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Vehicle Logo Classification using Deep Learning

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Background

Aim:

- Propose an integrated deep learning approach combining:
  - Deep Separable Convolutional Neural Networks (DSCNN)
  - Residual learning
  - Inception architectures
  - Attentional mechanisms
- Construct an accurate and efficient deep learning model
- Improve the accuracy of vehicle logo classification

Audience:

- Government Traffic Management
- Car park management
- City planners
- Automobile companies

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Dataset

VLD-45[1] dataset:

- Constructed by S. Yang et al.
- Contains images of 45 categories of vehicles
- Includes various backgrounds, angles, orientations, and brightness levels
- Used for deep learning projects such as:
  - Vehicle logo classification
  - Vehicle logo recognition
  - Vehicle classification and recognition
- Widely used in deep learning projects related to vehicles

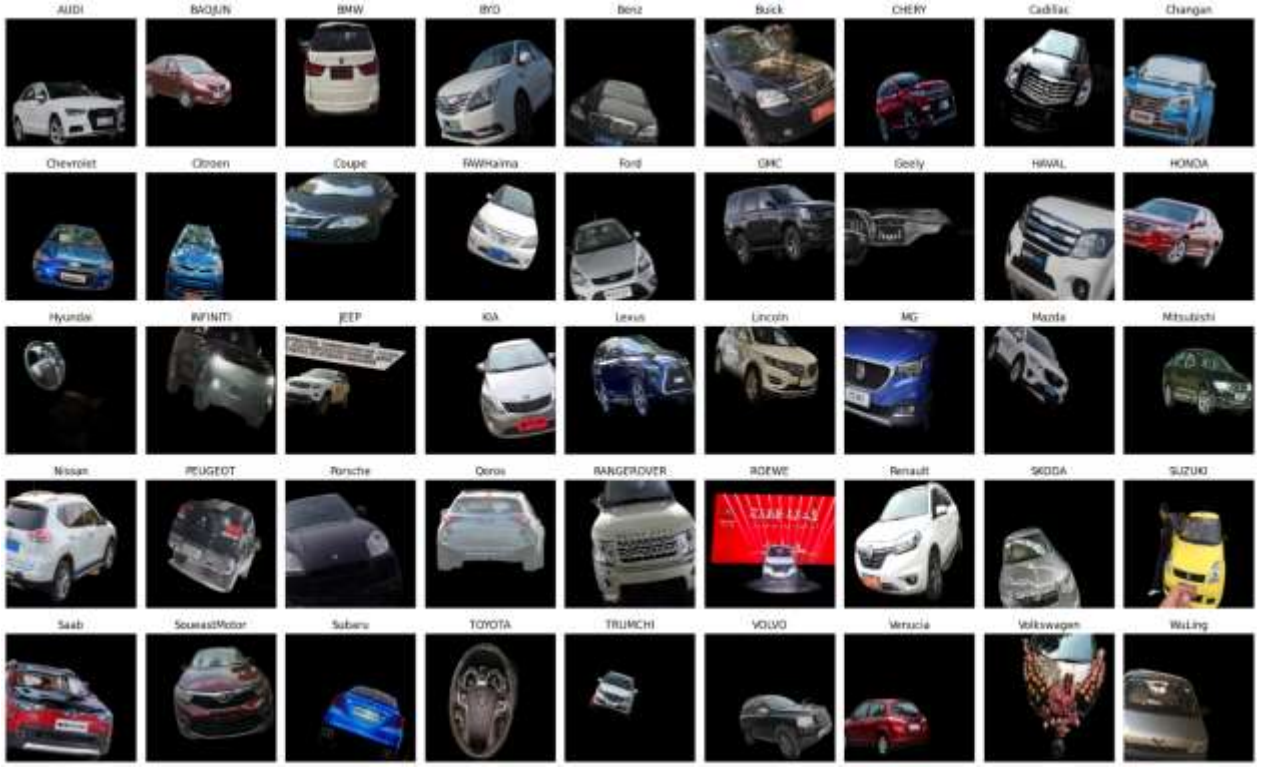

Figure: Sample data for each category

45 categories

Each category: 1000 images

Total: 45000 images

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Software and Hardware

Software	Framework	Tensorflow
	Language	Python
	Libraries	Numpy, Scikit learn, Pandas, OpenCV, Scipy
	Version management plan	Github
Hardware	Central processing unit (CPU)	12th Gen Intel(R) Core (TM) i7-12700H 2.30 GHz, Intel(R) Core(TM) i7-14700K 3.40 GHz
	Graphics Processing Unit	NVIDIA GeForce RTX 3070Ti Laptop GPU, Cloud Computer GeForce RTX 3080 10.6G, NVIDIA GeForce RTX 4080 Super

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Model Architecture

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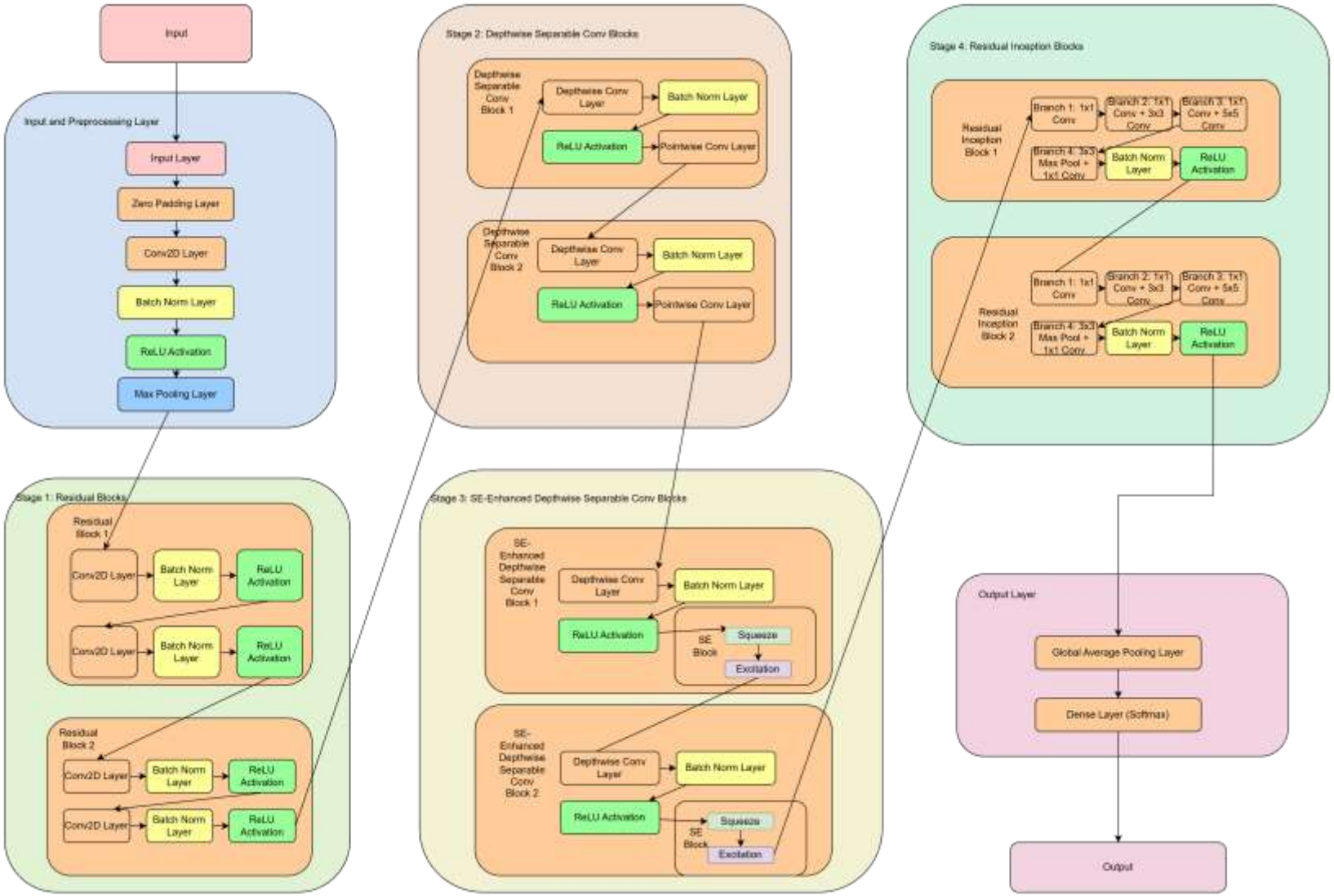
Model Architecture



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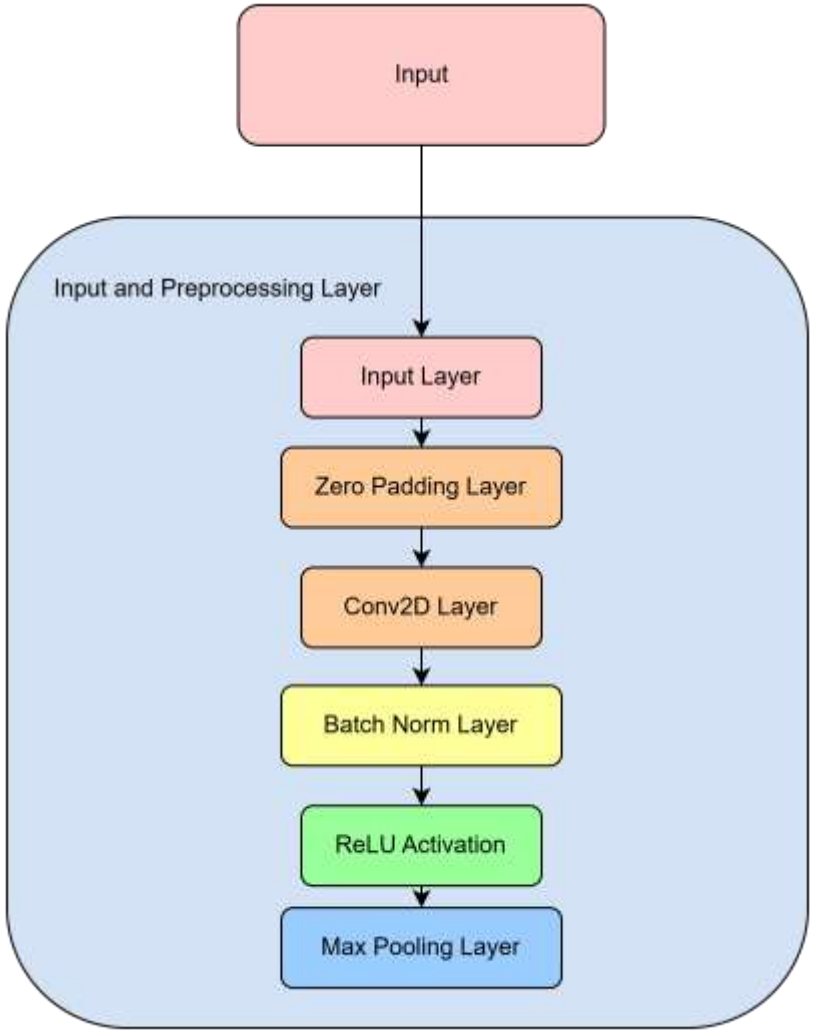
Model Architecture

Part A: Input and pre-processing layer



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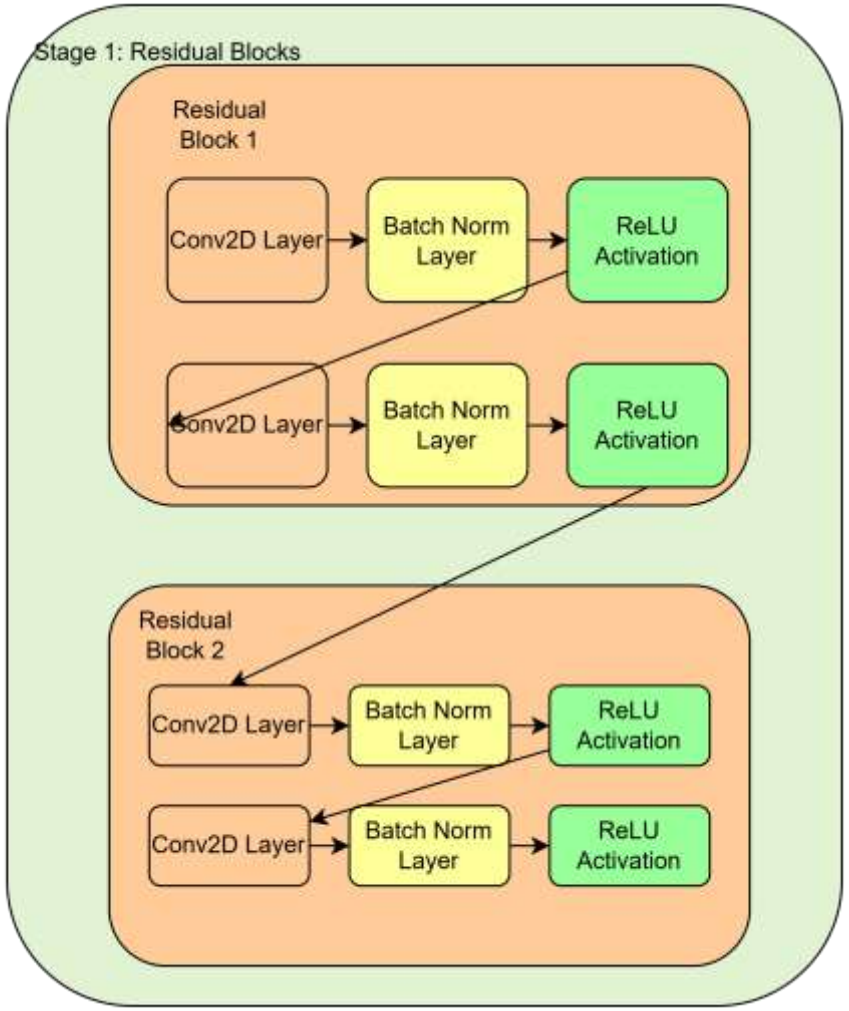
Model Architecture

Part B: Residual Blocks



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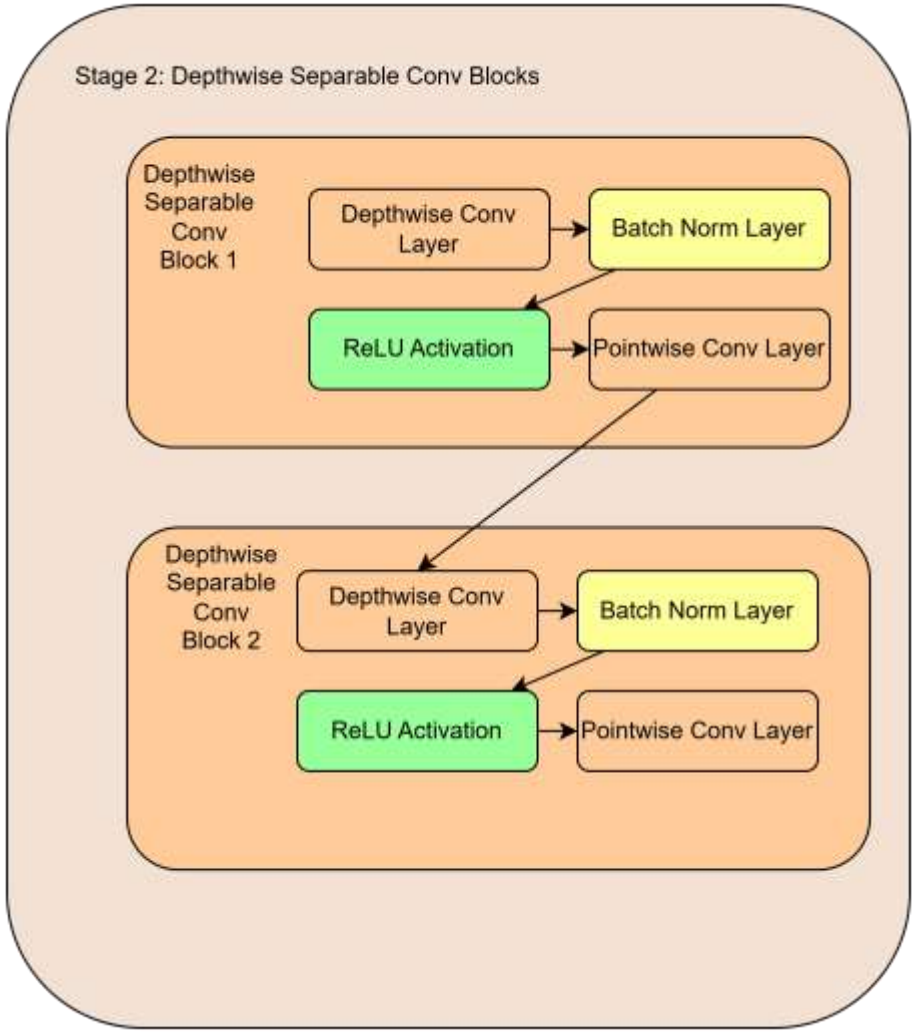
Model Architecture

Part C: Depthwise Separable Conv Blocks



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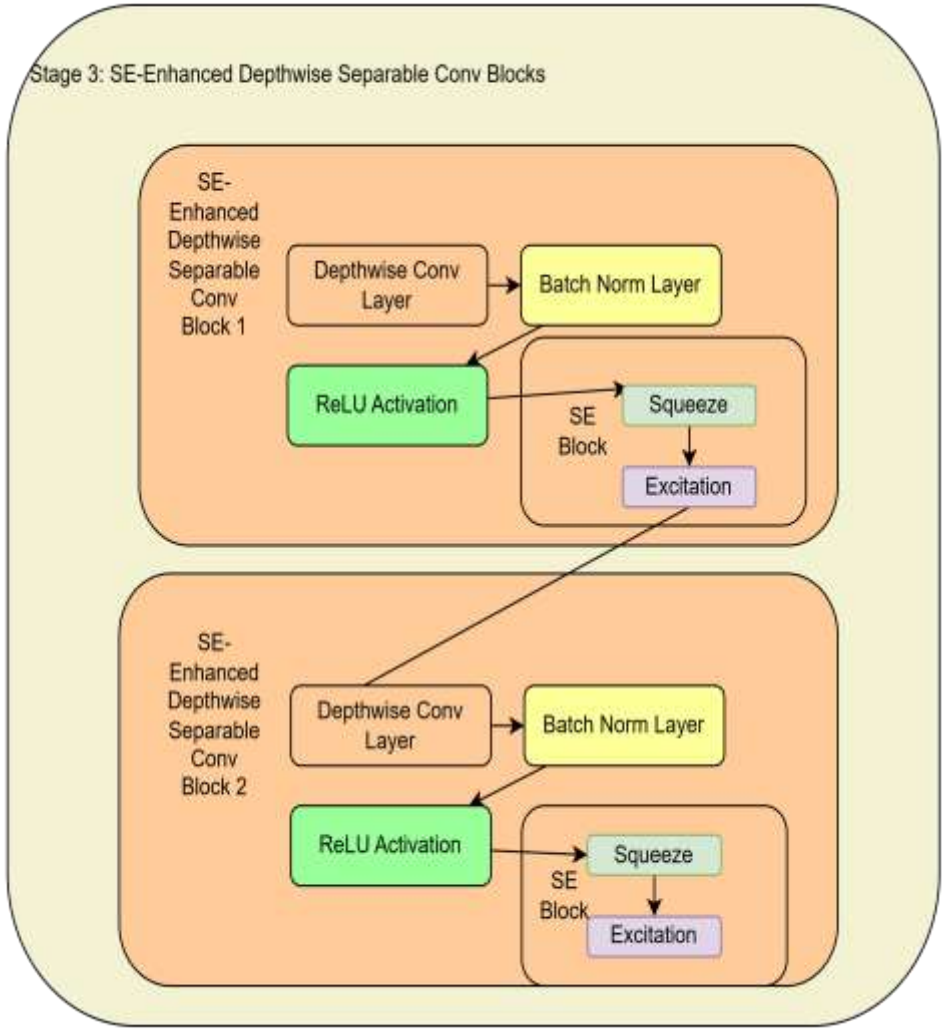
Model Architecture

Part D: SE-Enhanced Depthwise Separable Conv



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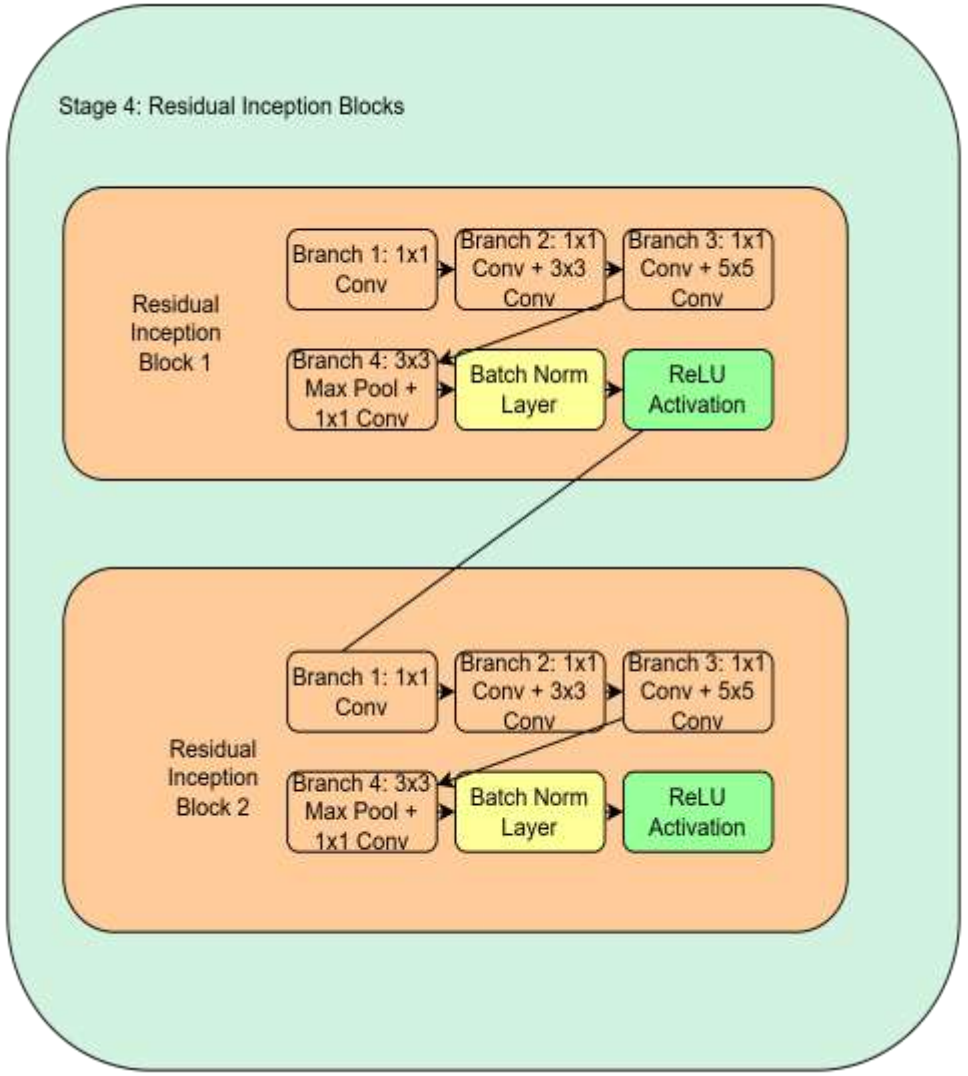
Model Architecture

Part E: Residual Inception Blocks



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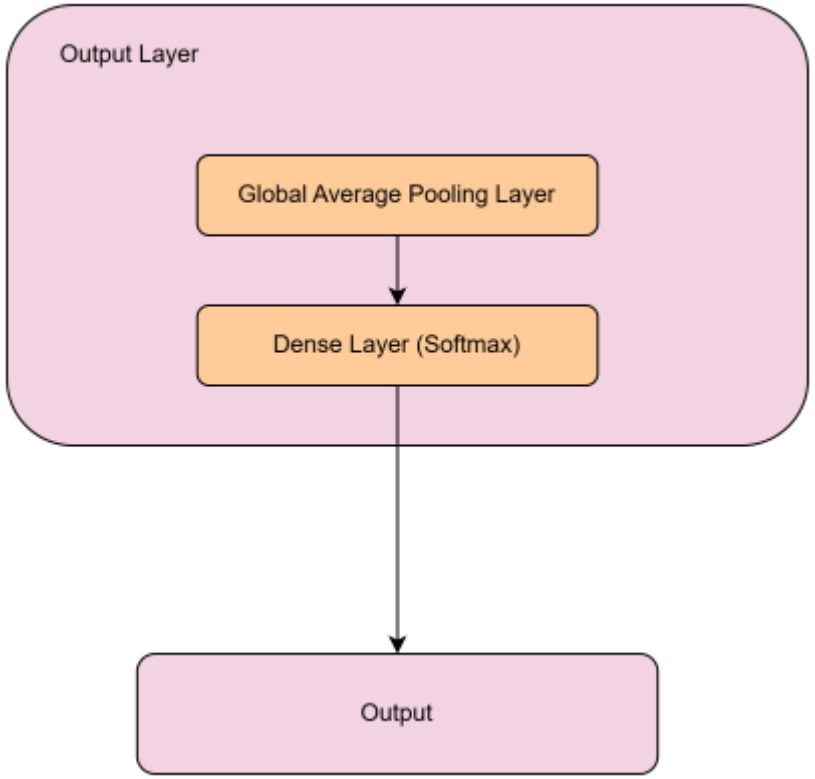
Model Architecture

Part F: Output Layer



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Model Hyperparameter

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Experiment 1: Compare different learning rate

Setting Item	Value
Train Images	26,997 images belonging to 45 classes
Validation images	17,996 images belonging to 45 classes
Input Size	(256,256,3)
Model	custom resnet50(resnet50+se+dscnn+inception)
Epochs	30
Batch Size	32
Optimizer	Adam
Loss	Categorical Crossentropy

Table: Parameter Settings for difference learning rates

Learning rate	Train loss	Train accuracy (%)	Validation loss	Validation accuracy (%)
0.0001	0.1567	95.33	0.6901	83.98
0.0005	0.2928	91.30	0.7566	80.79
0.0010	0.5734	83.30	0.9994	73.77
0.0050	3.8087	02.18	3.8076	02.22
0.0100	3.8106	02.01	3.8084	02.22
0.0500	3.8229	02.18	3.8242	02.22
0.1000	3.8359	02.17	3.8432	02.22
0.5000	3.9420	02.21	3.9569	02.22
1.0000	4.0785	02.14	4.1966	02.22

Table: Result of different learning rates

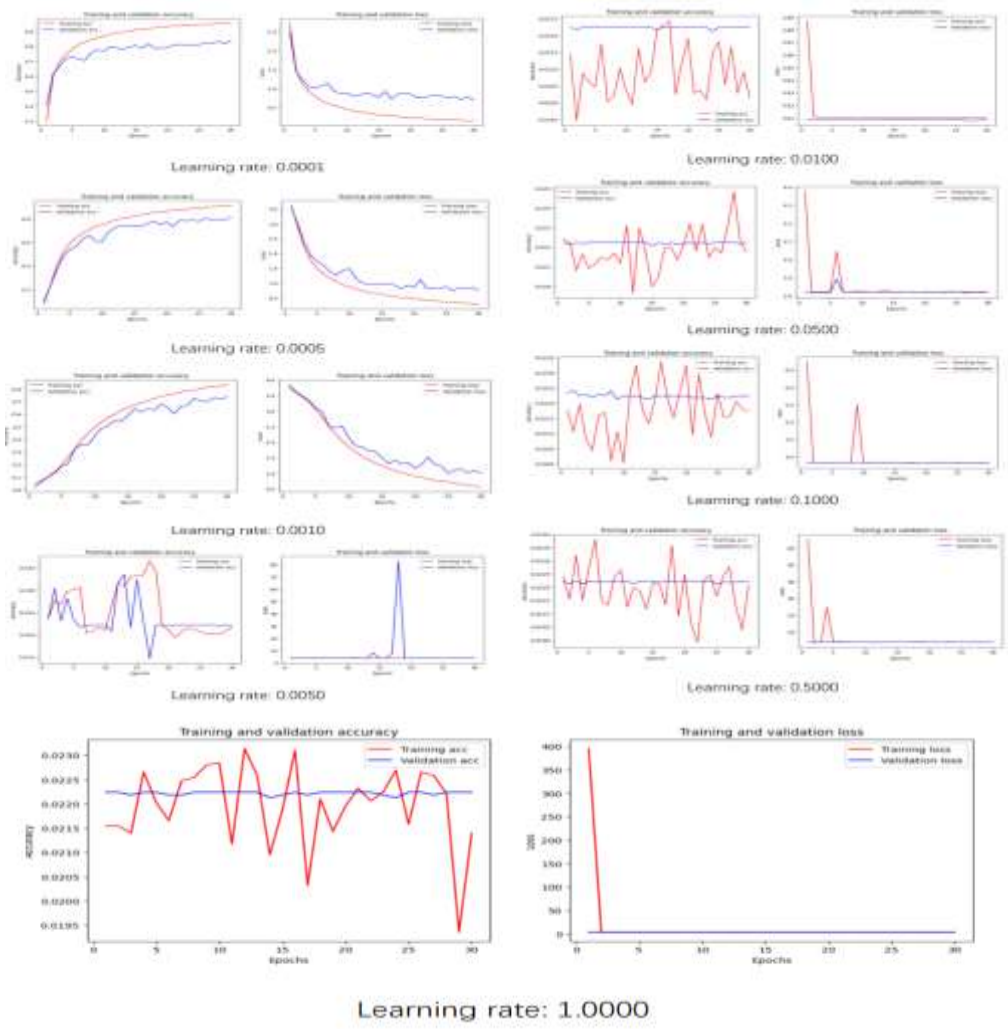

Figure: Loss and accuracy for different learning rates

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Experiment 2: Compare different batch size

Setting Item	Value
Train Images	26,997 images belonging to 45 classes
Validation images	17,996 images belonging to 45 classes
Input Size	(256,256,3)
Model	custom resnet50(resnet50+se+dscnn+inception)
Epochs	30
Learning rate	0.0001
Optimizer	Adam
Loss	Categorical Crossentropy

Table: Parameter Settings for difference batch sizes

Batch size	Graphics memory consumption (mb)	Train loss	Train accuracy (%)	Validation loss	Validation accuracy (%)
2	15558	0.3703	89.14	0.9321	79.52
4	15568	0.2481	92.66	0.6796	84.35
8	15321	0.1943	94.28	0.6363	84.54
16	15381	0.1637	95.19	0.7312	83.76
32	15301	0.1566	95.23	0.7652	82.30

Table: Result of compare batch size

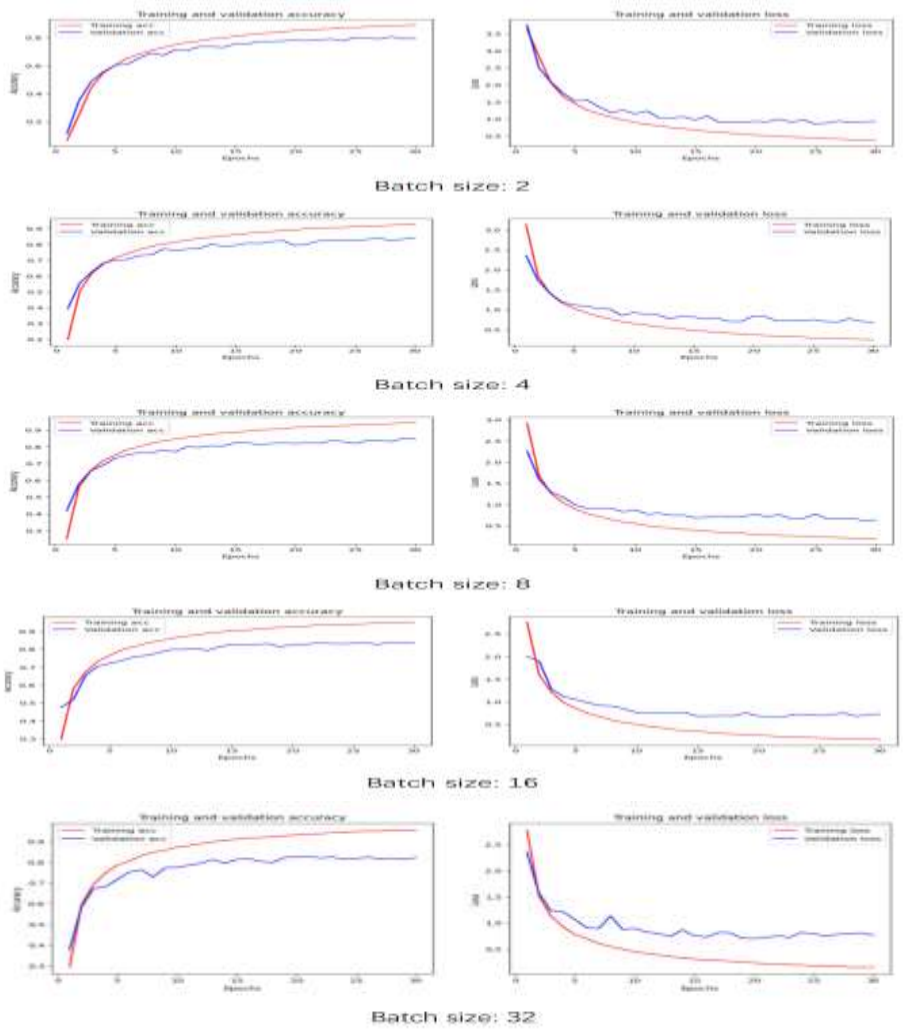

Figure: Loss and accuracy for different batch size

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Experiment 3: Compare different optimizers

Setting Item	Value
Train Images	26,997 images belonging to 45 classes
Validation images	17,996 images belonging to 45 classes
Input Size	(256,256,3)
Model	custom resnet50(resnet50+se+dscnn+inception)
Epochs	30
Batch Size	32
Learning rate	0.0001
Loss	Categorical Crossentropy

Table: Parameter Settings for difference optimizers

Optimizer	Train loss	Train accuracy (%)	Validation loss	Validation accuracy (%)
Adam	0.1567	95.33	0.6901	83.98
SGD	5.7399	04.12	5.7562	03.84
Rmsprop	0.4977	86.52	1.9984	60.88

Table: Result of compare optimizers

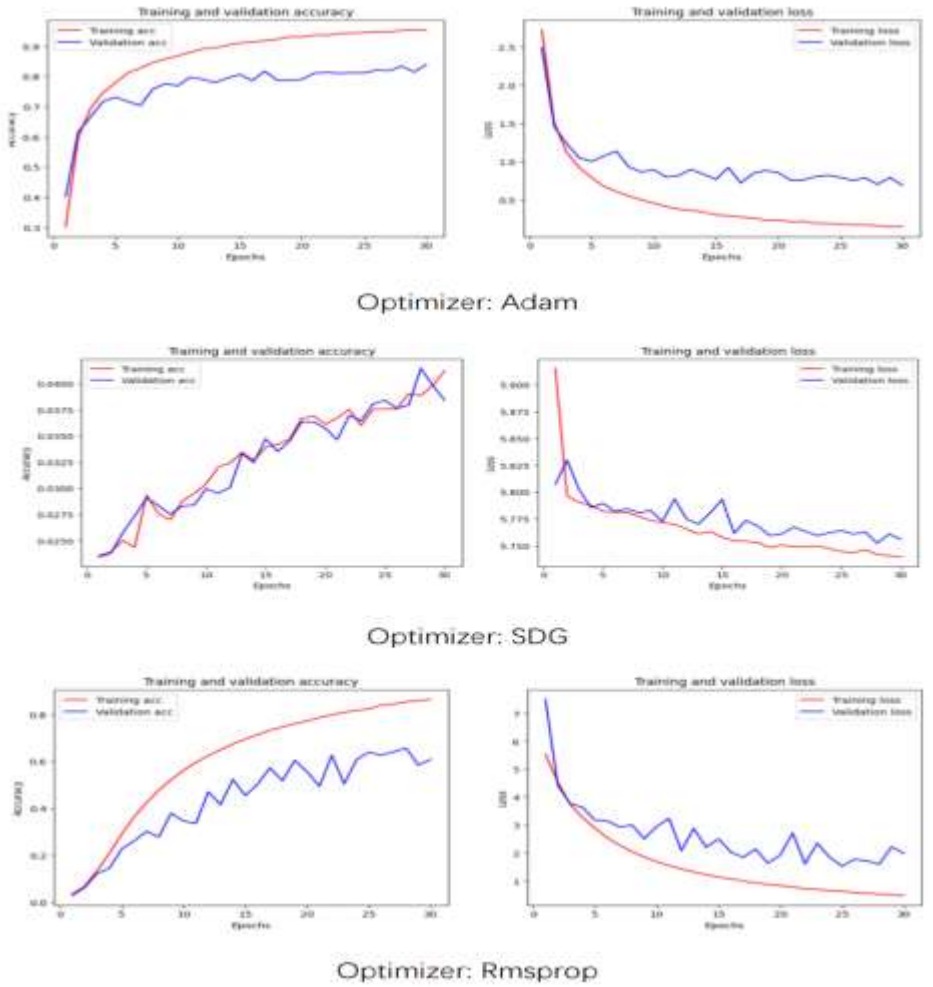

Figure: Loss and accuracy for different optimizers

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Experiment 4: Compare different model

Setting Item	Value
Train Images	26,997 images belonging to 45 classes
Validation images	17,996 images belonging to 45 classes
Input Size	(256,256,3)
Learning rate	0.0001
Epochs	30
Batch Size	32
Optimizer	Adam
Loss	Categorical Crossentropy

Table: Parameter Settings for difference Model

Model	Train loss	Train accuracy (%)	Validation loss	Validation accuracy (%)
CNN	3.1365	18.91	3.1751	18.45
Resnet50	0.3965	88.74	1.7249	63.90
Custom model(resnet50+se)	0.5849	83.95	2.0291	56.16
Custom model(resnet50+se+inception)	0.4987	86.32	1.9943	58.25
Custom model(resnet50+se+inception+dscnn)	0.1527	95.59	0.6313	84.93

Table: Result of compare Model

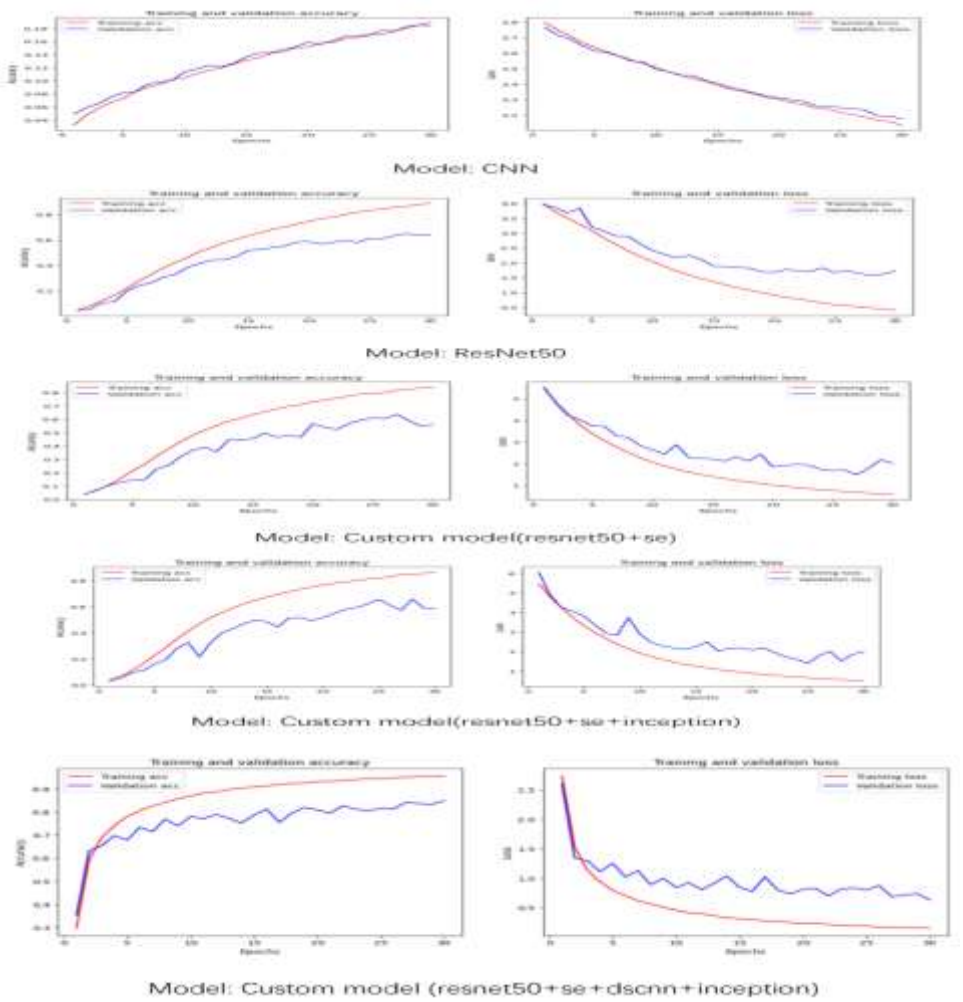

Figure: Loss and accuracy for different Model

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Best Result

Setting Item	Value
Train Images	26,997 images belonging to 45 classes
Validation images	17,996 images belonging to 45 classes
Input Size	(256,256,3)
Learning rate	0.0001
Epochs	30
Batch Size	32
Optimizer	Adam
Loss	Categorical Crossentropy
Model	custom resnet50(resnet50+se+dscnn+inception)

Table: Parameter Settings for best model

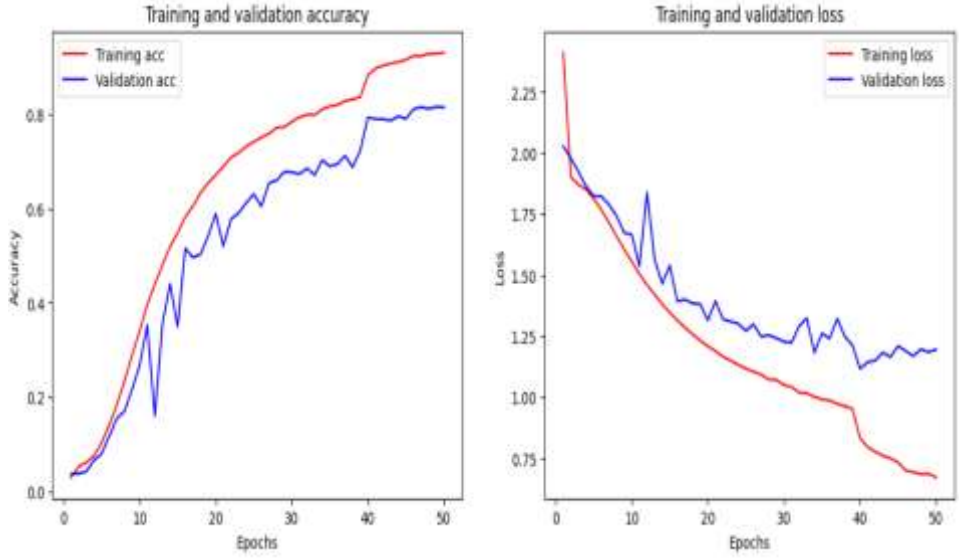

Figure: Loss and accuracy for best model

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Model evaluation

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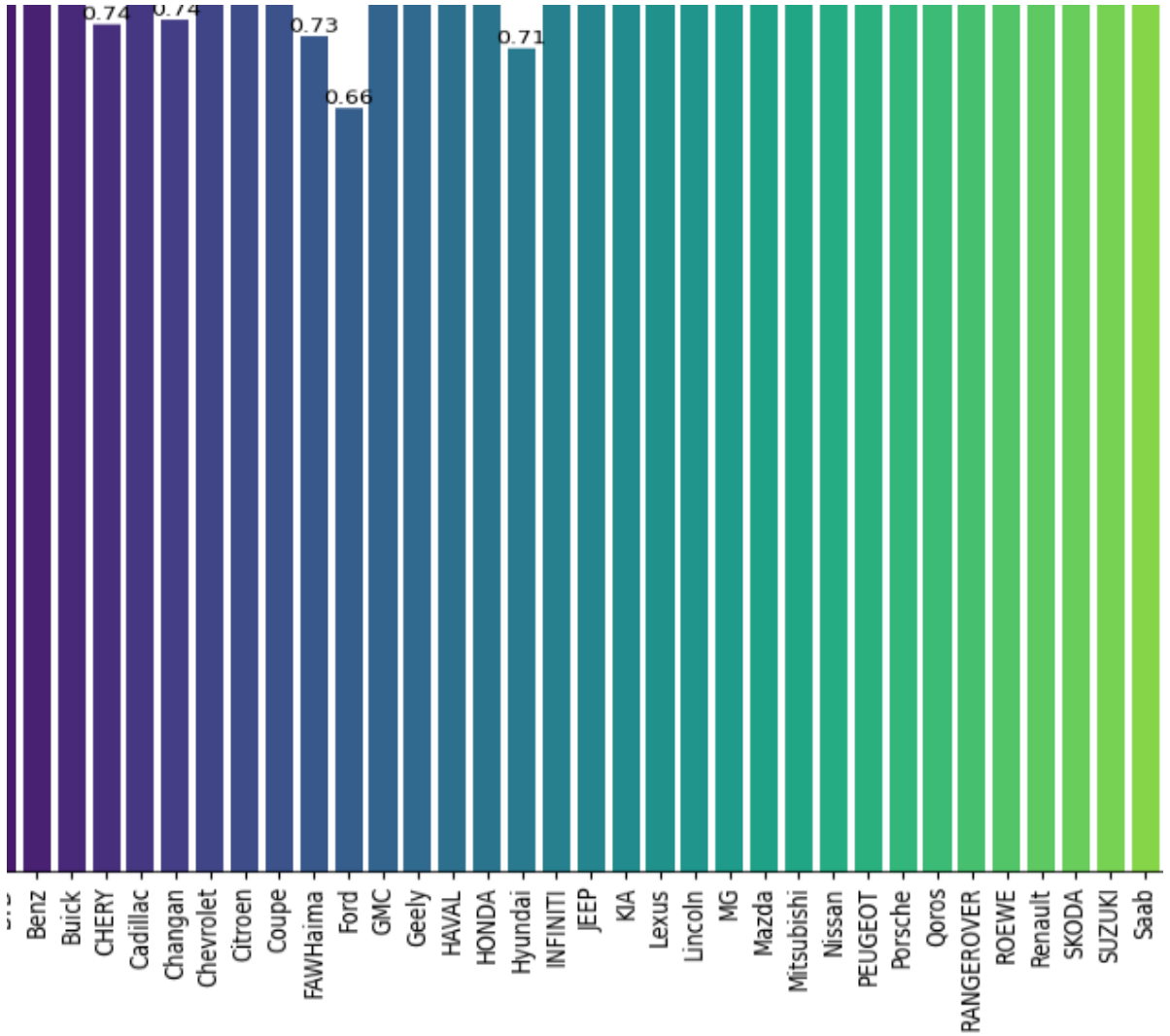
Model evaluation

F1 Scores by Class



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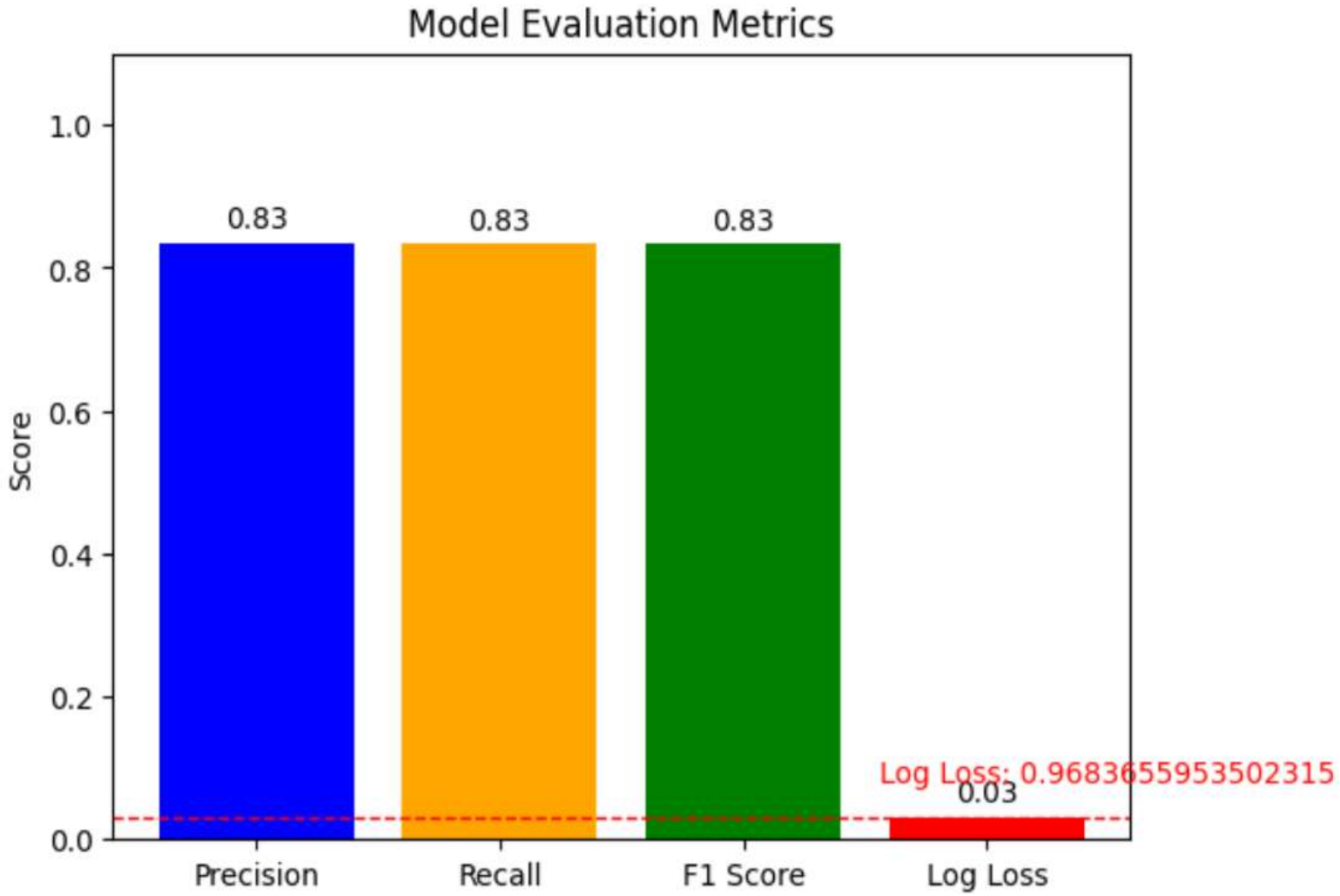
Model evaluation

Model Performance Metrics



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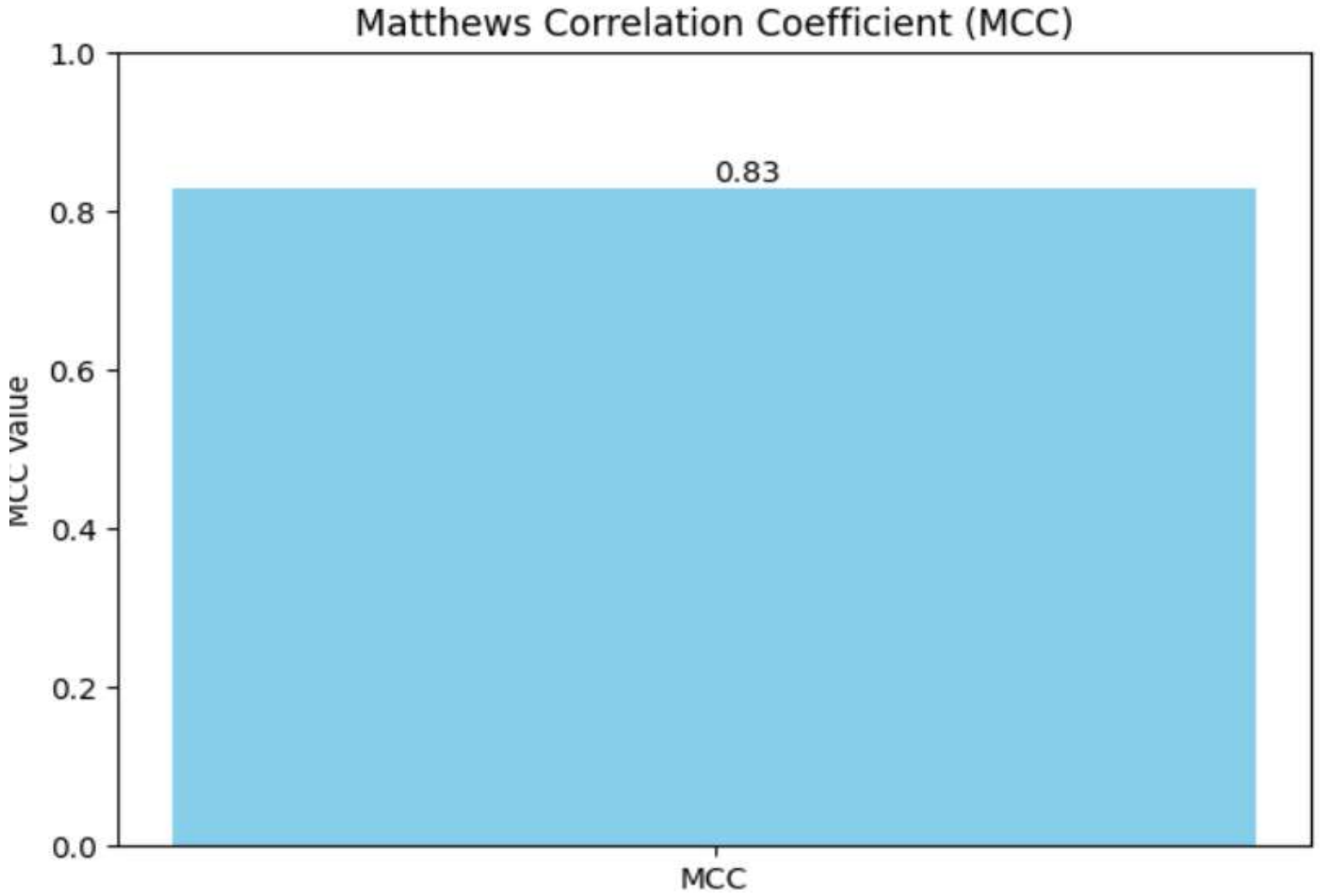
Model evaluation

Matthews Correlation Coefficient (MCC)



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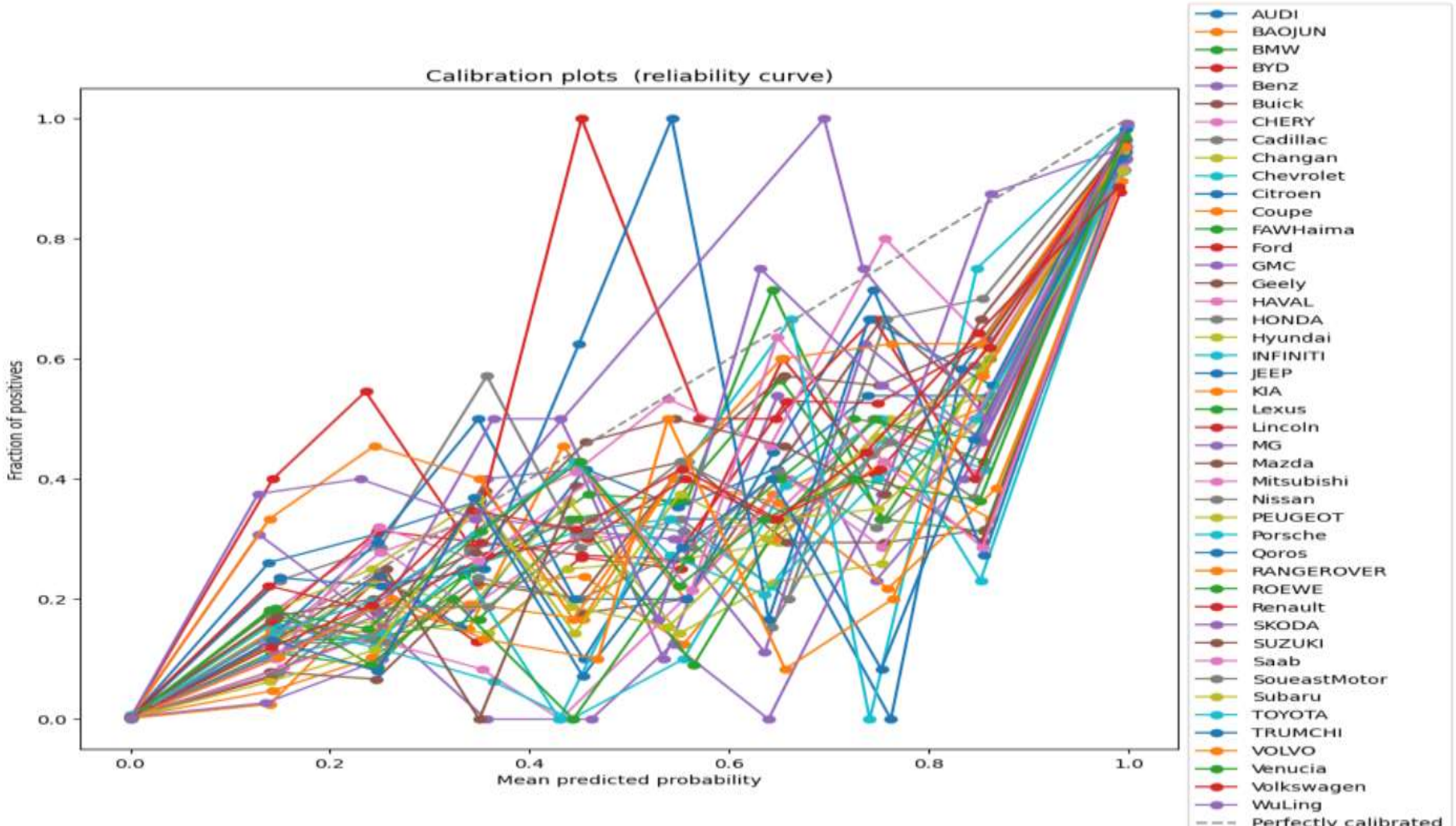
Model evaluation

Calibration plots (reliability curve)



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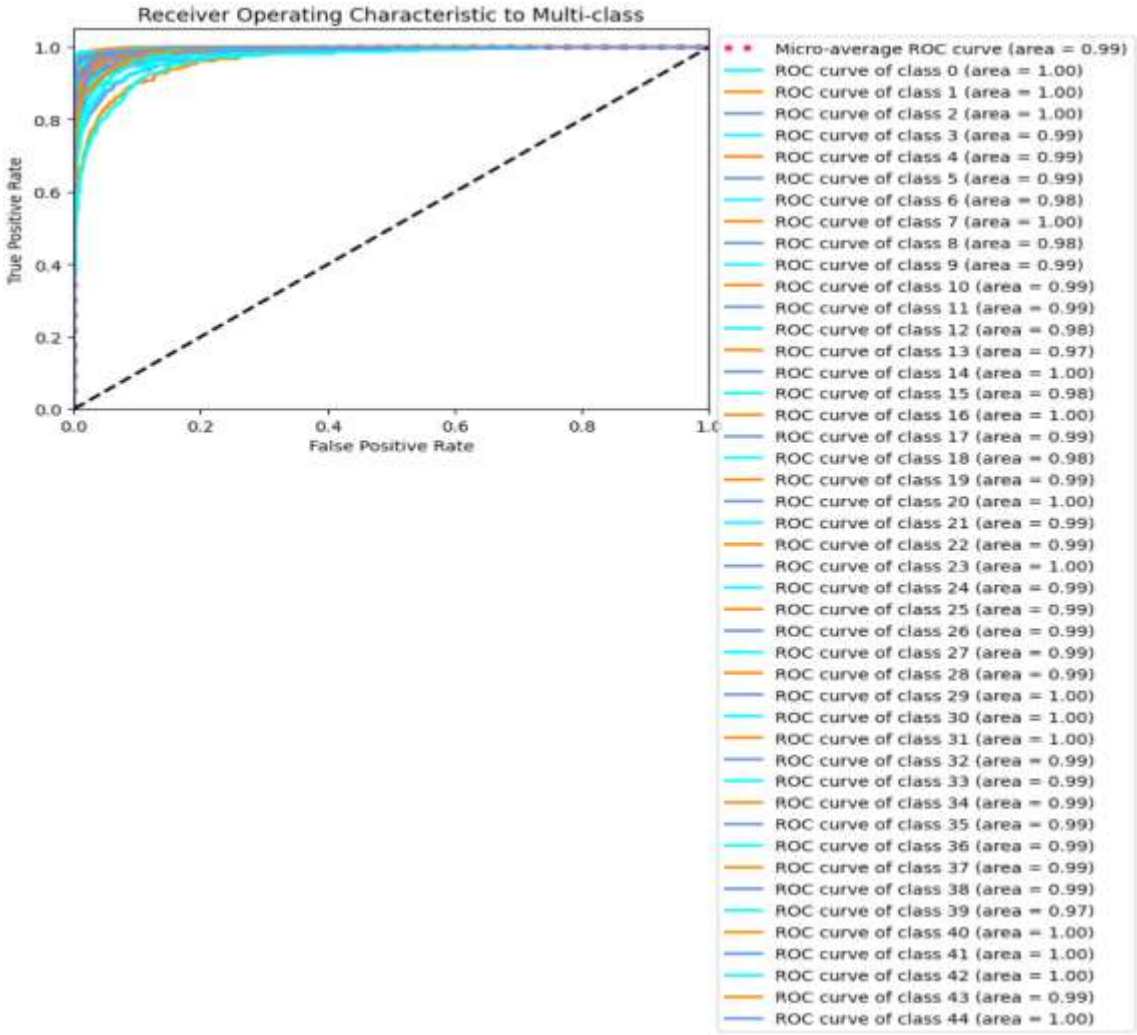
Model evaluation

Receiver Operating Characteristic to Multi-class



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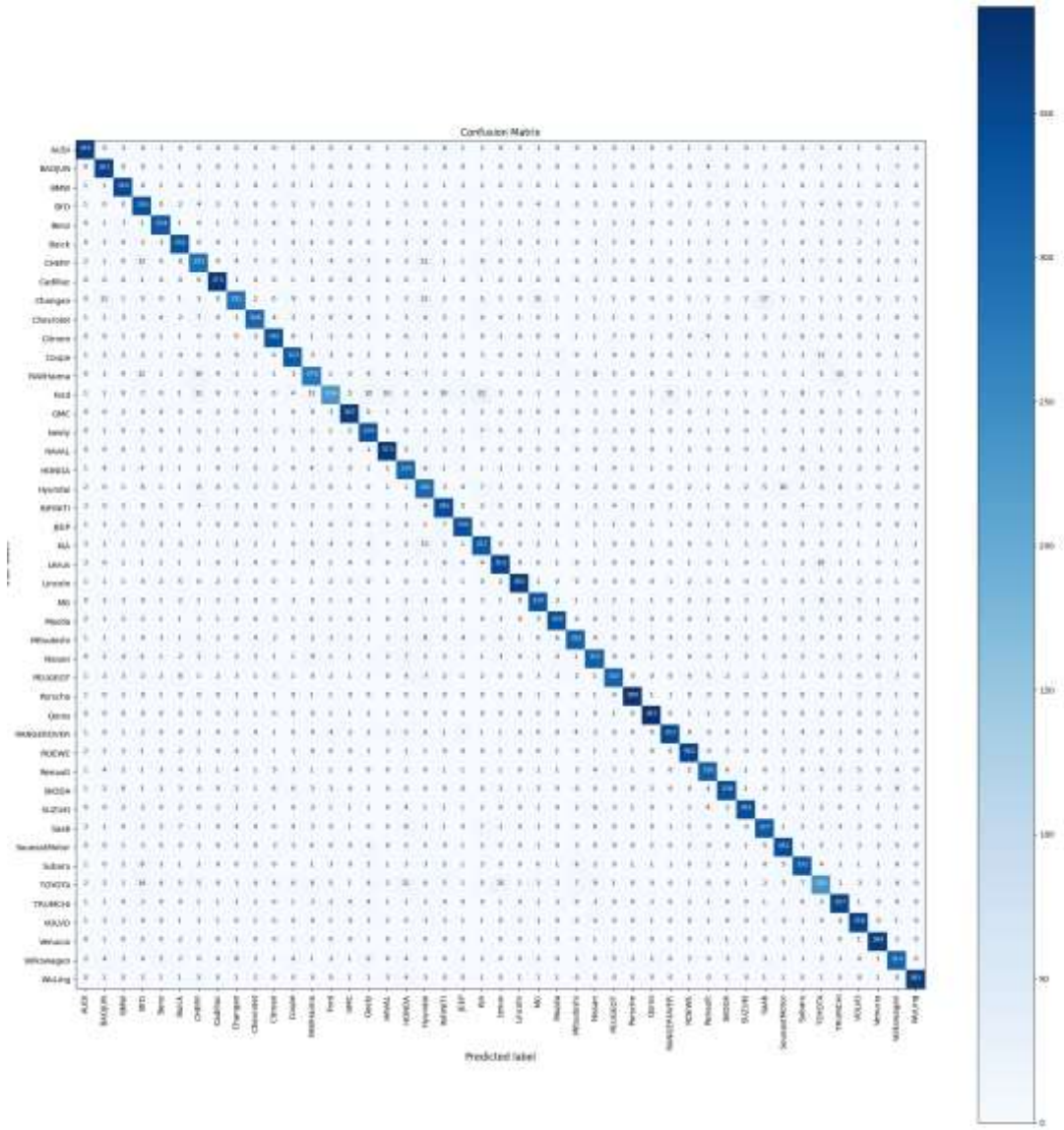
Model evaluation

Confusion matrix



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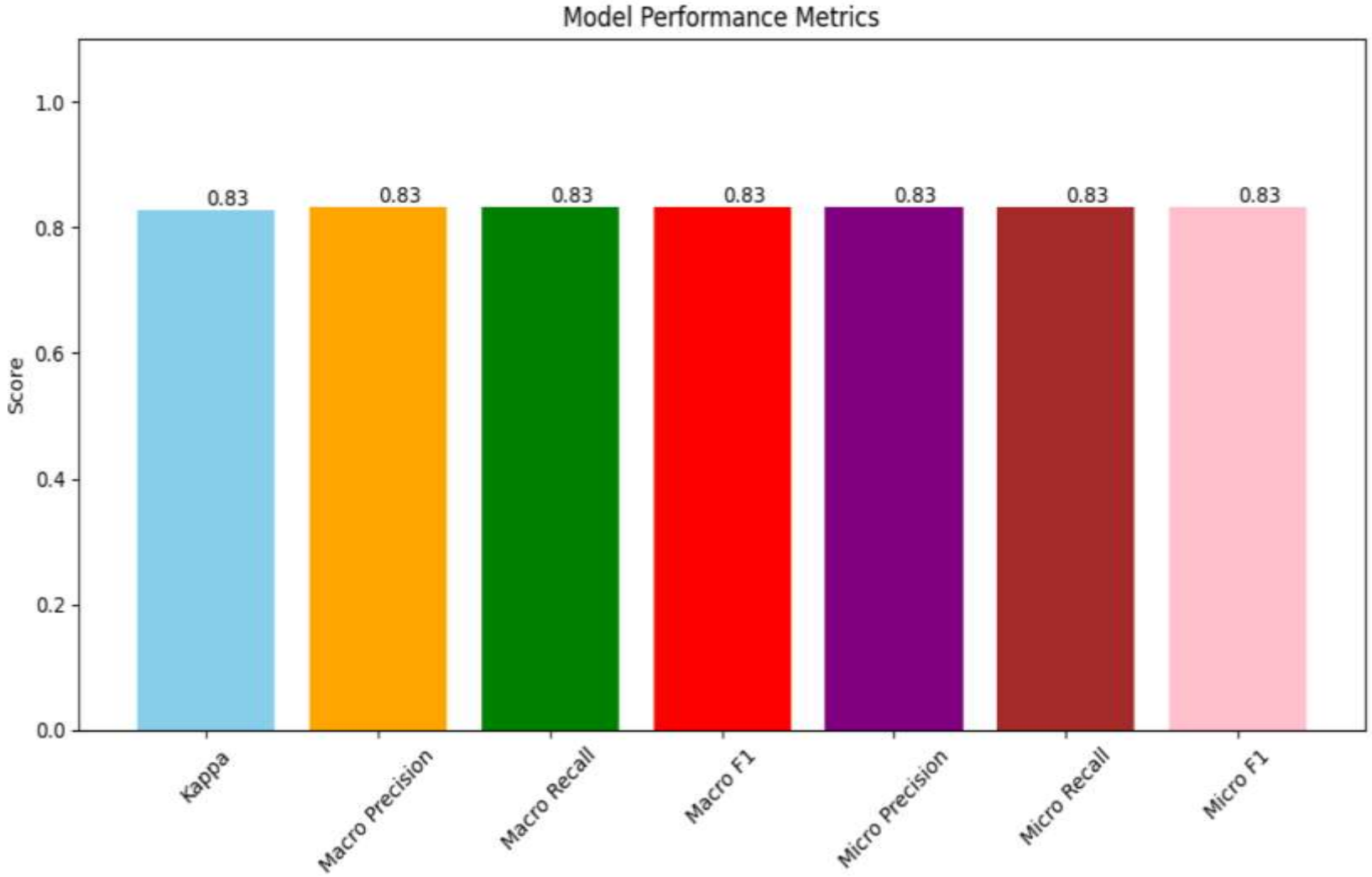
Model evaluation

Model Performance Metrics



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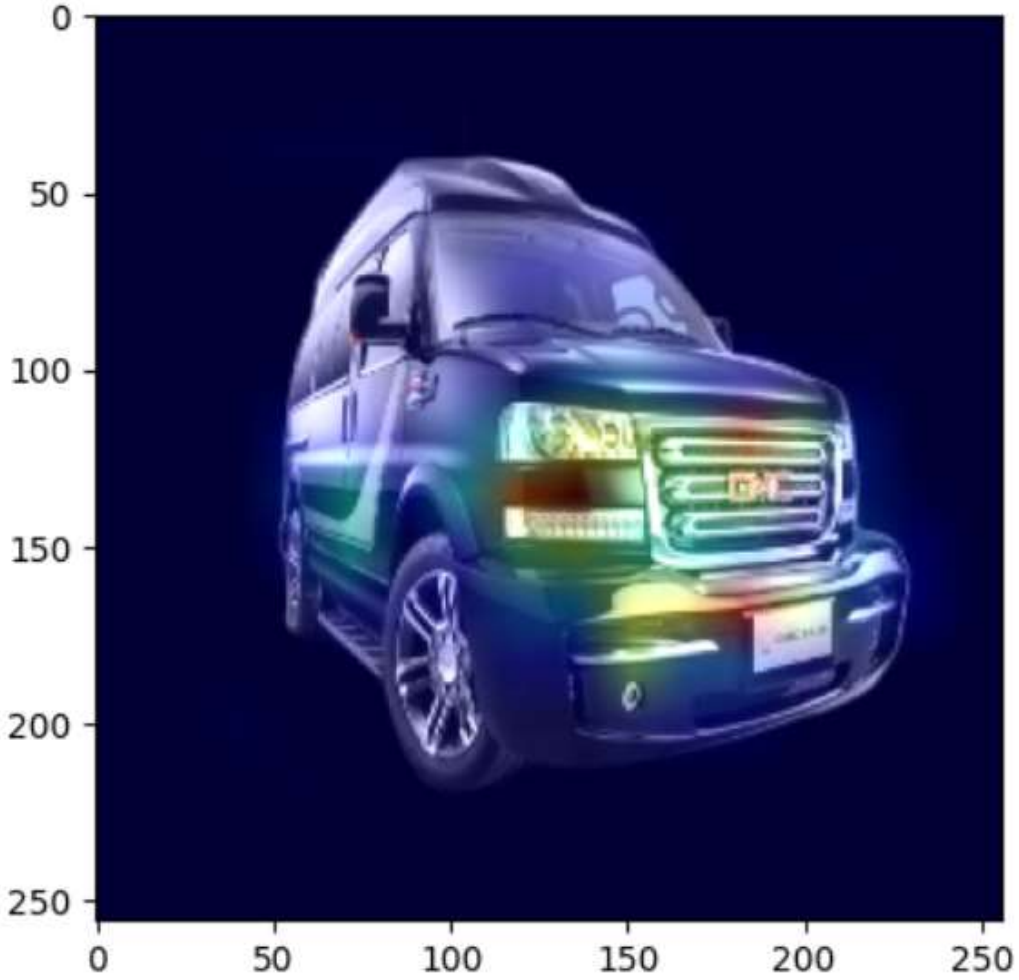
Model evaluation

Gradcam



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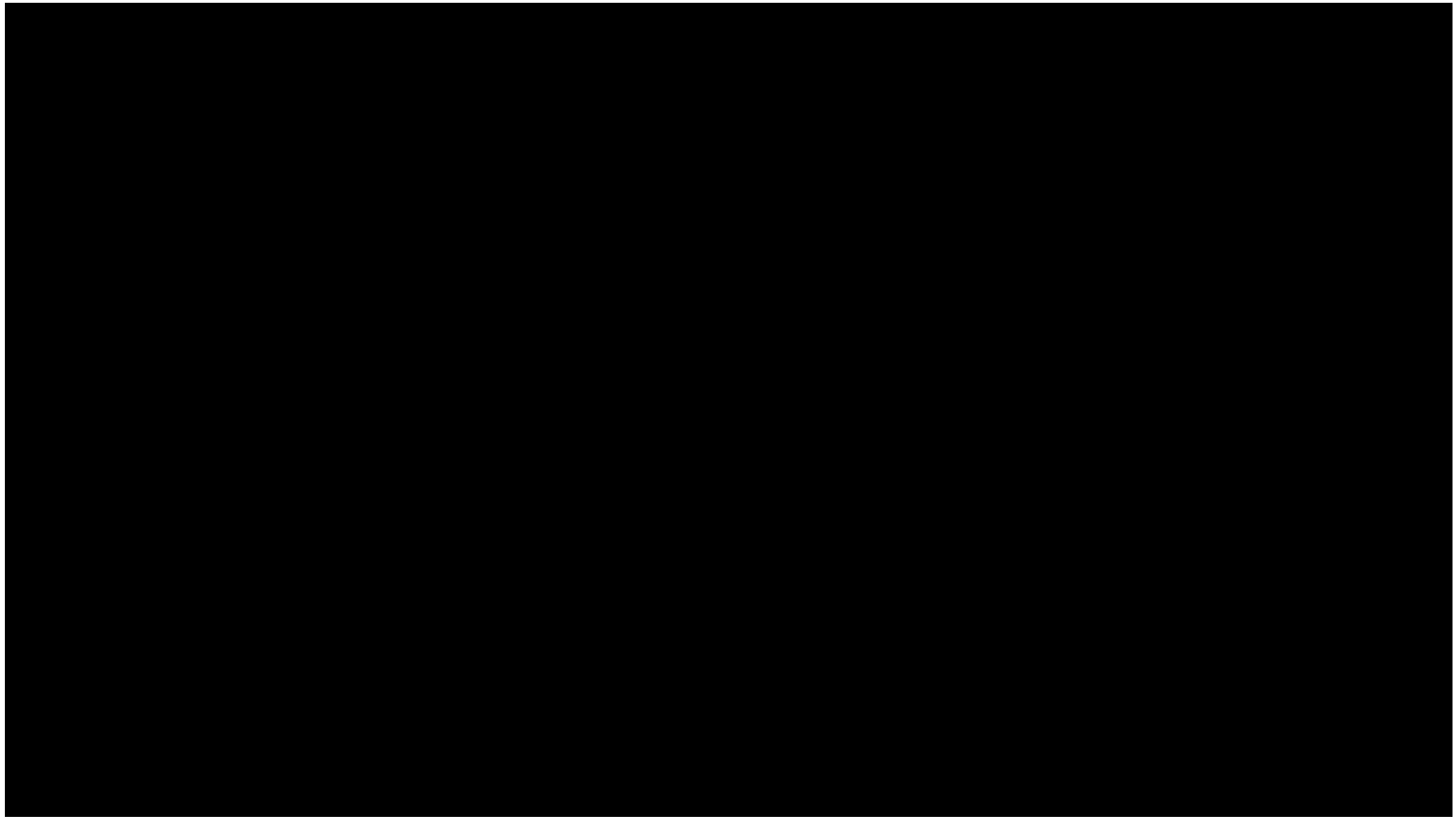
GUI for this study



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Reflections & Conclusion

There is still a lot of room for improvement in the model due to:

- The complexity of the environment in which the vehicles are located
- Different lighting conditions
- The fact that vehicle categories, although there are 45 categories in VLD-45, are not fully covered compared to existing vehicle types

Future considerations to improve the model to enhance the model's usability and performance:

- Adopt newer techniques to optimise the model
- Add more vehicle categories to the dataset

Thank you for your listening!

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References

[1] S. Yang, C. Bo, J. Zhang, P. Gao, Y. Li and S. Serikawa, "VLD-45: A Big Dataset for Vehicle Logo Classification and Detection," in IEEE Transactions on Intelligent Transportation Systems, vol. 23, no. 12, pp. 25567-25573, Dec. 2022, doi: 10.1109/TITS.2021.3062113.