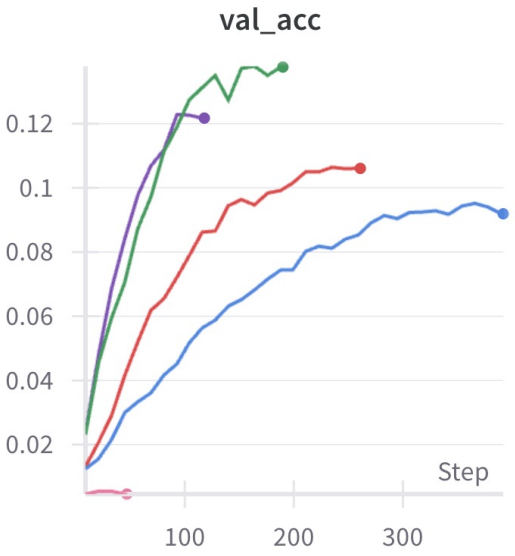
Two Approaches:
- Simple CNN
- ResNet

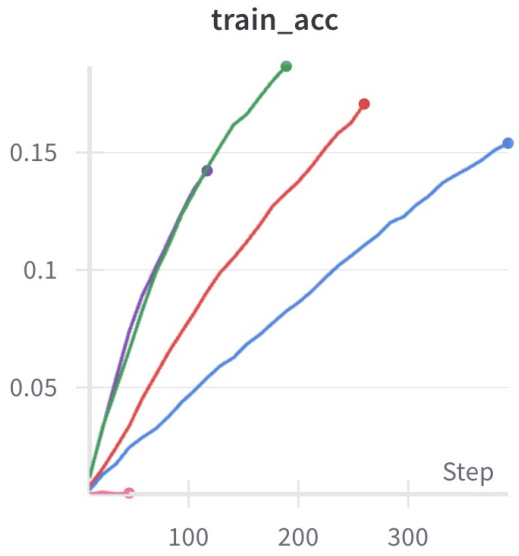


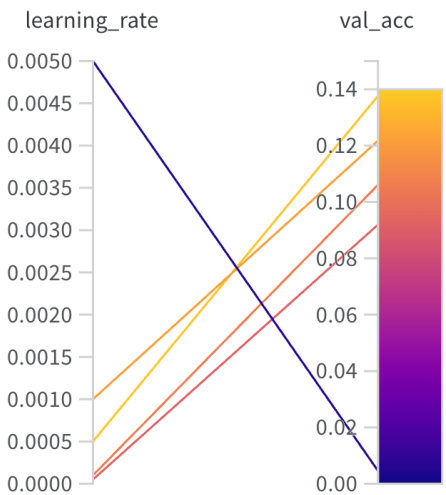
Deep Learning – Simple CNN

Simple CNN architecture:

- Dimensionality reduction through convolutions and pooling
- No systematic Architectural experimentation (by hand at the beginning)



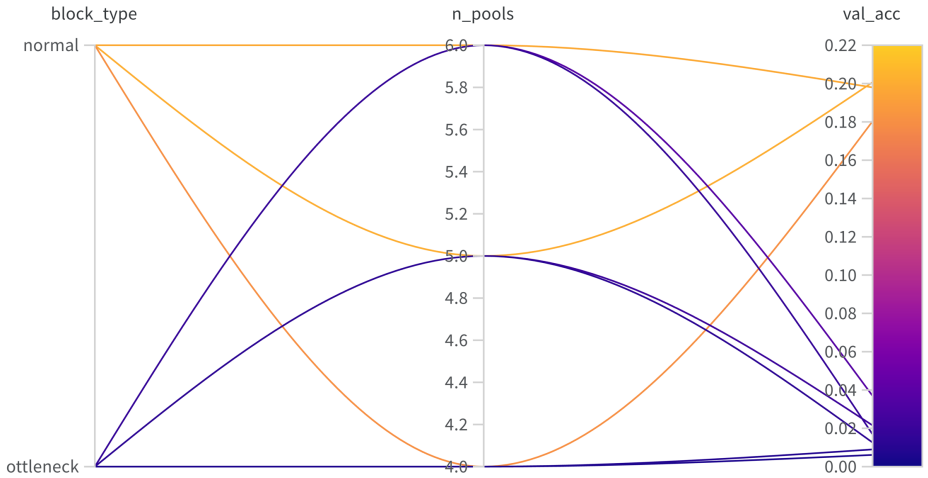


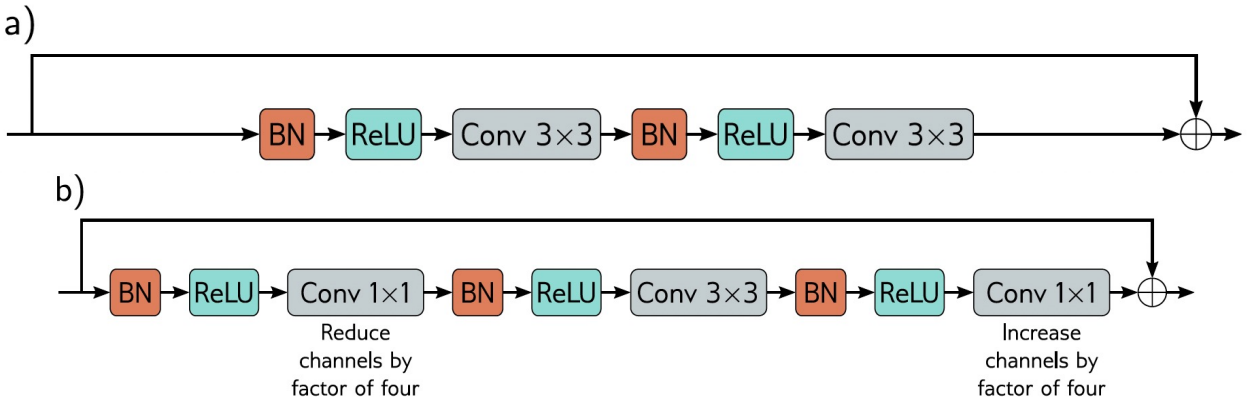


Deep Learning – Resnet I

Architecture Experimentation:

- Parameter economisation
- Backward from the linear layer
- N pools = [4,5,6]
- Type of Block = [‘normal’, ‘bottleneck’]

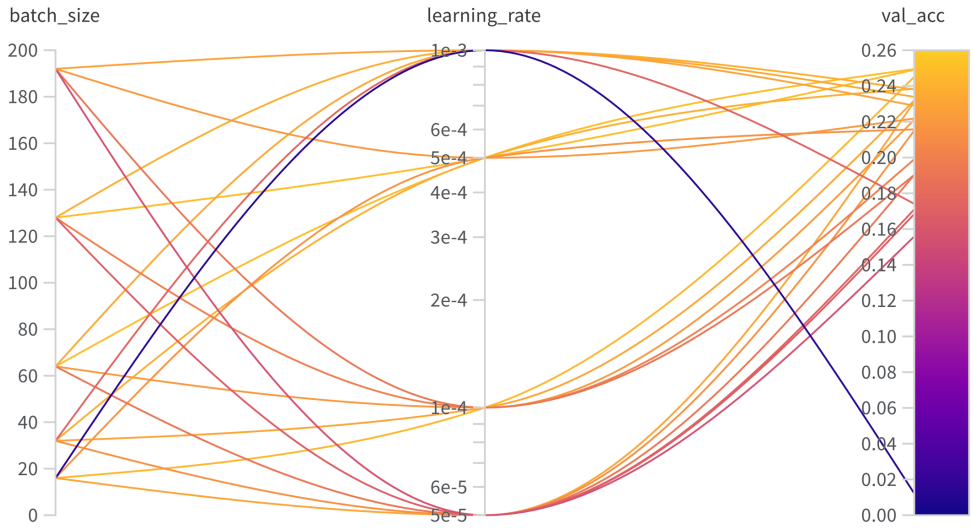




Deep Learning – Resnet II

Final Sweep:

- Learning Rate = [5e-5, 1e-4, 5e-4, 1e-3]
- Batch Size = [16, 32, 64, 128, 192]
- **Best Model = (5e-4, 64)**



Deep Learning – Final Evaluation

Test accuracy	0.2856
Test f1 score	0.2762
Test precision	0.3047
Test recall	0.2856

Good Performance

Better than validation

No test-to-train data leak

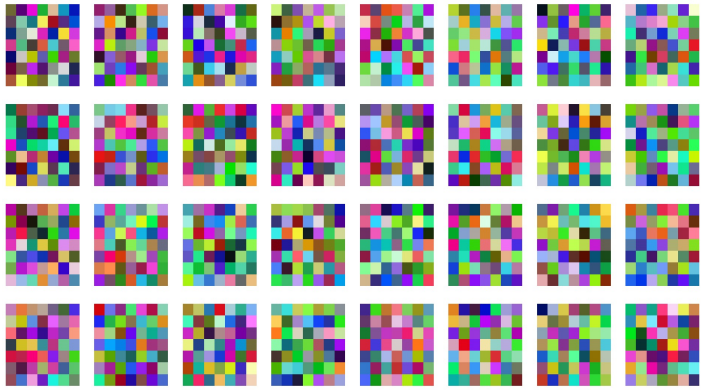
Deep Learning – Final Model Exploration

Mechanistic Interpretability

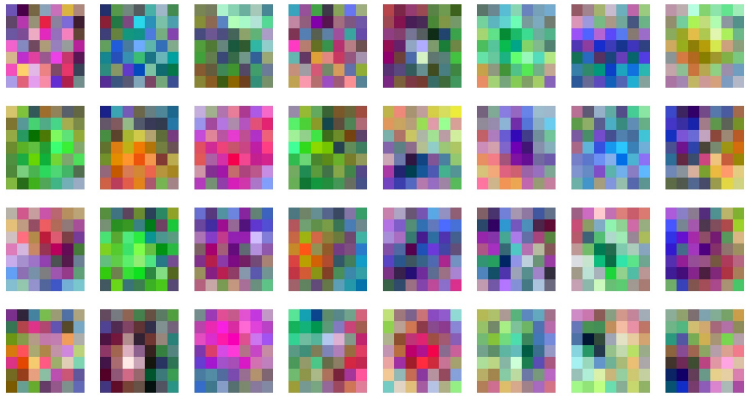
Instrumental Convergence towards **Gabor filters**

Model Exploration and Visualisation

	Mediocre	Best
Test accuracy	0.1828	0.2856
Test f1 score	0.1702	0.2762
Test precision	0.1828	0.3047
Test recall	0.1661	0.2856



Mediocre's Model Kernels



Best Model's Kernels

Conclusion

Comparison of Approaches for Image Recognition

Challenging Dataset (Noisy, High Similarity, Fine Grained)

Clear Advantage of the Deep Learning Approach

Computing limitationd in the Traditional Approach

Interesting Research in model's weights exploration

Tech Stack: Torch 🔥, Lightning⚡, WandB 🪄, OpenCV 👁️, SkLearn 🧮