

# Basics Of Deep Learning - Final Project

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## 1 Introduction

This is the final project report to conclude all the skills we learned during the Basics of Deep Learning course In order to solve a multi-class image classification problem with different methods which are Transfer Learning, KNN and End to End Convolutional Neural Network. This project is built with Tensorflow Keras platform, which is a neural network python library that is mainly used for building a Neural Network in much easier and simpler way. And we also used other libraries such as sklearn, numpy, pandas and matplotlib in order to create different metrics to appreciate our solution.

### 1.1 Data

We use the Stanford car dataset of 16,185 images of cars. The data set is split in a 50/50 ratio. Train set contains 8041 example and Test set contains 8144 examples. For this project we had 196 classes of types of cars.

### 1.2 Problem

The problem we have is a multi-class image classification for cars images of 196 different classes for each image.

## 2 Solution

### 2.1 General approach

In order to solve our cars classification problem we had to implement different approaches which we learned in our course such as Transfer Learning models which is using an already built CNN model for image classification and fine tuning it to fit our problem. Also a KNN model which is a model that classifies our images by the k nearest neighbours using distance methods such as the Euclidean distance formula and also full CNN models we build from scratch using the knowledge from our lectures and previous projects we made.

## 2.2 Design

So our code is divided for 3 different model building configuration methods which are: Transfer Learning, KNN and End to End CNN networks. We created 3 experiments for each configuration: The best model, and 2 other different experiments which we created for each configuration.

### 2.2.1 Preprocessing

Each image of our cars dataset has different shape. We scaled each image to a size of 170x170 and we divided each pixel by 255. Since we didn't have enough data, we used data augmentation methods to create more data for our training to have better performance and accuracy. The methods we used are image contrasting and we flipped also our images right to left to have new images. Also, because our ratio of the test and train set were 50/50 so we rearranged our dataset's test and train ratio to be 10/90 accordingly.

### 2.2.2 Transfer Learning

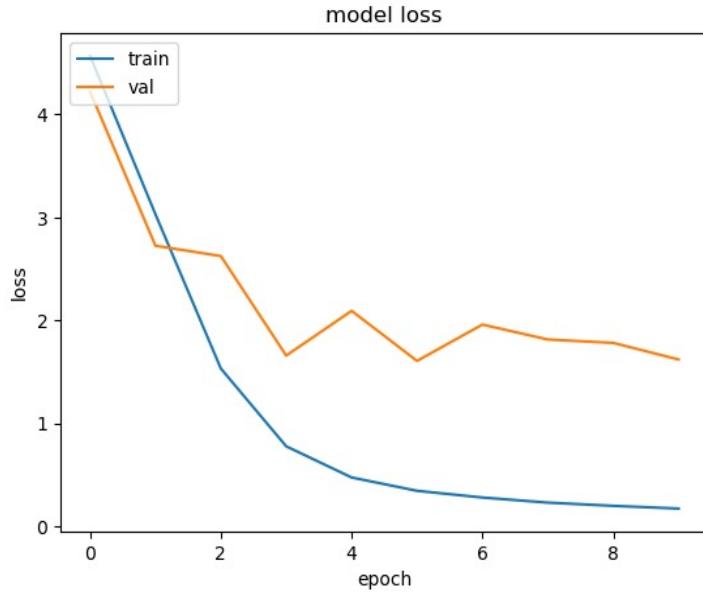
#### 2.2.2.1 Design

Most image classification solutions in our world took many resources and a lot of time in order to find the best model for each problem experts tried to solve. In general, people use models that have already been trained on another data set and use trained models to help classify the data by fine tuning it. In this approach we use a pre-trained model and we fine tune it to solve our problem. We used a transfer model called Xception, which is a pre-trained model on ImageNet. ImageNet is a large publicly available data set of labeled images, which has been widely used for training and evaluating computer vision algorithms. The dataset contains over 14 million images, covering more than 20,000 object categories. In our project, we used the Xception model and we froze only the last 10 layers of the model. We needed to train most of our layers from scratch because Xception classifies by category and we needed to tune the layers to find the specific type inside the cars category which is relatively harder. We didn't have to classify the last layers because their role is to represent our input image and it is not critical for us to train those layers from scratch. Then we added a GlobalAverage2DPooling layer to flatten our input image and we added hidden layers, and a last layer using the softmax activation function which is used to create probability distribution over the possible 196 cars classes. Then, we trained our augmentative data set and we evaluated the performance our new model. We also had 3 different experiments for our model: our best best model, an experiment using a different

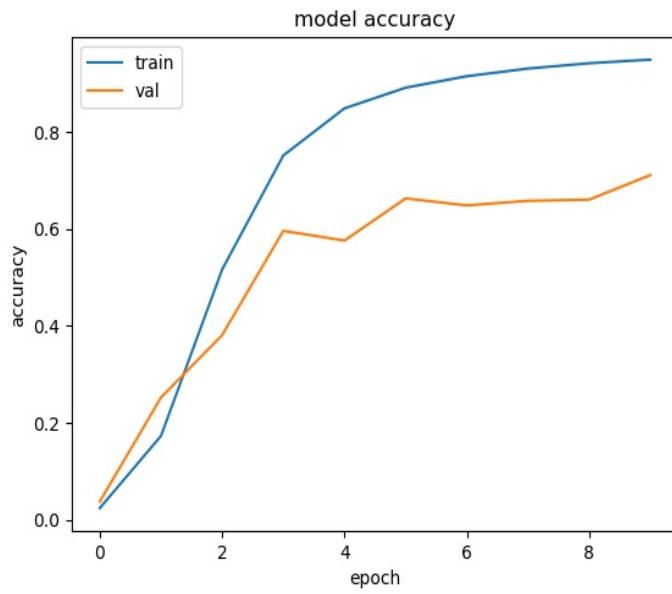
model architecture and an experiment using different model hyper parameters.

#### 2.2.2.2 First Experiment

In our first experiment, we paid more attention to our CNN architecture. we had the same feature extraction layers and dense layers for the transfer model we used, it only differs with the layers we added after the GlobalAverage2DPooling to classify our car image. Only the number layers and number of neurons per layer were different and the last layer the the final classification was the same. We added: hidden layer with 120 neurons, hidden layer with 60 neurons and hidden layer with 30 neurons, and then we add the output layer with 196 neurons according to the number of classes



Model Loss Graph



Model Accuracy Graph

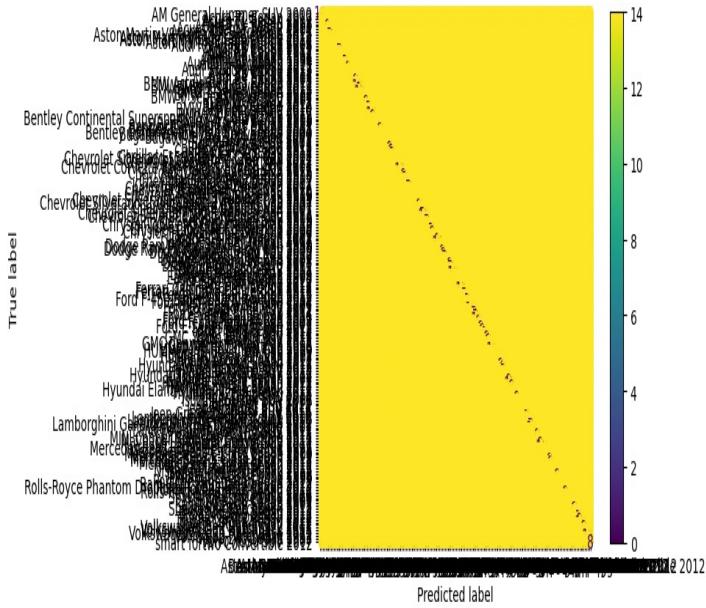
### Confusion Matrix:

```
[[10  0  0 ...  0  0  0]
 [ 0  2  0 ...  0  0  0]
 [ 0  0  2 ...  0  0  0]
 ...
 [ 0  0  0 ... 11  0  0]
 [ 0  0  0 ...  0  6  0]
 [ 0  0  0 ...  0  0  8]]
```

Accuracy: 71%

Balanced Accuracy: 71%

Confusion Matrix



Confusion Matrix As Table

		precision	recall	f1-score	support
AM General Hummer	SUV 2000	0.83	0.91	0.87	11
Acura RL Sedan	2012	1.00	0.46	0.57	5
Acura TL Sedan	2012	0.33	0.40	0.36	5
Acura TL Type-S	2008	0.75	0.75	0.75	8
Acura TSX Sedan	2012	0.56	0.83	0.67	6
Acura Integra Type R	2001	0.82	0.90	0.86	10
Acura ZDX Hatchback	2012	0.75	0.43	0.55	7
Aston Martin V8 Vantage	2012	0.24	0.57	0.33	7
Aston Martin V8 Vantage Coupe	2012	0.90	0.00	0.00	13
Aston Martin Virage Convertible	2012	0.33	0.12	0.18	8
Aston Martin Virage Coupe	2012	0.59	0.86	0.63	7
Audi RS 4 Convertible	2008	0.67	0.50	0.57	4
Audi A5 Coupe	2012	0.46	0.86	0.60	7
Audi A5 Coupe	2012	0.25	0.20	0.22	5
Audi R8 Coupe	2012	0.70	0.76	0.73	9
Audi V8 Sedan	1994	0.56	0.62	0.59	8
Audi 100 Sedan	1994	0.67	0.20	0.31	10
Audi 100 Wagon	1994	0.56	0.83	0.67	6
Audi TT Hatchback	2011	0.54	0.78	0.64	9
Audi S6 Sedan	2011	0.71	0.62	0.67	8
Audi S5 Sedan	2012	0.54	0.44	0.44	14
Audi S5 Coupe	2012	0.80	0.50	0.62	8
Audi S4 Sedan	2012	0.40	0.50	0.44	4
Audi S4 Sedan	2007	1.00	0.56	0.71	9
Audi TT RS Coupe	2012	0.75	0.60	0.67	10
BMW ActiveHybrid 7	2012	0.82	0.90	0.86	10
BMW 1 Series Convertible	2012	0.90	0.10	0.17	8
BMW 1 Series Coupe	2012	0.86	1.00	0.92	12
BMW 3 Series Sedan	2012	0.88	0.88	0.88	8
BMW 3 Series Wagon	2012	0.92	0.85	0.88	13
BMW 6 Series Convertible	2007	0.71	0.45	0.56	11
BMW 6 Series Coupe	2007	0.86	0.60	0.71	10
BMW X6 SUV	2012	0.90	0.50	0.57	4
BMW M3 Coupe	2012	0.89	0.80	0.84	10
BMW M3 Sedan	2010	0.67	0.57	0.62	7
BMW M6 Convertible	2010	0.58	0.70	0.64	10
BMW X3 SUV	2012	1.00	0.86	0.92	7
BMW Z4 Convertible	2012	1.00	0.77	0.87	13
Bentley Continental Supersports	2012	0.57	0.69	0.60	9
Bentley Arnage Sedan	2009	1.00	0.86	0.92	7
Bentley Mulsanne Sedan	2011	0.80	0.57	0.67	7
Bentley Continental GT Coupe	2012	0.50	0.33	0.40	9
Bentley Continental GT Coupe	2007	0.71	0.38	0.50	13
Bentley Continental Flying Spur Sedan	2007	0.73	1.00	0.84	8
Bugatti Veyron 16.4 Convertible	2009	0.90	0.18	0.55	8
Bugatti Veyron 16.4 Coupe	2009	1.00	0.50	0.67	6
Buick Regal GS	2012	1.00	0.71	0.83	7
Buick Rainier SUV	2007	0.75	0.33	0.46	9
Buick Verano Sedan	2012	0.57	0.67	0.62	6

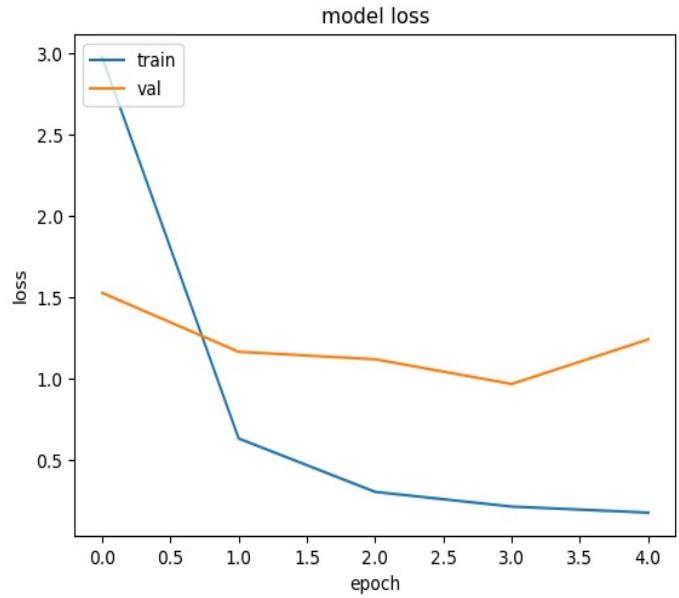
Buick Enclave	2009	1.00	0.30	0.55	8
Buick Enclave	2012	1.00	0.30	0.54	8
Cadillac CTS	2012	0.89	0.80	0.84	10
Cadillac SRX	SUV 2012	0.89	0.80	0.82	7
Cadillac Escalade	EXT Cab 2007	0.70	1.00	0.82	7
Cadillac Escalade	1500 Hybrid Crew Cab 2012	0.71	0.71	0.71	7
Chevrolet Corvette	Convertible 2012	0.33	0.40	0.36	5
Chevrolet Corvette	Z06 2007	0.60	0.38	0.46	8
Chevrolet Corvette	Mid Fender Edition 2008	0.57	0.37	0.40	7
Chevrolet Traverse	SUV 2012	0.50	0.20	0.29	5
Chevrolet Camaro	Convertible 2012	0.69	1.00	0.81	11
Chevrolet Camaro	MHR SS 2010	1.00	0.67	0.80	6
Chevrolet Impala	Sedan 2007	1.00	0.67	0.80	12
Chevrolet Tahoe	Hybrid SUV 2012	0.58	0.88	0.64	8
Chevrolet Sonic	sedan 2012	0.50	0.52	0.55	8
Chevrolet Express	Cargo Van 2007	0.40	0.67	0.50	6
Chevrolet Avalanche	Crew Cab 2012	0.64	0.78	0.70	9
Chevrolet Cobalt	SS 2010	0.75	0.75	0.75	4
Chevrolet Malibu	Hybrid Sedan 2010	0.56	0.83	0.67	6
Chevrolet TrailBlazer	SS 2009	0.71	0.71	0.71	7
Chevrolet Silverado	1500 Extended Cab 2007	1.00	0.67	0.72	7
Chevrolet Silverado	1500 Classic Extended Cab 2007	1.00	0.56	0.71	9
Chevrolet Express	Van 2007	0.33	0.20	0.25	5
Chevrolet Monte Carlo	Coupe 2007	0.73	0.80	0.76	10
Chevrolet Malibu	Sedan 2007	0.67	0.67	0.67	9
Chevrolet Silverado	1500 Extended Cab 2012	0.45	0.71	0.56	7
Chevrolet Silverado	1500 Regular Cab 2012	0.78	0.78	0.78	9
Chevrolet Silverado	1500 Regular Cab 2009	0.92	0.85	0.88	13
Chevrolet Aspens	Aspen 2009	0.83	0.71	0.77	7
Chevrolet Sebring	Convertible 2010	1.00	0.78	0.88	9
Chevrolet Town & Country	Minivan 2012	1.00	0.67	0.71	9
Chevrolet 300	SRT-8 2010	0.62	0.83	0.71	6
Chevrolet Crossfire	Convertible 2008	1.00	0.83	0.91	6
Chevrolet PT Cruze	Convertible 2008	1.00	0.70	0.82	10
Dodge Caliber	Wagon 2002	0.89	0.67	0.75	12
Dodge Caliber	Wagon 2012	0.57	0.50	0.53	8
Dodge Caliber	Wagon 2007	0.67	0.75	0.71	8
Dodge Caravan	Minivan 1997	1.00	0.82	0.90	11
Dodge Ram	Pickup 3500 Crew Cab 2010	0.73	0.92	0.81	12
Dodge Ram	Pickup 3500 Quad Cab 2009	0.62	0.71	0.67	7
Dodge Sprinter	Commercial 2009	0.67	0.67	0.67	6
Dodge Journey	SUV 2012	0.80	0.67	0.73	12
Dodge Dakota	Crew Cab 2010	0.73	0.89	0.80	9
Dodge Dakota	Club Cab 2007	0.88	0.78	0.82	9
Dodge Magnum	Wagon 2008	1.00	0.75	0.86	4
Dodge Challenger	SRT-8 2011	0.65	0.75	0.67	4
Dodge Durango	SUV 2002	0.56	0.60	0.56	10
Dodge Durango	SUV 2007	1.00	0.88	0.93	8
Dodge Charger	Sedan 2012	0.50	0.50	0.50	10
Dodge Charger	SRT-8 2009	0.71	0.92	0.80	13
Eagle Talon	Hatchback 1998	1.00	0.67	0.80	9
Fiat 500	Abarth 2012	0.43	0.75	0.55	4
FIAT 500	Convertible 2012	1.00	0.67	0.80	9
Ferrari FF	Coupe 2012	1.00	0.29	0.44	7
Ferrari California	Convertible 2012	1.00	0.60	0.67	10
Ferrari 458	Italia Convertible 2012	0.38	0.92	0.54	12
Ferrari 458	Italia Coupe 2012	0.17	0.14	0.15	7
Fisker Karma	Sedan 2012	1.00	0.54	0.70	13
Ford F-450	Super Duty Crew Cab 2012	1.00	1.00	1.00	4
Ford Mustang	Convertible 2007	0.58	1.00	0.74	7
Ford Freestyle	Minivan 2007	0.73	0.53	0.63	6
Ford Expedition	EL SUV 2009	0.86	0.86	0.86	7
Ford Edge	SUV 2012	0.62	0.77	0.69	13
Ford Ranger	SuperCab 2011	1.00	0.62	0.77	8
Ford GT	Coupe 2008	1.00	0.70	0.82	10
Ford F-150	Regular Cab 2012	1.00	1.00	1.00	7
Ford F-150	Regular Cab 2007	0.91	1.00	0.95	10
Ford Focus	Sedan 2007	1.00	0.80	0.89	10
Ford E-Series	Wagon Van 2012	1.00	0.60	0.75	5
Ford Fiesta	Sedan 2012	0.73	0.73	0.73	11
GMC Savana	Van 2012	0.89	1.00	0.94	8
GMC Savana	Van 2010	0.80	0.65	0.76	13
GMC Yukon	Hybrid SUV 2012	0.44	0.57	0.50	7
GMC Acadia	SUV 2012	0.80	0.80	0.80	10
GMC Canyon	Extended Cab 2012	1.00	0.80	0.89	10
Geo Metro	Convertible 1993	1.00	0.83	0.91	6
Hummer H3	Coupe 2010	0.71	1.00	0.83	5
HUMMER H2	SUT Crew Cab 2009	0.45	0.92	0.76	12
Honda Odyssey	Minivan 2012	0.86	0.67	0.75	9
Honda Odyssey	Minivan 2007	1.00	0.67	0.80	6
Honda Accord	Coupe 2012	0.40	1.00	0.57	4
Honda Accord	Sedan 2012	0.83	0.45	0.59	11
Hyundai Veloster	Hatchback 2012	0.44	0.57	0.53	5
Hyundai Santa Fe	SUV 2012	0.89	0.80	0.84	10
Hyundai Tucson	SUV 2012	1.00	0.90	0.95	10
Hyundai Veracruz	SUV 2012	0.64	0.78	0.70	9
Hyundai Sonata	Hybrid Sedan 2012	0.60	0.75	0.67	4
Hyundai Elantra	Sedan 2007	0.67	0.75	0.71	8
Hyundai Elantra	Touring Hatchback 2012	0.60	0.57	0.57	4
Hyundai Genesis	Sedan 2012	0.67	1.00	0.80	8
Hyundai Sonata	Sedan 2012	0.92	0.86	0.89	14
Hyundai Elantra	Touring Hatchback 2012	0.73	0.67	0.70	12
Hyundai Azera	Sedan 2012	1.00	0.17	0.29	6
Infiniti G37	Coupe 2012	1.00	0.45	0.71	9
Infiniti QX56	SUV 2011	0.71	0.83	0.77	5
Isuzu Ascender	SUV 2008	0.73	0.80	0.76	10
Jaguar XK	XKR 2012	1.00	0.62	0.77	8
Jeep Patriot	SUV 2012	1.00	0.75	0.86	8
Jeep Wrangler	SUV 2012	0.90	0.90	0.90	7
Jeep Liberty	SUV 2012	0.60	1.00	0.75	8
Jeep Grand Cherokee	SUV 2012	0.67	0.67	0.67	9
Jeep Compass	SUV 2012	0.67	0.75	0.71	8
Lamborghini Aventador	Coupe 2012	0.60	0.75	0.67	4
Lamborghini Gallardo	LP 570-4 Superleggera 2012	1.00	0.75	0.86	8

Lamborghini Diablo Coupe	2001	0.70	1.00	0.82	7
Land Rover Range Rover SUV	2012	0.93	0.93	0.93	15
Land Rover LR2 SUV	2012	0.83	0.56	0.67	9
Lincoln Town Car Sedan	2011	1.00	0.83	0.91	6
MINI Cooper Roadster Convertible	2012	0.75	0.90	0.82	10
Maybach Landaulet Convertible	2012	0.60	0.50	0.55	6
Mazda Tribute SUV	2011	0.62	1.00	0.77	5
McLaren MP4-12C Coupe	2012	0.80	1.00	0.89	8
Mercedes-Benz 300-Class Convertible	1993	0.59	1.00	0.74	10
Mercedes-Benz C-Class Sedan	2012	1.00	1.00	1.00	6
Mercedes-Benz SL-Class Coupe	2009	0.43	0.60	0.50	5
Mercedes-Benz E-Class Sedan	2012	0.46	0.67	0.55	9
Mercedes-Benz S-Class Sedan	2012	1.00	0.43	0.60	7
Mercedes-Benz Sprinter Van	2012	0.82	0.90	0.86	10
Mitsubishi Lancer Sedan	2012	1.00	0.80	0.89	10
Nissan Leaf Hatchback	2012	0.71	0.83	0.77	6
Nissan NV Passenger Van	2012	0.75	0.75	0.75	8
Nissan Juke Hatchback	2012	0.25	1.00	0.48	2
Nissan 350Z Coupe	1998	0.77	0.56	0.75	7
Plymouth Neon Coupe	1999	1.00	0.89	0.94	9
Porsche Panamera Sedan	2012	0.75	0.67	0.71	9
Ram C/V Cargo Van Minivan	2012	0.57	0.57	0.57	7
Rolls-Royce Phantom Drophead Coupe Convertible	2012	1.00	0.67	0.80	6
Rolls-Royce Ghost Sedan	2012	0.60	0.50	0.55	6
Rolls-Royce Phantom Sedan	2012	0.60	0.67	0.63	9
Scion xD Hatchback	2012	0.73	1.00	0.84	8
Spyker C8 Convertible	2009	0.33	0.17	0.22	6
Spieser C8 Coupe	2009	0.62	0.42	0.62	8
Suzuki Aerio Sedan	2007	0.60	0.60	0.60	5
Suzuki Kizashi Sedan	2012	0.75	0.86	0.89	7
Suzuki SX4 Hatchback	2012	0.55	0.86	0.67	7
Suzuki SX4 Sedan	2012	0.80	0.73	0.76	11
Tesla Model S Sedan	2012	1.00	0.43	0.60	7
Toyota Sequoia SUV	2012	0.71	1.00	0.83	5
Toyota Camry Sedan	2012	0.50	0.78	0.61	9
Toyota Corolla Sedan	2012	0.67	0.80	0.73	10
Toyota 4Runner SUV	2012	0.91	1.00	0.95	10
Volkswagen Jetta Hatchback	2012	0.67	0.60	0.73	5
Volkswagen Golf Hatchback	1991	0.67	1.00	0.80	8
Volkswagen Beetle Hatchback	2012	1.00	0.62	0.77	8
Volvo C30 Hatchback	2012	0.75	0.60	0.67	10
Volvo 240 Sedan	1993	1.00	0.92	0.96	12
Volvo XC90 SUV	2007	0.50	0.75	0.60	8
smart fortwo Convertible	2012	0.47	1.00	0.64	8
accuracy				0.71	1600
macro avg		0.74	0.71	0.69	1600
weighted avg		0.75	0.71	0.71	1600

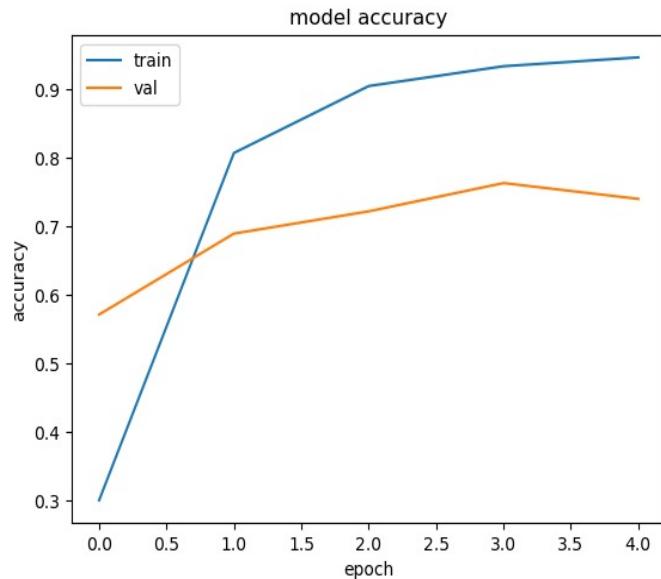
F1 Score metric

### 2.2.2.3 Second Experiment

In the second experiment, we paid more attention to the hyperparameters of the model. We used different learning rate, batch size and number of epochs for our training. Our model architecture had a flatten layer, a dropout layer and an output layer. We used: learning rate of 0.001, batch size of 40, and 5 number of epochs.



Model Loss Graph



Model Accuracy Graph

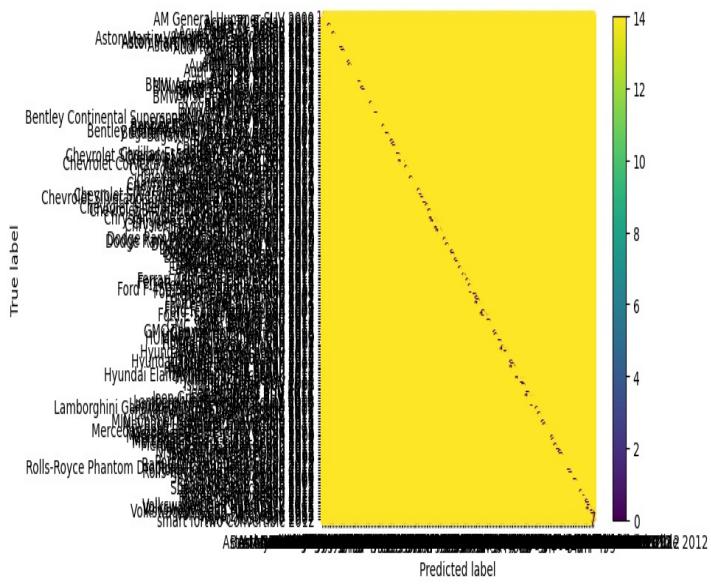
## Confusion Matrix:

```
[[12  0  0 ...  0  0  0]
 [ 0  3  0 ...  0  0  0]
 [ 0  0  5 ...  0  0  0]
 ...
 [ 0  0  0 ... 11  0  0]
 [ 0  0  0 ...  0  7  0]
 [ 0  0  0 ...  0  0  7]]
```

Accuracy: 74%

Balanced Accuracy: 75%

Confusion Matrix



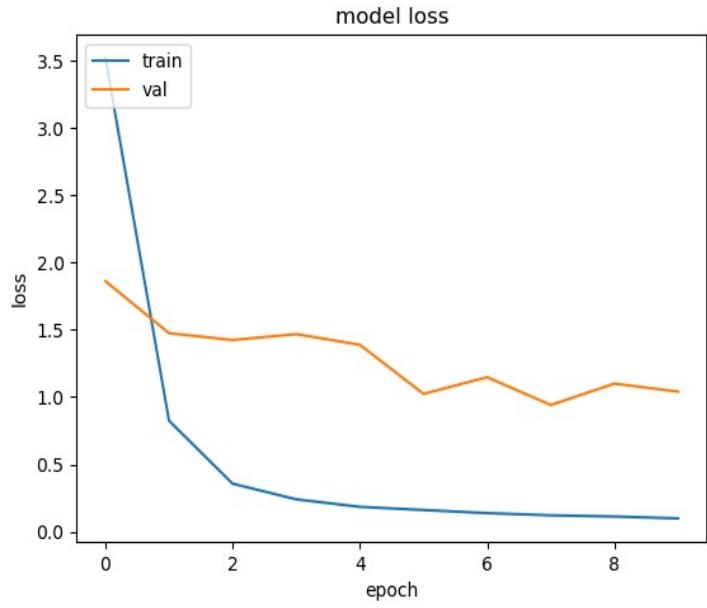
Confusion Matrix As Table

	precision	recall	f1-score	support
AM General Hummer SUV 2000	0.75	1.00	0.86	12
Acura RL Sedan 2012	0.60	0.60	0.60	5
Acura TL Sedan 2012	0.71	1.00	0.83	5
Acura TSX Type S 2008	0.98	0.76	0.50	8
Acura TSX Sedan 2012	1.00	0.20	0.13	5
Acura Integra Type R 2001	0.89	0.89	0.89	9
Acura ZDX Hatchback 2012	0.83	0.71	0.77	7
Aston Martin V8 Vantage Convertible 2012	0.75	0.43	0.55	7
Aston Martin V8 Vantage Coupe 2012	0.89	0.52	0.73	13
Aston Martin Virage Convertible 2012	0.90	0.50	0.57	6
Aston Martin Virage Coupe 2012	0.67	0.86	0.75	7
Audi RS 4 Convertible 2008	1.00	0.49	0.57	5
Audi A5 Coupe 2012	0.62	0.71	0.67	7
Audi TT S Coupe 2012	0.36	0.80	0.50	5
Audi RS Coupe 2012	1.00	0.78	0.88	9
Audi A8 Sedan 2004	0.54	0.84	0.74	8
Audi 100 Sedan 1994	0.59	0.10	0.17	10
Audi 100 Wagon 1994	0.59	0.59	0.50	6
Audi TT Hatchback 2011	0.57	0.40	0.47	10
Audi S6 Sedan 2011	0.56	1.00	0.72	9
Audi SS Convertible 2012	0.59	0.57	0.70	14
Audi S8 Coupe 2012	0.83	0.77	0.77	7
Audi S4 Sedan 2012	0.60	0.75	0.67	4
Audi S4 Sedan 2007	0.60	0.67	0.63	9
Audi TT RS Coupe 2012	0.83	0.50	0.62	10
BMW Activehybrid 5 Sedan 2012	0.60	0.55	0.57	11
BMW 1 Series Convertible 2012	1.00	0.29	0.44	7
BMW 1 Series Sedan 2012	0.90	0.50	0.54	12
BMW 3 Series Sedan 2012	0.62	0.62	0.62	8
BMW 3 Series Wagon 2012	0.89	0.62	0.73	13
BMW 6 Series Convertible 2007	0.88	0.58	0.70	12
BMW X5 SUV 2007	0.83	0.50	0.62	10
BMW X6 SUV 2012	0.75	0.75	0.75	4
BMW M3 Coupe 2012	1.00	0.60	0.75	10
BMW M5 Sedan 2010	0.89	0.57	0.67	7
BMW M6 Convertible 2010	0.53	0.73	0.62	11
BMW X3 SUV 2012	1.00	0.83	0.91	6
BMW Z4 Convertible 2012	1.00	0.42	0.59	12
Bentley Continental Supersports Coupe 2009	0.90	0.50	0.71	9
Bentley Arnage Sedan 2009	0.64	1.00	0.78	7
Bentley Mulsanne Sedan 2011	0.26	0.86	0.40	7
Bentley Continental GT Coupe 2012	0.62	0.56	0.59	9
Bentley Continental GT Coupe 2007	1.00	0.21	0.35	14
Bentley Continental Flying Spur Sedan 2007	0.62	0.62	0.62	8
Bugatti Veyron 16.4 Coupe 2009	0.57	1.00	0.80	8
Bugatti Veyron 16.4 Coupe 2009	0.83	1.00	0.91	5
Buick Regal GS 2012	1.00	1.00	1.00	6
Buick Rainier SUV 2007	1.00	0.70	0.82	10
Buick Verano Sedan 2012	0.75	0.86	0.80	7
Buick Enclave SUV 2012	1.00	0.62	0.77	8
Cadillac Escalade Sedan 2012	0.44	1.00	0.65	8
Cadillac SRX SUV 2012	0.89	0.80	0.84	10
Cadillac Escalade EXT Crew Cab 2007	0.64	1.00	0.78	7
Chevrolet Silverado 1500 Hybrid Crew Cab 2012	1.00	0.57	0.73	7
Chevrolet Corvette Convertible 2012	0.43	0.60	0.50	5
Chevrolet Corvette ZR1 2012	0.64	0.88	0.74	8
Chevrolet Corvette Rockford Fosgate 2012	0.77	0.53	0.69	7
Chevrolet Traverse SUV 2012	1.00	0.60	0.75	5
Chevrolet Camaro Convertible 2012	1.00	0.91	0.95	11
Chevrolet HHR SS 2010	1.00	0.86	0.92	7
Chevrolet Impala Sedan 2007	0.75	0.75	0.75	12
Chevrolet Equinox SUV 2012	0.67	0.67	0.77	9
Chevrolet Sonic Sedan 2012	1.00	0.75	0.86	8
Chevrolet Express Cargo Van 2007	0.75	0.50	0.60	6
Chevrolet Avalanche Crew Cab 2012	0.57	1.00	0.73	8
Chevrolet Cobalt SS 2012	0.60	0.75	0.67	4
Chevrolet Malibu Hybrid Sedan 2010	0.67	0.33	0.44	6
Chevrolet TrailBlazer SS 2009	0.71	0.71	0.71	7
Chevrolet Silverado 2500HD Regular Cab 2012	0.75	0.43	0.55	7
Chevrolet Silverado 1500 Classic Extended Cab 2007	0.90	1.00	0.95	9
Chevrolet Express Van 2007	0.20	0.20	0.20	5
Chevrolet Monte Carlo Cabrio 2007	0.70	0.70	0.70	10
Chevrolet Malibu Sedan 1997	0.78	0.78	0.78	9
Chevrolet Silverado 1500 Extended Cab 2012	0.56	0.63	0.67	6
Chevrolet Silverado 1500 Regular Cab 2012	0.64	0.88	0.74	8
Crysler Aspec SUV 2008	1.00	0.64	0.78	14
Crysler Sebring Convertible 2010	0.62	0.71	0.67	7
Crysler Town and Country Minivan 2012	0.67	1.00	0.80	8
Crysler 300 SRT-8 2010	0.59	0.83	0.31	6
Crysler Crossfire Convertible 2008	1.00	0.62	0.77	8
Crysler PT Cruiser Convertible 2008	0.85	1.00	0.92	11
Daewoo Nubira Wagon 2002	1.00	0.63	0.91	12
Dodge Avenger Wagon 2012	0.67	0.75	0.71	8
Dodge Caliber Wagon 2007	0.71	0.42	0.67	8
Dodge Caravan Minivan 1997	1.00	0.91	0.95	11
Dodge Ram Pickup 3500 Crew Cab 2010	0.92	0.92	0.92	12
Dodge Ram Pickup 3500 Quad Cab 2009	0.67	0.67	0.67	6
Dodge Durango Cargo Van 2009	0.67	0.33	0.44	6
Dodge Journey SUV 2012	1.00	0.47	0.80	12
Dodge Dakota Crew Cab 2010	0.80	0.44	0.57	9
Dodge Dakota Club Cab 2007	1.00	0.80	0.89	10
Dodge Magnum Wagon 2008	0.43	0.75	0.55	4
Dodge Challenger Sedan 2011	0.80	1.00	0.85	4
Dodge Charger Sedan 2012	0.90	0.90	0.90	10
Dodge Durango SUV 2007	0.88	0.88	0.88	8
Dodge Charger Sedan 2012	0.80	0.44	0.57	9
Dodge Charger SRT-8 2009	0.89	0.62	0.73	13
Eagle Talon Hatchback 1998	1.00	0.70	0.82	10
Fiat 500 Spider 2012	0.17	1.00	0.23	4
FIAT 500 Convertible 2012	0.82	1.00	0.90	9
Ferrari FF Coupe 2012	0.75	0.43	0.55	7
Ferrari California Convertible 2012	0.83	0.50	0.62	10
Ferrari 458 Italia Convertible 2012	0.73	0.67	0.70	12

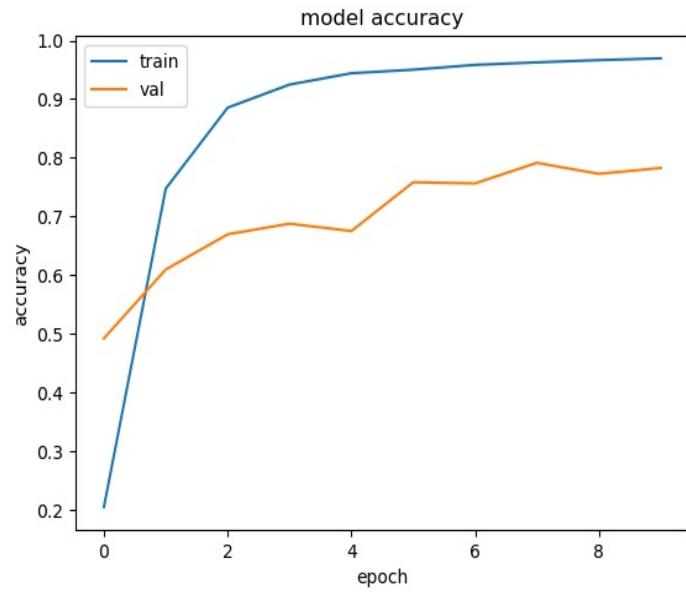
Ferrari 458 Italia Coupe 2012	0.57	0.57	0.57	7
Fisker Karma sedan 2012	1.00	0.75	0.66	12
Ford F-450 Super Duty Crew Cab 2012	0.75	1.00	0.86	3
Ford Mustang Convertible 2007	1.00	1.00	1.00	8
Ford Freestar Minivan 2007	0.86	0.86	0.86	7
Ford Expedition EL SUV 2009	1.00	0.86	0.92	7
Ford Edge SUV 2012	1.00	0.93	0.91	12
Ford Ranger SuperCab 2011	0.78	0.88	0.82	8
Ford GT Coupe 2006	0.67	0.89	0.76	9
Ford F-150 Regular Cab 2012	1.00	1.00	1.00	7
Ford 150 Super Cab 2007	1.00	0.90	0.72	10
Ford E-Series Wagon Van 2012	0.83	1.00	0.91	5
Ford Fiesta Sedan 2012	1.00	0.73	0.84	11
GMC Terrain SUV 2012	1.00	1.00	1.00	10
GMC Savana Van 2012	0.79	0.79	0.79	14
GMC Yukon SUV 2012	0.76	0.76	0.74	7
GMC Acadia SUV 2012	0.78	0.74	0.70	11
GMC Canyon Extended Cab 2012	1.00	0.60	0.75	10
Geo Metro Convertible 1993	1.00	0.83	0.91	6
HUMMER H3T Crew Cab 2010	1.00	0.40	0.57	5
HUMMER H2 SUV 2009	0.82	0.82	0.82	11
Honda Odyssey Minivan 2012	1.00	0.89	0.89	9
Honda Odyssey Minivan 2007	1.00	0.83	0.91	6
Honda Accord Coupé 2012	1.00	1.00	1.00	4
Hyundai Elantra Sedan 2012	1.00	0.64	0.78	11
Hyundai Elantra Hatchback 2012	0.83	0.83	0.83	6
Hyundai Santa Fe SUV 2012	1.00	0.73	0.84	11
Hyundai Tucson SUV 2012	0.71	0.91	0.80	11
Hyundai Veracruz SUV 2012	1.00	0.78	0.88	9
Hyundai Sonata Hybrid Sedan 2012	0.75	0.60	0.67	5
Hyundai Elantra Sedan 2007	0.86	0.86	0.86	7
Hyundai Genesis Sedan 2012	0.75	1.00	0.85	3
Hyundai Genesis Sedan 2012	0.67	1.00	0.80	8
Hyundai Sonata Sedan 2012	1.00	0.58	0.74	12
Hyundai Elantra Touring Hatchback 2012	0.81	1.00	0.90	13
Hyundai Elantra Sedan 2012	0.46	1.00	0.63	6
Infiniti G Coupe 2012	1.00	0.72	0.76	9
Infiniti QX50 SUV 2011	1.00	1.00	1.00	6
Isuzu Ascender SUV 2008	0.83	0.91	0.87	11
Jaguar XK XKR 2012	1.00	0.29	0.44	7
Jeep Patriot SUV 2012	0.78	0.88	0.82	8
Jeep Patriot SUV 2012	1.00	1.00	1.00	7
Jeep Liberty SUV 2012	0.67	0.80	0.73	5
Jeep Grand Cherokee SUV 2012	1.00	0.67	0.80	9
Jeep Compass SUV 2012	0.64	0.88	0.74	8
Lamborghini Reventon Coupe 2008	0.91	1.00	0.95	10
Lamborghini Aventador Coupe 2012	0.57	1.00	0.86	4
Lamborghini LP 570-4 Superleggera 2012	1.00	0.57	0.73	7
Lamborghini Diablo Coupe 2001	1.00	0.86	0.92	7
Land Rover Range Rover SUV 2012	0.82	1.00	0.90	14
Land Rover LR2 SUV 2012	0.82	1.00	0.90	9
Lincoln Town Car Sedan 2011	0.56	0.83	0.67	6
MINI Cooper Roadster Convertible 2012	0.80	0.80	0.80	10
Maybach Landaulet Convertible 2012	0.38	0.50	0.43	6
Mazda Tribute SUV 2011	0.83	1.00	0.91	5
McLaren MP4-12C Coupe 2012	0.80	1.00	0.89	8
Mercedes-Benz 300-Class Convertible 1993	0.89	0.80	0.84	10
Mercedes-Benz E-Class Sedan 2012	0.75	0.86	0.80	7
Mercedes-Benz SL-Class Coupe 2009	0.50	0.49	0.44	5
Mercedes-Benz E-Class Sedan 2012	0.86	0.75	0.80	8
Mercedes-Benz S-Class Sedan 2012	1.00	0.86	0.92	7
Mercedes-Benz Sprinter Van 2012	0.45	0.90	0.60	10
Mitsubishi Lancer Sedan 2012	0.40	1.00	0.57	8
Nissan Leaf Hatchback 2012	0.43	1.00	0.60	6
Nissan NV Passenger Van 2012	1.00	1.00	1.00	8
Nissan Juke Hatchback 2012	0.29	1.00	0.44	2
Nissan 240SX Coupe 1998	1.00	1.00	1.00	7
Plymouth Neon Coupe 1999	0.80	0.89	0.84	9
Porsche Panamera Sedan 2012	0.54	0.70	0.61	10
Ram C/V Cargo Van Minivan 2012	0.83	0.83	0.83	6
Rolls-Royce Phantom Drophead Coupe Convertible 2012	1.00	0.33	0.50	6
Rolls-Royce Ghost Sedan 2012	0.60	0.50	0.55	6
Rolls-Royce Phantom Sedan 2012	0.60	0.38	0.46	8
Scion xD Hatchback 2012	0.83	0.56	0.67	9
Spyker C8 Convertible 2009	0.64	1.00	0.76	7
Spyker C8 Coupe 2009	0.70	0.70	0.70	10
Suzuki Aero Sedan 2007	0.50	1.00	0.67	5
Suzuki Kizashi Sedan 2012	0.75	0.86	0.80	7
Suzuki SX4 Hatchback 2012	0.70	1.00	0.82	7
Suzuki SX4 Sedan 2012	0.45	0.50	0.48	10
Tesla Model S Sedan 2012	0.71	0.71	0.71	7
Toyota Sequoia SUV 2012	1.00	1.00	1.00	5
Toyota Corolla Sedan 2012	0.75	1.00	0.86	9
Toyota 4Runner SUV 2012	1.00	0.90	0.95	10
Volkswagen Golf Hatchback 2012	0.60	0.60	0.60	5
Volkswagen Golf Hatchback 1991	0.64	1.00	0.78	9
Volkswagen Beetle Hatchback 2012	1.00	0.88	0.93	8
Volkswagen C30 Hatchback 2012	1.00	0.70	0.82	10
Volvo XC60 Sedan 1993	1.00	0.92	0.96	12
Volvo XC90 SUV 2007	0.78	0.88	0.82	8
smart fortwo Convertible 2012	1.00	0.88	0.93	8
accuracy			0.74	1600
macro avg	0.78	0.75	0.73	1600
weighted avg	0.80	0.74	0.74	1600

#### 2.2.2.4 Best model Results and Metrics

Our best model architecture had the Xception Transfer Learning model layers, the GlobalAverage2DPooling layer that we used for the flatten layer, a dropout layer and an output layer using the softmax activation function with 196 neurons for each class we have.



Model Loss Graph



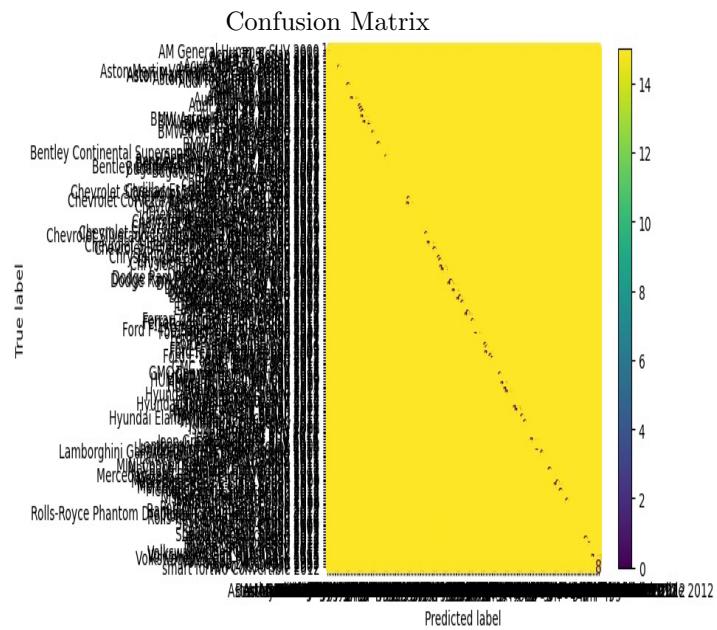
Model Accuracy Graph

### Confusion Matrix:

```
[[11  0  0 ...  0  0  0]
 [ 0  2  1 ...  0  0  0]
 [ 0  0  4 ...  0  0  0]
 ...
 [ 0  0  0 ... 10  0  0]
 [ 0  0  0 ...  0  7  0]
 [ 0  0  0 ...  0  0  8]]
```

Accuracy: 78%

Balanced Accuracy: 79%



	precision	recall	f1-score	support
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AM General Hummer SUV 2000	0.92	0.92	0.92	12
Acura RL Sedan 2012	0.67	0.40	0.50	5
Acura TL Sedan 2012	0.57	0.88	0.67	5
Acura TSX Type S 2008	0.86	0.55	0.69	8
Acura TSX Sedan 2012	0.80	0.67	0.73	6
Acura Integra Type R 2001	1.00	0.60	0.75	10
Acura ZDX Hatchback 2012	0.78	1.00	0.88	7
Aston Martin V8 Vantage Convertible 2012	0.45	0.71	0.56	7
Aston Martin Virage Convertible 2012	0.44	0.50	0.47	8
Aston Martin Virage Coupe 2012	0.79	1.00	0.82	7
Audi RS 4 Convertible 2008	1.00	0.50	0.67	4
Audi A5 Coupe 2012	0.75	0.43	0.55	7
Audi TT S Coupe 2012	0.43	0.60	0.50	5
Audi TT Coupe 2008	0.58	0.52	0.57	9
Audi V8 Sedan 1994	0.73	1.00	0.84	8
Audi 100 Sedan 1994	1.00	0.10	0.18	10
Audi 100 Wagon 1994	0.55	1.00	0.71	6
Audi TT Hatchback 2011	0.67	0.60	0.63	10
Audi S6 Sedan 2012	1.00	0.44	0.62	9
Audi S8 Sedan 2012	0.72	0.74	0.70	8
Audi S5 Coupe 2012	0.43	0.75	0.55	14
Audi S4 Sedan 2012	0.50	0.75	0.60	4
Audi S4 Sedan 2007	0.90	1.00	0.95	9
Audi TT RS Coupe 2012	0.89	0.80	0.84	10
BMW ActiveHybrid 5 Sedan 2012	0.80	0.88	0.88	10
BMW 1 Series Convertible 2012	0.70	0.78	0.78	8
BMW 1 Series Coupe 2012	1.00	0.83	0.91	12
BMW 3 Series Sedan 2012	1.00	0.75	0.86	8
BMW 3 Series Wagon 2012	0.71	0.92	0.86	13
BMW 6 Series Convertible 2007	0.57	0.73	0.64	11
BMW 6 Series 2008	1.00	0.70	0.82	10
BMW X6 SUV 2012	1.00	0.59	0.67	4
BMW M3 Coupe 2012	0.89	0.89	0.89	9
BMW M5 Sedan 2010	0.67	0.57	0.62	7
BMW M6 Convertible 2010	0.57	0.40	0.47	10
BMW X3 SUV 2012	0.83	0.83	0.83	6
BMW Z4 Coupe 2009	0.75	0.75	0.76	10
Bentley Continental Supersports Conv. Convertible 2012	0.70	0.78	0.74	9
Bentley Arnage Sedan 2009	1.00	0.57	0.73	7
Bentley Mulsanne Sedan 2011	0.80	0.57	0.67	7
Bentley Continental GT Coupe 2012	0.62	0.56	0.59	9
Bentley Continental GT Coupe 2007	0.69	0.64	0.67	14
Bentley Continental Flying Spur 2007	0.63	0.55	0.58	6
Bugatti Veyron 16.4 Convertible 2009	0.75	0.75	0.75	8
Bugatti Veyron 16.4 Coupe 2009	0.80	0.80	0.80	5
Buick Regal GS 2012	1.00	1.00	1.00	6
Buick Rainier SUV 2007	1.00	0.33	0.50	9
Buick Verano Sedan 2012	0.80	0.57	0.67	7
Buick Enclave SUV 2012	0.70	0.88	0.78	8
Cadillac CTS-V Sedan 2012	1.00	0.88	0.93	8
Cadillac SRX SUV 2012	1.00	0.70	0.82	10
Cadillac Escalade EXT Crew Cab 2007	0.88	1.00	0.93	7
Chevrolet Silverado 1500 Hybrid Crew Cab 2012	0.64	1.00	0.78	7
Chevrolet Corvette Convertible 2012	0.40	0.80	0.53	5
Chevrolet Corvette ZR1 2012	0.78	0.88	0.82	8
Chevrolet Corvette Ron Fellows Edition Z06 2007	0.67	0.67	0.75	7
Chevrolet Traverse SUV 2012	0.33	1.00	0.50	5
Chevrolet Camaro Convertible 2012	1.00	0.82	0.90	11
Chevrolet HHR SS 2010	1.00	0.83	0.91	6
Chevrolet Impala Sedan 2007	1.00	0.92	0.96	12
Chevrolet Tahoe Hybrid SUV 2012	0.86	0.75	0.80	8
Chevrolet Sonic Sedan 2012	1.00	0.88	0.93	8
Chevrolet Express Cargo Van 2007	0.50	0.50	0.50	6
Chevrolet Avalanche Crew Cab 2012	1.00	0.78	0.88	9
Chevrolet Cobalt SS 2010	1.00	1.00	1.00	4
Chevrolet Malibu Hybrid Sedan 2010	0.56	0.83	0.67	6
Chevrolet Trailblazer SS 2009	0.58	1.00	0.74	7
Chevrolet Silverado 2500HD Regular Cab 2012	0.47	1.00	0.64	7
Chevrolet Silverado 1500 Classic Extended Cab 2007	1.00	0.56	0.71	9
Chevrolet Express Van 2007	0.43	0.60	0.50	5
Chevrolet Monte Carlo Coupe 2007	0.82	0.90	0.86	10
Chevrolet Malibu Sedan 2007	0.54	0.78	0.64	9
Chevrolet Silverado 1500 Extended Cab 2012	0.60	0.43	0.58	7
Chevrolet Silverado 1500 Regular Cab 2012	0.55	0.67	0.60	9
Chevrolet Aspen SUV 2009	1.00	0.71	0.83	14
Chevrolet Sebring Convertible 2010	0.67	0.57	0.62	7
Chevrolet Town and Country Minivan 2012	1.00	1.00	1.00	8
Chevrolet 300 SRT-8 2010	1.00	0.67	0.80	6
Chevrolet Crossfire Convertible 2008	1.00	0.71	0.83	7
Chevrolet PT Cruiser Convertible 2008	0.89	0.88	0.84	10
Daewoo Nubira Wagon 2002	1.00	0.75	0.86	12
Dodge Caliber Wagon 2012	0.50	0.75	0.60	8
Dodge Caliber Wagon 2007	0.33	0.12	0.18	8
Dodge Caravan Minivan 1997	0.69	1.00	0.81	11
Dodge Ram Pickup 3500 Crew Cab 2010	1.00	0.51	0.95	11
Dodge Ram Pickup 2500 Quad Cab 2009	1.00	0.71	0.63	7
Dodge Sprinter Cargo Van 2009	0.62	0.83	0.71	6
Dodge Journey SUV 2012	1.00	0.50	0.67	12
Dodge Dakota Crew Cab 2010	0.73	0.89	0.80	9
Dodge Dakota Club Cab 2007	0.77	1.00	0.87	10
Dodge Magnum Wagon 2008	0.75	0.75	0.75	4
Dodge Challenger SRT8 2011	1.00	1.00	1.00	4
Dodge Durango SUV 2012	0.71	1.00	0.83	10
Dodge Durango SUV 2007	0.78	0.88	0.82	8
Dodge Charger Sedan 2012	0.82	0.90	0.86	10
Dodge Charger SRT-8 2009	1.00	0.77	0.87	13

Eagle Talon Hatchback	1998	0.90	0.90	0.90	10
FIAT 500 Abarth	2012	0.80	1.00	0.89	4
FIAT 500 Convertible	2012	1.00	0.78	0.88	9
Ferrari FF Coupe	2012	0.80	0.57	0.67	7
Ferrari California Convertible	2012	0.89	0.80	0.84	10
Ferrari 458 Italia Convertible	2012	0.65	0.92	0.76	12
Ferrari 458 Italia Coupe	2012	0.86	0.86	0.86	7
Fisker Karma Sedan	2012	1.00	0.69	0.82	13
Ford F-450 Super Duty CrewCab	2012	0.80	1.00	0.89	4
Ford Mustang Convertible	2007	0.83	0.62	0.71	8
Ford Freestar Minivan	2007	1.00	0.86	0.92	7
Ford Expedition EL SUV	2009	1.00	1.00	1.00	7
Ford Edge SUV	2012	0.93	1.00	0.96	13
Ford Ranger SuperCab	2011	1.00	0.62	0.77	8
Ford GT Coupe	2006	0.64	0.78	0.70	9
Ford F-150 Regular Cab	2012	1.00	1.00	1.00	7
Ford F-150 Regular Cab	2007	1.00	0.90	0.95	10
Ford Focus Sedan	2007	1.00	0.90	0.95	10
Ford E-Series Econoline	2012	1.00	1.00	1.00	5
Ford Fiesta Sedan	2012	1.00	0.91	0.95	11
GMC Terrain SUV	2012	0.82	1.00	0.90	9
GMC Savana Van	2012	1.00	0.69	0.82	13
GMC Yukon Hybrid SUV	2012	0.80	0.57	0.67	7
GMC Acadia SUV	2012	1.00	0.55	0.71	11
GMC Canyon Extended Cab	2012	1.00	0.56	0.71	9
Geo Metro Convertible	1993	0.86	1.00	0.92	6
HUMMER H3T Crew Cab	2010	0.56	1.00	0.71	5
HUMMER H2S Sport Cab	2009	1.00	0.75	0.86	12
Honda Odyssey Minivan	2012	0.65	0.67	0.75	9
Honda Odyssey Minivan	2007	0.67	0.67	0.67	6
Honda Accord Coupe	2012	0.67	1.00	0.80	4
Honda Accord Sedan	2012	1.00	1.00	1.00	12
Hyundai Veloster Hatchback	2012	0.56	0.83	0.67	6
Hyundai Santa Fe SUV	2012	1.00	0.91	0.95	11
Hyundai Tucson SUV	2012	0.85	1.00	0.92	11
Hyundai Veracruz SUV	2012	0.75	0.67	0.71	9
Hyundai Sonata Hybrid Sedan	2012	0.80	0.80	0.80	5
Hyundai Elantra Sedan	2007	0.30	0.50	0.33	8
Hyundai Accent Sedan	2012	1.00	0.75	0.86	4
Hyundai Genesis Sedan	2012	0.86	0.86	0.86	7
Hyundai Sonata Sedan	2012	0.79	0.85	0.81	13
Hyundai Elantra Touring Hatchback	2012	1.00	0.85	0.92	13
Hyundai Azera Sedan	2012	0.60	0.50	0.55	6
Infiniti G Coupe IPL	2012	0.89	0.89	0.89	9
Infiniti QX56 SUV	2011	0.86	1.00	0.92	6
Isuzu Ascender SUV	2008	0.69	0.90	0.78	10
Jaguar XK XKR	2012	0.70	1.00	0.82	7
Jeep Patriot SUV	2012	0.86	0.75	0.80	8
Jeep Wrangler SUV	2012	0.78	1.00	0.88	7
Jeep Liberty SUV	2012	0.75	0.50	0.60	6
Jeep Grand Cherokee SUV	2012	0.54	0.78	0.70	9
Jeep Compass SUV	2012	0.70	0.88	0.78	8
Lamborghini Reventon Coupe	2008	0.77	1.00	0.87	10
Lamborghini Aventador Coupe	2012	0.60	0.75	0.67	4
Lamborghini Gallardo LP 570-4 Superleggera	2012	0.86	0.86	0.86	7
Lamborghini Diablo Coupe	2001	0.86	0.86	0.86	7
Land Rover Range Rover SUV	2012	0.88	1.00	0.94	15
Land Rover LR2 SUV	2012	0.90	1.00	0.95	9
Lincoln Town Car Sedan	2011	0.67	1.00	0.80	6
MINI Cooper Roadster Convertible	2012	0.86	0.60	0.71	10
Maybach Landaulet Convertible	2012	1.00	0.83	0.91	6
Mazda Tribute SUV	2011	1.00	1.00	1.00	5
McLaren MP4-12C Coupe	2012	0.88	1.00	0.93	7
Mercedes-Benz 300-Class Convertible	1993	1.00	0.88	0.89	10
Mercedes-Benz C-Class Sedan	2012	0.67	1.00	0.80	6
Mercedes-Benz E-Class Coupe	2009	1.00	0.80	0.89	5
Mercedes-Benz E-Class Sedan	2012	1.00	0.78	0.88	9
Mercedes-Benz S-Class Sedan	2012	0.90	0.57	0.73	7
Mercedes-Benz Sprinter Van	2012	0.90	0.82	0.86	11
Mitsubishi Lancer Sedan	2012	0.56	1.00	0.71	10
Nissan Leaf Hatchback	2012	1.00	1.00	1.00	5
Nissan NV Passenger Van	2012	1.00	1.00	1.00	8
Nissan Juke Hatchback	2012	0.25	1.00	0.40	2
Nissan 240SX Coupe	1998	0.67	0.66	0.75	7
Plymouth Neon Coupe	1999	1.00	0.56	0.71	9
Porsche Panamera Sedan	2012	0.69	0.90	0.78	10
Ram C/V Cargo Van Minivan	2012	0.75	0.86	0.80	7
Rolls-Royce Phantom Drophead Coupe Convertible	2012	1.00	0.50	0.67	6
Rolls-Royce Ghost Sedan	2012	0.50	0.83	0.62	6
Rolls-Royce Phantom Sedan	2012	1.00	0.50	0.55	8
Saab 900 Hatchback	2012	1.00	0.50	0.53	8
Spyker C8 Convertible	2009	0.75	0.86	0.80	7
Spyker C8 Coupe	2009	0.75	0.67	0.71	9
Suzuki Aerio Sedan	2007	1.00	0.40	0.57	5
Suzuki Kizashi Sedan	2012	1.00	1.00	1.00	7
Suzuki SX4 Hatchback	2012	1.00	0.86	0.92	7
Suzuki SX4 Sedan	2012	1.00	0.55	0.71	11
Tesla Model S Sedan	2012	0.86	0.86	0.86	7
Toyota Sequoia SUV	2012	1.00	1.00	1.00	5
Toyota Camry Sedan	2012	0.80	0.89	0.84	9
Toyota Corolla Sedan	2012	0.80	0.44	0.57	9
Toyota 4Runner SUV	2012	0.90	0.90	0.90	10
Volkswagen Golf Hatchback	2012	0.43	0.60	0.50	5
Volkswagen Golf Hatchback	1991	1.00	0.67	0.80	9

Volkswagen Beetle Hatchback 2012	1.00	0.75	0.86	8	
Volvo C30 Hatchback 2012	0.88	0.78	0.82	9	
Volvo 240 Sedan 1993	0.91	0.91	0.91	11	
Volvo XC90 SUV 2007	0.78	0.88	0.82	8	
smart fortwo Convertible 2012	1.00	1.00	1.00	8	
accuracy			0.79	1600	
macro avg	0.81	0.79	0.78	1600	
weighted avg	0.83	0.79	0.78	1600	

### 2.2.3 Image Retrieval(KNN)

#### 2.2.3.1 Design

In the KNN approach for solving our multi-class classification problem we use the KNN algorithm for classification. In KNN classification, the algorithm works by finding the k-nearest neighbours in the training data set to a given test data point, based on a distance metric such as Euclidean distance. The predicted class label of the test data point is then determined by a majority vote of the class labels. We used the best model we created in the transfer learning approach we implemented previously. After we loaded the best model we took only the layers until the flattening layer with it as well, then we run the model on our training set. After we got the signature values of each car image in our training set we fitted the KNN model with the actual classification of the training set. Then, with the KNN model fitted, we predicted the test set signature values and ran the KNN model on them and we evaluated the performance of the KNN model.

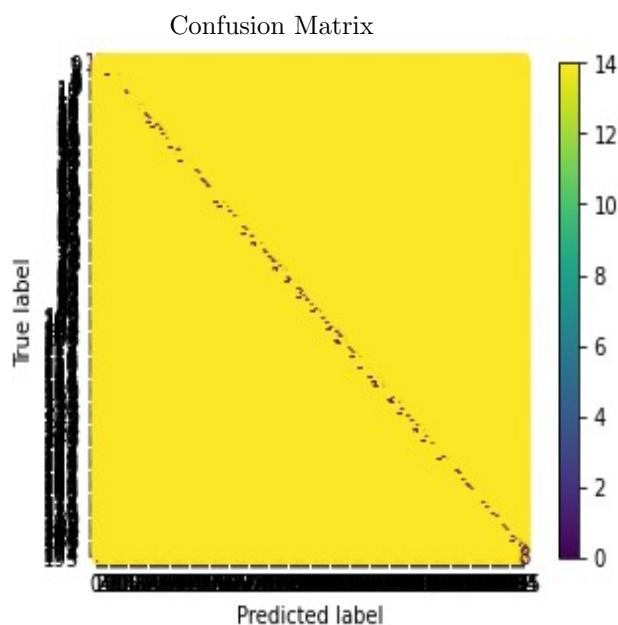
#### 2.2.3.2 First Experiment

In the first experiment, we paid more attention to the number of neighbours our KNN model uses in order to predict the classification of the encoded label input. We used: 5 number of neighbours.

```
[[11  0  0  ...  0  0  0]
 [ 0  3  0  ...  0  0  0]
 [ 0  0  4  ...  0  0  0]
 ...
 [ 0  0  0  ...  11 0  0]
 [ 0  0  0  ...  0  8  0]
 [ 0  0  0  ...  0  0  8]]
```

Accuracy: 82%

Balanced Accuracy: 82%



Confusion Matrix As Table

		precision	recall	f1-score	support
AM General	Hummer SUV 2000	0.60	0.60	0.60	5
Acura	RL Sedan 2012	0.67	0.80	0.73	5
Acura	TL Sedan 2012	0.50	0.71	0.59	7
Acura	TL Type-S 2008	0.57	0.80	0.67	5
Acura	TSX Sedan 2012	0.86	0.67	0.75	9
Acura	Integra Type R 2001	1.00	0.71	0.83	7
Acura	ZDX Hatchback 2012	0.38	0.43	0.40	7
Aston Martin	V8 Vantage Convertible 2012	0.71	0.77	0.74	13
Aston Martin	V8 Vantage Coupe 2012	0.62	0.71	0.67	7
Aston Martin	Virage Convertible 2012	0.46	0.86	0.60	7
Aston Martin	Virage Coupe 2012	0.50	0.25	0.33	4
Audi	RS 4 Convertible 2008	0.55	0.86	0.67	7
Audi	AS Coupe 2012	0.20	0.48	0.27	5
Audi	TTS Coupe 2012	0.89	0.89	0.89	9
Audi	R8 Coupe 2012	0.58	0.88	0.70	8
Audi	V8 Sedan 1994	0.75	0.30	0.43	10
Audi	100 Sedan 1994	0.71	0.83	0.77	6
Audi	100 Wagon 1994	0.50	0.40	0.44	10
Audi	TT Hatchback 2011	0.86	0.67	0.75	9
Audi	S6 Sedan 2011	0.73	0.62	0.67	13
Audi	S5 Convertible 2012	0.44	0.57	0.50	7
Audi	S5 Coupe 2012	0.43	0.75	0.55	4
Audi	S4 Sedan 2012	0.90	1.00	0.95	9
Audi	S4 Sedan 2007	0.78	0.70	0.74	10
Audi	TT RS Coupe 2012	0.82	0.90	0.86	10
BMW	ActiveHybrid 5 Sedan 2012	1.00	0.86	0.92	7
BMW	1 Series Convertible 2012	0.92	0.92	0.92	12
BMW	1 Series Coupe 2012	0.88	0.88	0.88	8
BMW	3 Series Sedan 2012	0.92	0.92	0.92	13
BMW	3 Series Wagon 2012	0.78	0.70	0.74	10
BMW	6 Series Convertible 2007	0.70	0.78	0.74	9
BMW	X5 SUV 2007	1.00	0.75	0.86	4
BMW	X6 SUV 2012	1.00	0.90	0.95	10
BMW	M3 Coupe 2012	0.80	0.57	0.67	7
BMW	M5 Sedan 2010	0.55	0.60	0.57	10
BMW	M6 Convertible 2010	0.86	0.86	0.86	7
BMW	X3 SUV 2012	0.92	0.79	0.85	14
BMW	Z4 Convertible 2012	0.64	1.00	0.78	9
Bentley	Continental Supersports Conv. Convertible 2012	1.00	0.86	0.92	7
Bentley	Arnage Sedan 2009	0.83	0.71	0.77	7
Bentley	Mulsanne Sedan 2011	0.75	0.67	0.71	9
Bentley	Continental GT Coupe 2012	0.71	0.71	0.71	14
Bentley	Continental GT Coupe 2007	0.60	0.86	0.71	7
Bentley	Continental Flying Spur Sedan 2007	1.00	0.71	0.83	7
Bugatti	Veyron 16.4 Convertible 2009	0.83	0.83	0.83	6
Bugatti	Veyron 16.4 Coupe 2009	0.70	1.00	0.82	7
Buick	Regal GS 2012	0.89	0.89	0.89	9
Buick	Rainier SUV 2007	0.86	0.86	0.86	7
Buick	Verano Sedan 2012	1.00	0.88	0.93	8
Buick	Enclave SUV 2012	1.00	1.00	1.00	7
Cadillac	CTS-V Sedan 2012	1.00	0.99	0.95	10
Cadillac	SRX SUV 2012	0.70	1.00	0.82	7
Cadillac	Escalade EXT Crew Cab 2007	0.67	0.86	0.75	7
Chevrolet	Silverado 1500 Hybrid Crew Cab 2012	0.62	1.00	0.77	5
Chevrolet	Corvette Convertible 2012	0.67	0.75	0.71	8
Chevrolet	Corvette ZR1 2012	0.86	0.86	0.86	7
Chevrolet	Corvette Ron Fellows Edition Z06 2007	0.62	1.00	0.77	5
Chevrolet	Traverse SUV 2012	0.85	1.00	0.92	11
Chevrolet	Camaro Convertible 2012	1.00	0.83	0.91	6
Chevrolet	HHR SS 2010	1.00	0.92	0.96	13
Chevrolet	Impala Sedan 2007	1.00	0.62	0.77	8
Chevrolet	Tahoe Hybrid SUV 2012	1.00	0.88	0.93	8
Chevrolet	Sonic Sedan 2012	0.43	0.43	0.43	7
Chevrolet	Express Cargo Van 2007	0.62	1.00	0.76	8
Chevrolet	Avalanche Crew Cab 2012	0.83	1.00	0.91	5
Chevrolet	Cobalt SS 2010	0.80	0.57	0.67	7
Chevrolet	Malibu Hybrid Sedan 2010	0.67	0.86	0.75	7
Chevrolet	Trailblazer SS 2009	0.64	1.00	0.78	7
Chevrolet	Silverado 2500HD Regular Cab 2012	0.89	1.00	0.94	8
Chevrolet	Silverado 1500 Classic Extended Cab 2007	0.38	0.60	0.46	5
Chevrolet	Express Van 2007	0.83	0.91	0.87	11
Chevrolet	Monte Carlo Coupe 2007	0.64	0.78	0.70	9
Chevrolet	Malibu Sedan 2007	0.60	0.50	0.55	6
Chevrolet	Silverado 1500 Extended Cab 2012	0.83	0.56	0.67	9
Chevrolet	Silverado 1500 Regular Cab 2012	1.00	0.86	0.92	14
Chrysler	Aspen SUV 2009	0.67	0.57	0.62	7
Chrysler	Sebring Convertible 2010	1.00	1.00	1.00	9
Chrysler	Town and Country Minivan 2012	1.00	0.88	0.93	8
Chrysler	300 SRT-8 2010	0.86	0.86	0.86	7
Chrysler	Crossfire Convertible 2008	0.88	0.70	0.78	10

Chrysler PT Cruiser Convertible	2008	1.00	0.82	0.90	11
Daewoo Nubira Wagon	2002	0.64	0.78	0.70	9
Dodge Caliber Wagon	2012	0.71	0.62	0.67	8
Dodge Caliber Wagon	2007	0.80	0.73	0.76	11
Dodge Caravan Minivan	1997	1.00	0.92	0.96	12
Dodge Ram Pickup 3500 Crew Cab	2010	0.67	0.86	0.75	7
Dodge Ram Pickup 3500 Quad Cab	2009	0.67	0.67	0.67	6
Dodge Sprinter Cargo Van	2009	1.00	0.67	0.80	12
Dodge Journey SUV	2012	1.00	0.78	0.88	9
Dodge Dakota Crew Cab	2010	0.91	1.00	0.95	10
Dodge Dakota Club Cab	2007	0.75	0.75	0.75	4
Dodge Magnum Wagon	2008	0.80	1.00	0.89	4
Dodge Challenger SRT8	2011	0.75	0.90	0.82	10
Dodge Durango SUV	2012	0.73	1.00	0.84	8
Dodge Durango SUV	2007	1.00	0.89	0.94	9
Dodge Charger Sedan	2012	0.92	0.92	0.92	13
Dodge Charger SRT-8	2009	0.88	0.70	0.78	10
Eagle Talon Hatchback	1998	1.00	1.00	1.00	5
FIAT 500 Abarth	2012	1.00	0.89	0.94	9
FIAT 500 Convertible	2012	0.57	0.57	0.57	7
Ferrari FF Coupe	2012	1.00	0.90	0.95	10
Ferrari California Convertible	2012	0.85	0.92	0.88	12
Ferrari 458 Italia Convertible	2012	0.75	0.86	0.80	7
Ferrari 458 Italia Coupe	2012	1.00	0.58	0.74	12
Fisker Karma Sedan	2012	0.75	1.00	0.86	3
Ford F-450 Super Duty Crew Cab	2012	0.88	0.88	0.88	8
Ford Mustang Convertible	2007	0.86	0.86	0.86	7
Ford Freestar Minivan	2007	0.78	1.00	0.88	7
Ford Expedition EL SUV	2009	0.85	0.92	0.88	12
Ford Edge SUV	2012	0.88	0.78	0.82	9
Ford Ranger SuperCab	2011	0.89	0.80	0.84	10
Ford GT Coupe	2006	1.00	1.00	1.00	7
Ford F-150 Regular Cab	2012	1.00	1.00	1.00	10
Ford F-150 Regular Cab	2007	0.91	1.00	0.95	10
Ford Focus Sedan	2007	1.00	1.00	1.00	5
Ford E-Series Wagon Van	2012	1.00	0.82	0.90	11
Ford Fiesta Sedan	2012	0.90	1.00	0.95	9
GMC Terrain SUV	2012	1.00	0.62	0.76	13
GMC Savana Van	2012	0.80	0.57	0.67	7
GMC Yukon Hybrid SUV	2012	1.00	1.00	1.00	11
GMC Acadia SUV	2012	1.00	0.56	0.71	9
GMC Canyon Extended Cab	2012	0.80	0.80	0.80	5
Geo Metro Convertible	1993	0.83	1.00	0.91	5
HUMMER H3T Crew Cab	2010	1.00	0.91	0.95	11
HUMMER H2 SUT Crew Cab	2009	0.86	0.67	0.75	9
Honda Odyssey Minivan	2012	0.67	0.67	0.67	6
Honda Odyssey Minivan	2007	0.67	1.00	0.80	4
Honda Accord Coupe	2012	1.00	1.00	1.00	11
Honda Accord Sedan	2012	1.00	1.00	1.00	6
Hyundai Veloster Hatchback	2012	1.00	0.91	0.95	11
Hyundai Santa Fe SUV	2012	0.92	1.00	0.96	11
Hyundai Tucson SUV	2012	0.67	0.67	0.67	9
Hyundai Veracruz SUV	2012	0.80	0.80	0.80	5
Hyundai Sonata Hybrid Sedan	2012	0.57	0.57	0.57	7
Hyundai Elantra Sedan	2007	0.50	1.00	0.67	3
Hyundai Accent Sedan	2012	0.80	1.00	0.89	8
Hyundai Genesis Sedan	2012	1.00	0.85	0.92	13
Hyundai Sonata Sedan	2012	1.00	1.00	1.00	13
Hyundai Elantra Touring Hatchback	2012	0.83	0.83	0.83	6
Hyundai Azera Sedan	2012	0.88	0.78	0.82	9
Infiniti G Coupe IPL	2012	0.86	1.00	0.92	6
Infiniti QX56 SUV	2011	1.00	1.00	1.00	10
Isuzu Ascender SUV	2008	0.64	0.88	0.74	8
Jaguar XK XKR	2012	1.00	0.75	0.86	8
Jeep Patriot SUV	2012	0.78	1.00	0.88	7
Jeep Wrangler SUV	2012	0.75	0.60	0.67	5
Jeep Liberty SUV	2012	0.78	0.78	0.78	9
Jeep Grand Cherokee SUV	2012	0.75	0.75	0.75	8

Jeep Compass SUV 2012	0.91	1.00	0.95	18
Lamborghini Reventon Coupe 2008	0.75	0.75	0.75	4
Lamborghini Aventador Coupe 2012	1.00	1.00	1.00	8
Lamborghini Gallardo LP 570-4 Superleggera 2012	0.75	0.86	0.80	7
Lamborghini Diablo Coupe 2001	1.00	1.00	1.00	14
Land Rover Range Rover SUV 2012	1.00	0.89	0.94	9
Land Rover LR2 SUV 2012	1.00	1.00	1.00	6
Lincoln Town Car Sedan 2011	1.00	0.60	0.75	18
MINI Cooper Roadster Convertible 2012	0.75	1.00	0.86	6
Maybach Landaulet Convertible 2012	0.71	1.00	0.83	5
Mazda Tribute SUV 2011	1.00	0.88	0.93	8
McLaren MP4-12C Coupe 2012	0.91	1.00	0.95	18
Mercedes-Benz 300-Class Convertible 1993	0.75	1.00	0.86	6
Mercedes-Benz C-Class Sedan 2012	0.75	0.50	0.60	6
Mercedes-Benz SL-Class Coupe 2009	0.50	0.50	0.50	8
Mercedes-Benz E-Class Sedan 2012	1.00	0.57	0.73	7
Mercedes-Benz S-Class Sedan 2012	0.82	0.90	0.86	18
Mercedes-Benz Sprinter Van 2012	0.88	0.88	0.88	8
Mitsubishi Lancer Sedan 2012	0.75	1.00	0.86	6
Nissan Leaf Hatchback 2012	1.00	0.88	0.93	8
Nissan NV Passenger Van 2012	0.67	1.00	0.80	2
Nissan Juke Hatchback 2012	0.78	1.00	0.88	7
Nissan 240SX Coupe 1998	1.00	0.78	0.88	9
Plymouth Neon Coupe 1999	0.82	0.90	0.86	18
Porsche Panamera Sedan 2012	0.86	1.00	0.92	6
Ram C/V Cargo Van Minivan 2012	1.00	0.83	0.91	6
Rolls-Royce Phantom Drophead Coupe Convertible 2012	0.50	0.50	0.50	6
Rolls-Royce Ghost Sedan 2012	0.80	0.44	0.57	9
Rolls-Royce Phantom Sedan 2012	1.00	0.88	0.93	8
Scion xD Hatchback 2012	0.62	0.71	0.67	7
Spyker C8 Convertible 2009	0.78	0.78	0.78	9
Spyker C8 Coupe 2009	1.00	0.60	0.75	5
Suzuki Aerio Sedan 2007	1.00	0.86	0.92	7
Suzuki Kizashi Sedan 2012	1.00	1.00	1.00	7
Suzuki SX4 Hatchback 2012	0.88	0.70	0.78	18
Suzuki SX4 Sedan 2012	0.83	0.71	0.77	7
Tesla Model S Sedan 2012	1.00	1.00	1.00	5
Toyota Sequoia SUV 2012	0.89	0.89	0.89	9
Toyota Camry Sedan 2012	0.89	0.73	0.80	11
Toyota Corolla Sedan 2012	1.00	0.80	0.89	18
Toyota 4Runner SUV 2012	1.00	0.60	0.75	5
Volkswagen Golf Hatchback 2012	1.00	0.67	0.80	9
Volkswagen Golf Hatchback 1991	0.88	1.00	0.93	7
Volkswagen Beetle Hatchback 2012	1.00	0.70	0.82	10
Volvo C30 Hatchback 2012	1.00	0.92	0.96	12
Volvo 240 Sedan 1993	0.89	1.00	0.94	8
Volvo XC90 SUV 2007	1.00	1.00	1.00	8
micro avg	0.82	0.82	0.82	1588
macro avg	0.82	0.82	0.81	1588
weighted avg	0.84	0.82	0.82	1588

### 2.2.3.3 Second Experiment

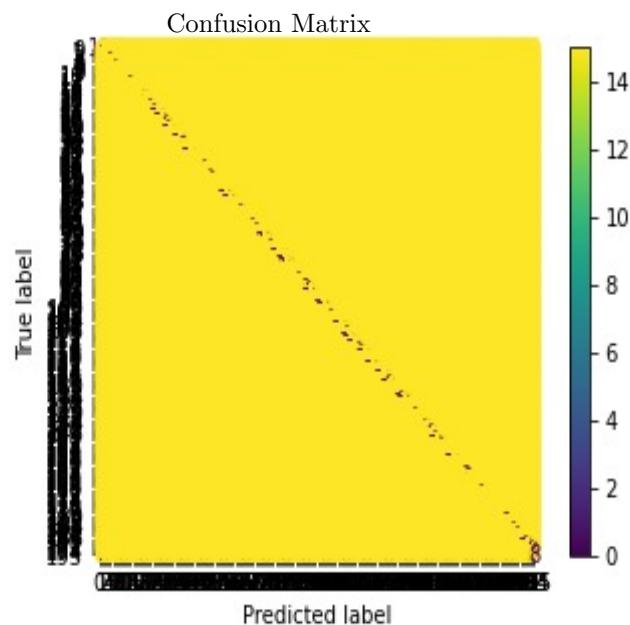
In the second experiment, we paid more attention the power of the distance method our KNN model uses in order to predict the classification of the encoded label input. The value of the power is 3 in this experiment.

Confusion Matrix:

```
[[10  0  0 ...  0  0  0]
 [ 0  3  0 ...  0  0  0]
 [ 0  0  4 ...  0  0  0]
 ...
 [ 0  0  0 ... 11  0  0]
 [ 0  0  0 ...  0  8  0]
 [ 0  0  0 ...  0  0  8]]
```

Accuracy: 82%

Balanced Accuracy: 81%



		precision	recall	f1-score	support
AM General	Hummer SUV 2000	1.00	0.91	0.95	11
Acura	RL Sedan 2012	0.75	0.60	0.67	5
Acura	TL Sedan 2012	0.67	0.80	0.73	5
Acura	TL Type-S 2008	0.67	0.50	0.57	8
Acura	TSX Sedan 2012	0.71	0.83	0.77	6
Acura	Integra Type R 2001	0.89	0.80	0.84	10
Acura	ZDX Hatchback 2012	1.00	0.71	0.83	7
Aston Martin	V8 Vantage Convertible 2012	0.31	0.57	0.40	7
Aston Martin	V8 Vantage Coupe 2012	0.38	0.69	0.49	13
Aston Martin	Virage Convertible 2012	0.57	0.50	0.53	8
Aston Martin	Virage Coupe 2012	0.67	0.86	0.75	7
Audi	R5 4 Convertible 2008	1.00	0.25	0.40	4
Audi	A5 Coupe 2012	0.68	0.86	0.71	7
Audi	TTS Coupe 2012	0.44	0.80	0.57	5
Audi	R8 Coupe 2012	1.00	0.89	0.94	9
Audi	V8 Sedan 1994	0.58	0.88	0.64	8
Audi	100 Sedan 1994	0.75	0.30	0.43	10
Audi	100 Wagon 1994	0.58	0.80	0.62	5
Audi	TT Hatchback 2011	0.58	0.56	0.53	9
Audi	S6 Sedan 2011	0.86	0.67	0.75	9
Audi	S5 Convertible 2012	0.75	0.64	0.69	14
Audi	S5 Coupe 2012	0.58	0.50	0.50	8
Audi	S4 Sedan 2012	0.58	0.75	0.60	4
Audi	S4 Sedan 2007	0.82	1.00	0.90	9
Audi	TT RS Coupe 2012	0.75	0.60	0.67	10
BMW	ActiveHybrid 5 Sedan 2012	0.90	0.90	0.90	10
BMW	1 Series Convertible 2012	1.00	0.88	0.93	8
BMW	1 Series Coupe 2012	0.92	0.92	0.92	12
BMW	3 Series Sedan 2012	0.86	0.75	0.80	8
BMW	3 Series Wagon 2012	0.85	0.85	0.85	13
BMW	6 Series Convertible 2007	0.73	0.73	0.73	11
BMW	X5 SUV 2007	0.67	0.80	0.73	10
BMW	X6 SUV 2012	1.00	0.50	0.67	4
BMW	M3 Coupe 2012	1.00	1.00	1.00	10
BMW	M5 Sedan 2010	1.00	0.57	0.73	7
BMW	M6 Convertible 2010	0.64	0.70	0.67	10
BMW	X1 SUV 2012	0.86	0.80	0.86	7
BMW	Z4 Convertible 2012	0.91	0.77	0.83	13
Bentley	Continental Supersports Conv. Convertible 2012	0.64	1.00	0.78	9
Bentley	Arnage Sedan 2009	1.00	0.86	0.92	7
Bentley	Mulsanne Sedan 2011	0.71	0.71	0.71	7
Bentley	Continental GT Coupe 2012	0.71	0.56	0.63	9
Bentley	Continental GT Coupe 2007	0.71	0.71	0.71	14
Bentley	Continental Flying Spur Sedan 2007	0.64	0.88	0.74	8
Bugatti	Veyron 16.4 Convertible 2009	1.00	0.62	0.77	8
Bugatti	Veyron 16.4 Coupe 2009	0.71	0.33	0.77	6
Buick	Regal GS 2013	1.00	1.00	1.00	7
Buick	Rainier SUV 2007	0.89	0.89	0.89	9
Buick	Verano Sedan 2012	0.62	0.83	0.71	6
Buick	Enclave SUV 2012	0.86	0.75	0.80	8
Cadillac	CTS-V Sedan 2012	1.00	1.00	1.00	8
Cadillac	SRX SUV 2012	1.00	0.90	0.95	10
Cadillac	Escalade EXT Crew Cab 2007	0.78	1.00	0.88	7
Chevrolet	Silverado 1500 Hybrid Crew Cab 2012	0.68	0.86	0.71	7
Chevrolet	Corvette Convertible 2012	0.62	1.00	0.77	5
Chevrolet	Corvette ZR1 2012	0.62	0.62	0.62	8
Chevrolet	Corvette Ron Fellows Edition Z06 2007	0.86	0.80	0.86	7
Chevrolet	Corvette Traverse SUV 2012	0.58	1.00	0.67	5
Chevrolet	Camaro Convertible 2012	0.85	1.00	0.92	11
Chevrolet	Camaro SS 2010	1.00	0.33	0.31	6
Chevrolet	Impala Sedan 2007	1.00	0.85	0.92	13
Chevrolet	Tahoe Hybrid SUV 2012	0.86	0.75	0.80	8
Chevrolet	Sonic Sedan 2012	0.78	0.88	0.82	8
Chevrolet	Express Cargo Van 2007	0.49	0.33	0.36	6
Chevrolet	Avalanche Crew Cab 2012	0.73	1.00	0.84	8
Chevrolet	Cobalt SS 2010	0.80	1.00	0.89	4
Chevrolet	Malibu Hybrid Sedan 2010	0.75	0.50	0.60	6
Chevrolet	Malibu Regular Cab 2012	0.58	1.00	0.74	7
Chevrolet	Silverado 1500 Classic Extended Cab 2007	1.00	0.89	0.94	9
Chevrolet	Express Van 2007	0.38	0.60	0.46	5
Chevrolet	Monte Carlo Coupe 2007	0.90	0.90	0.90	10
Chevrolet	Malibu Sedan 2007	0.64	0.78	0.70	9
Chevrolet	Silverado 1500HD Crew Cab 2012	0.57	0.57	0.57	7
Chevrolet	Silverado 1500 Regular Cab 2012	0.83	0.56	0.67	9
Chevrolet	Aspen SUV 2009	1.00	0.85	0.92	13
Chevrolet	Sebring Convertible 2010	0.71	0.71	0.71	7
Chevrolet	Town and Country Minivan 2012	0.90	1.00	0.95	9
Chevrolet	300 SRT-8 2010	0.75	1.00	0.86	6
Chevrolet	Crossfire Convertible 2008	0.83	0.83	0.83	6
Chevrolet	PT Cruiser Convertible 2008	0.88	0.70	0.78	10
Daewoo	Nubira Wagon 2002	0.91	0.83	0.87	12
Dodge	Caliber Wagon 2012	0.60	0.75	0.67	8
Dodge	Caliber Wagon 2007	0.57	0.50	0.53	8
Dodge	Caravan Minivan 1997	0.83	0.91	0.87	11
Dodge	Ram Pickup 3500 Crew Cab 2010	1.00	0.92	0.96	12
Dodge	Ram Pickup 3500 Quad Cab 2009	0.75	0.86	0.80	7

Dodge Sprinter Cargo Van	2009	0.83	0.83	0.83	6
Dodge Journey SUV	2012	1.00	0.58	0.74	12
Dodge Dakota Crew Cab	2010	1.00	0.67	0.80	9
Dodge Dakota Club Cab	2007	0.82	1.00	0.90	9
Dodge Magnum Wagon	2008	1.00	0.75	0.86	4
Dodge Challenger SRT8	2011	1.00	1.00	1.00	4
Dodge Durango SUV	2012	0.82	0.98	0.86	10
Dodge Durango SUV	2007	0.73	1.00	0.84	8
Dodge Charger Sedan	2012	0.78	0.78	0.74	10
Dodge Charger SRT-8	2009	0.92	0.92	0.92	13
Eagle Talon Hatchback	1998	0.88	0.78	0.82	9
FIAT 500 Abarth	2012	1.00	1.00	1.00	5
FIAT 500 Convertible	2012	1.00	0.78	0.88	9
Ferrari FF Coupe	2012	0.67	0.57	0.62	7
Ferrari California Convertible	2012	0.91	1.00	0.95	10
Ferrari 458 Italia Convertible	2012	0.79	0.92	0.85	12
Ferrari 458 Italia Coupe	2012	0.75	0.86	0.80	7
Fisker Karma Sedan	2012	1.00	0.69	0.82	13
Ford F-450 Super Duty Crew Cab	2012	0.67	1.00	0.80	4
Ford Mustang Convertible	2007	0.78	0.88	0.82	8
Ford Freestar Minivan	2007	0.86	0.86	0.86	7
Ford Expedition EL SUV	2009	0.88	1.00	0.93	7
Ford Edge SUV	2012	0.86	0.92	0.89	13
Ford Ranger SuperCab	2011	0.88	0.88	0.88	8
Ford GT Coupe	2006	0.89	0.88	0.84	10
Ford F-150 Regular Cab	2012	1.00	1.00	1.00	7
Ford F-150 Regular Cab	2007	1.00	1.00	1.00	10
Ford Focus Sedan	2007	1.00	1.00	1.00	10
Ford E-Series Wagon Van	2012	0.83	1.00	0.91	5
Ford Fiesta Sedan	2012	1.00	0.91	0.95	11
GMC Terrain SUV	2012	0.89	1.00	0.94	8
GMC Savana Van	2012	1.00	0.69	0.82	13
GMC Yukon Hybrid SUV	2012	0.80	0.57	0.67	7
GMC Acadia SUV	2012	1.00	0.91	0.95	11
GMC Canyon Extended Cab	2012	1.00	0.67	0.80	9
Geo Metro Convertible	1993	0.83	0.83	0.83	6
HUMMER H3T Crew Cab	2010	0.83	1.00	0.91	5
HUMMER H2 SUT Crew Cab	2009	0.92	0.92	0.92	12
Honda Odyssey Minivan	2012	0.88	0.78	0.82	9
Honda Odyssey Minivan	2007	0.88	0.67	0.73	6
Honda Accord Coupe	2012	1.00	1.00	1.00	4
Honda Accord Sedan	2012	1.00	0.80	0.95	11
Hyundai Veloster Hatchback	2012	1.00	0.83	0.91	6
Hyundai Santa Fe SUV	2012	1.00	0.90	0.95	10
Hyundai Tucson SUV	2012	0.91	0.91	0.91	11
Hyundai Veracruz SUV	2012	0.62	0.62	0.62	8
Hyundai Sonata Hybrid Sedan	2012	0.80	0.88	0.88	5
Hyundai Elantra Sedan	2007	0.62	0.62	0.62	8
Hyundai Accent Sedan	2012	0.60	0.75	0.67	4
Hyundai Genesis Sedan	2012	1.00	1.00	1.00	8
Hyundai Sonata Sedan	2012	1.00	0.93	0.96	14
Hyundai Elantra Touring Hatchback	2012	1.00	1.00	1.00	12
Hyundai Azera Sedan	2012	1.00	0.83	0.91	6
Infiniti G Coupe IPL	2012	0.88	0.78	0.82	9
Infiniti QX56 SUV	2011	0.86	1.00	0.92	6
Isuzu Ascender SUV	2008	1.00	0.68	0.95	10
Jaguar XK XKR	2012	0.57	0.75	0.71	8
Jeep Patriot SUV	2012	1.00	0.75	0.65	8
Jeep Wrangler SUV	2012	0.68	1.00	0.93	7
Jeep Liberty SUV	2012	1.00	0.83	0.91	6
Jeep Grand Cherokee SUV	2012	0.80	0.89	0.84	9
Jeep Compass SUV	2012	0.86	0.75	0.80	8
Lamborghini Reventon Coupe	2008	0.90	0.90	0.90	10
Lamborghini Aventador Coupe	2012	1.00	0.75	0.86	4
Lamborghini Gallardo LP 570-4 Superleggera	2012	1.00	1.00	1.00	8
Lamborghini Diablo Coupe	2001	0.75	0.86	0.80	7
Land Rover Range Rover SUV	2012	1.00	1.00	1.00	15
Land Rover LR2 SUV	2012	1.00	0.89	0.94	9
Lincoln Town Car Sedan	2011	1.00	1.00	1.00	6
MINI Cooper Roadster Convertible	2012	1.00	0.58	0.67	10
Maybach Landaulet Convertible	2012	0.67	1.00	0.80	6
Mazda Tribute SUV	2011	0.71	1.00	0.83	5
Mitsubishi i-MiEV	2012	1.00	0.68	0.73	8
Mercedes-Benz 300-Class Convertible	1993	0.91	1.00	0.95	10
Mercedes-Benz C-Class Sedan	2012	0.60	1.00	0.75	6
Mercedes-Benz SL-Class Coupe	2009	0.50	0.49	0.44	5
Mercedes-Benz E-Class Sedan	2012	0.67	0.67	0.67	9
Mercedes-Benz S-Class Sedan	2012	0.80	0.57	0.67	7
Mercedes-Benz Sprinter Van	2012	0.80	0.80	0.84	10
Mitsubishi Lancer Sedan	2012	0.75	1.00	0.86	9
Nissan Leaf Hatchback	2012	0.75	1.00	0.86	6
Nissan NV Passenger Van	2012	1.00	0.88	0.93	8
Nissan Juke Hatchback	2012	0.67	1.00	0.80	2
Nissan 240SX Coupe	1998	0.75	0.86	0.80	7
Plymouth Neon Coupe	1999	1.00	0.75	0.86	8
Porsche Panamera Sedan	2012	1.00	0.89	0.94	9
Ram C/V Cargo Van Minivan	2012	0.83	1.00	0.91	5

Rolls-Royce Phantom Drophead Coupe Convertible 2012	1.00	0.83	0.91	6
Rolls-Royce Ghost Sedan 2012	0.43	0.50	0.46	6
Rolls-Royce Phantom Sedan 2012	0.71	0.56	0.63	9
Scion xD Hatchback 2012	1.00	0.88	0.93	8
Spyker C8 Convertible 2009	0.67	0.67	0.67	6
Spyker C8 Coupe 2009	0.75	0.75	0.75	8
Suzuki Aerio Sedan 2007	1.00	0.60	0.75	5
Suzuki Kizashi Sedan 2012	1.00	1.00	1.00	7
Suzuki SX4 Hatchback 2012	1.00	1.00	1.00	6
Suzuki SX4 Sedan 2012	1.00	0.73	0.84	11
Tesla Model S Sedan 2012	0.71	0.71	0.71	7
Toyota Sequoia SUV 2012	1.00	1.00	1.00	5
Toyota Camry Sedan 2012	0.73	0.89	0.80	9
Toyota Corolla Sedan 2012	0.88	0.70	0.78	10
Toyota 4Runner SUV 2012	1.00	0.80	0.89	10
Volkswagen Golf Hatchback 2012	1.00	0.60	0.75	5
Volkswagen Golf Hatchback 1991	1.00	0.62	0.77	8
Volkswagen Beetle Hatchback 2012	0.88	0.88	0.88	8
Volvo C30 Hatchback 2012	1.00	0.80	0.89	10
Volvo 240 Sedan 1993	1.00	0.92	0.96	12
Volvo XC90 SUV 2007	0.89	1.00	0.94	8
smart fortwo Convertible 2012	1.00	1.00	1.00	8
accuracy			0.82	1600
macro avg	0.83	0.81	0.81	1600
weighted avg	0.84	0.82	0.82	1600

#### 2.2.3.4 Best model Results and Metrics

Our best model in the KNN method had a power of 2 which is the Euclidean distance formula and 5 number of neighbours.

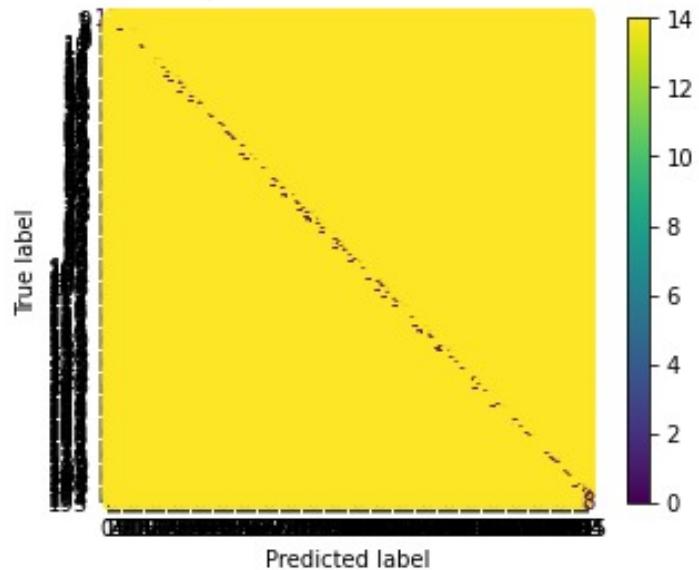
#### Confusion Matrix:

```
[[11  0  0 ...  0  0  0]
 [ 0  2  0 ...  0  0  0]
 [ 0  0  4 ...  0  0  0]
 ...
 [ 0  0  0 ... 11  0  0]
 [ 0  0  0 ...  0  8  0]
 [ 0  0  0 ...  0  0  8]]
```

Accuracy: 81%

Balanced Accuracy: 81%

Confusion Matrix



Confusion Matrix As Table

	precision	recall	f1-score	support
AM General Hummer SUV 2000	0.92	0.92	0.92	12
Acura RL Sedan 2012	0.50	0.40	0.44	5
Acura TL Sedan 2012	0.67	0.80	0.73	5
Acura TL Type-S 2008	0.71	0.62	0.67	8
Acura TSX Sedan 2012	0.44	0.80	0.57	5
Acura Integra Type R 2001	0.75	0.60	0.67	10
Acura ZDX Hatchback 2012	1.00	0.86	0.92	7
Aston Martin V8 Vantage Convertible 2012	0.44	0.57	0.50	7
Aston Martin V8 Vantage Coupe 2012	0.71	0.77	0.74	13
Aston Martin Virage Convertible 2012	0.67	0.67	0.67	9
Aston Martin Virage Coupe 2012	0.50	0.86	0.63	7
Audi RS 4 Convertible 2008	0.50	0.25	0.33	4
Audi A5 Coupe 2012	0.60	0.86	0.71	7
Audi TTS Coupe 2012	0.25	0.40	0.31	5
Audi R8 Coupe 2012	1.00	0.89	0.94	9
Audi 100 Sedan 1994	0.50	0.88	0.64	8
Audi 100 Wagon 1994	0.75	0.30	0.43	10
Audi 100 Wagon 1996	0.83	0.83	0.83	6
Audi TT Hatchback 2011	0.36	0.40	0.38	10
Audi S6 Sedan 2011	0.83	0.62	0.71	8
Audi S5 Convertible 2012	0.75	0.64	0.69	14
Audi S5 Coupe 2012	0.40	0.57	0.47	7
Audi S4 Sedan 2012	0.43	0.75	0.55	4
Audi S4 Sedan 2007	0.89	1.00	0.94	8
Audi TT RS Coupe 2012	0.86	0.60	0.71	10
BMW ActiveHybrid 5 Sedan 2012	0.90	0.90	0.90	10
BMW 1 Series Convertible 2012	1.00	0.86	0.92	7
BMW 1 Series Coupe 2012	0.92	0.92	0.92	12
BMW 3 Series Sedan 2012	0.86	0.75	0.80	8
BMW 3 Series Wagon 2012	0.71	0.92	0.80	13
BMW 6 Series Convertible 2007	0.70	0.70	0.70	10
BMW X5 SUV 2007	0.73	0.80	0.76	10
BMW X6 SUV 2012	0.75	0.75	0.75	4
BMW M3 Coupe 2012	0.77	1.00	0.87	10
BMW M5 Sedan 2010	1.00	0.57	0.73	7
BMW M6 Convertible 2010	0.58	0.70	0.64	10

	BMW X3 SUV 2012	1.00	0.86	0.92	7
Bentley	Z4 Convertible 2012	0.92	0.79	0.85	14
Continental	Supersports Conv. Convertible 2012	0.64	1.00	0.78	9
	Bentley Arnage Sedan 2009	1.00	0.86	0.92	7
	Bentley Mulsanne Sedan 2011	0.75	0.86	0.80	7
	Bentley Continental GT Coupe 2012	0.75	0.67	0.71	9
	Bentley Continental GT Coupe 2007	0.69	0.69	0.69	13
Bentley	Continental Flying Spur Sedan 2007	0.78	0.88	0.82	8
	Bugatti Veyron 16.4 Convertible 2009	1.00	0.75	0.86	8
	Bugatti Veyron 16.4 Coupe 2009	0.62	0.83	0.71	6
	Buick Regal GS 2012	1.00	1.00	1.00	7
	Buick Rainier SUV 2007	0.89	0.89	0.89	9
	Buick Verano Sedan 2012	0.75	0.86	0.80	7
	Buick Enclave SUV 2012	0.88	0.88	0.88	8
Cadillac	CTS-V Sedan 2012	1.00	1.00	1.00	7
	Cadillac SRX SUV 2012	1.00	0.90	0.95	10
Cadillac	Escalade EXT Crew Cab 2007	0.78	1.00	0.88	7
Chevrolet	Silverado 1500 Hybrid Crew Cab 2012	0.62	0.71	0.67	7
	Chevrolet Corvette Convertible 2012	0.60	0.60	0.60	5
	Chevrolet Corvette ZR1 2012	0.78	0.88	0.82	8
Chevrolet	Corvette Ron Fellows Edition Z06 2007	0.75	0.86	0.80	7
	Chevrolet Traverse SUV 2012	0.57	0.80	0.67	5
	Chevrolet Camaro Convertible 2012	0.73	1.00	0.85	11
	Chevrolet HHR SS 2010	1.00	0.83	0.91	6
	Chevrolet Impala Sedan 2007	1.00	0.92	0.96	12
	Chevrolet Tahoe Hybrid SUV 2012	1.00	0.71	0.83	7
	Chevrolet Sonic Sedan 2012	0.75	0.75	0.75	8
Chevrolet	Express Cargo Van 2007	0.57	0.57	0.57	7
	Chevrolet Avalanche Crew Cab 2012	0.69	1.00	0.82	9
	Chevrolet Cobalt SS 2010	1.00	1.00	1.00	5
	Chevrolet Malibu Hybrid Sedan 2010	0.83	0.71	0.77	7
	Chevrolet TrailBlazer SS 2009	0.83	0.83	0.83	6
Chevrolet	Silverado 2500HD Regular Cab 2012	0.58	1.00	0.74	7
	Chevrolet Silverado 1500 Classic Extended Cab 2007	0.89	0.89	0.89	9
	Chevrolet Express Van 2007	0.44	0.80	0.57	5
	Chevrolet Monte Carlo Coupe 2007	0.91	0.91	0.91	11
	Chevrolet Malibu Sedan 2007	0.64	0.78	0.70	9
Chevrolet	Silverado 1500 Extended Cab 2012	0.43	0.50	0.46	6
	Chevrolet Silverado 1500 Regular Cab 2012	0.75	0.43	0.55	7
	Chrysler Aspen SUV 2009	1.00	0.86	0.92	14
Chrysler	Sebring Convertible 2010	0.57	0.57	0.57	7
Chrysler	Town and Country Minivan 2012	1.00	0.89	0.94	9
	Chrysler 300 SRT-8 2010	1.00	0.88	0.93	8
	Chrysler Crossfire Convertible 2008	0.86	0.86	0.86	7
Chrysler	PT Cruiser Convertible 2008	0.82	0.90	0.86	10
	Daewoo Nubira Wagon 2002	1.00	0.83	0.91	12
	Dodge Caliber Wagon 2012	0.70	0.78	0.74	9
	Dodge Caliber Wagon 2007	0.56	0.62	0.59	8
	Dodge Caravan Minivan 1997	0.91	0.91	0.91	11
Dodge	Ram Pickup 3500 Crew Cab 2010	1.00	1.00	1.00	12
Dodge	Ram Pickup 3500 Quad Cab 2009	0.78	0.88	0.82	8
Dodge	Sprinter Cargo Van 2009	0.36	0.67	0.47	6
	Dodge Journey SUV 2012	1.00	0.64	0.78	11
	Dodge Dakota Crew Cab 2010	1.00	0.67	0.88	9
	Dodge Dakota Club Cab 2007	0.91	1.00	0.95	10
	Dodge Magnum Wagon 2008	1.00	0.75	0.86	4
Dodge	Challenger SRT-8 2011	1.00	1.00	1.00	4
	Dodge Durango SUV 2012	0.90	0.90	0.90	10
	Dodge Durango SUV 2007	0.80	1.00	0.89	8
Dodge	Charger Sedan 2012	1.00	0.90	0.95	10
	Dodge Charger SRT-8 2009	1.00	0.92	0.96	13
Eagle	Talon Hatchback 1998	0.88	0.70	0.78	10
	FIAT 500 Abarth 2012	0.80	1.00	0.89	4
FIAT	500 Convertible 2012	0.89	0.89	0.89	9
Ferrari	458 FF Coupe 2012	0.50	0.57	0.53	7
	California Convertible 2012	0.90	0.90	0.90	10
Ferrari	458 Italia Convertible 2012	0.91	0.83	0.87	12
	458 Italia Coupe 2012	0.60	0.86	0.71	7
Fisker	Karma Sedan 2012	1.00	0.67	0.88	12
Ford	F-450 Super Duty Crew Cab 2012	0.80	1.00	0.89	4
	Ford Mustang Convertible 2007	0.75	0.86	0.88	7
	Ford Freestar Minivan 2007	0.71	0.83	0.77	6
Ford	Expedition EL SUV 2009	0.75	1.00	0.86	6
	Edge SUV 2012	0.85	0.92	0.88	12
Ford	Ranger SuperCab 2011	0.88	0.78	0.82	9
	GT Coupe 2006	0.89	0.80	0.84	10
Ford	F-150 Regular Cab 2012	1.00	1.00	1.00	7
	F-150 Regular Cab 2007	1.00	1.00	1.00	10
Ford	Focus Sedan 2007	0.90	1.00	0.95	9
Ford	E-Series Wagon Van 2012	1.00	1.00	1.00	5

Ford Fiesta Sedan	2012	1.00	0.91	0.95	11
GMC Terrain SUV	2012	0.98	1.00	0.95	9
GMC Savana Van	2012	1.00	0.62	0.76	13
GMC Yukon Hybrid SUV	2012	0.88	0.57	0.67	7
GMC Acadia SUV	2012	1.00	1.00	1.00	10
GMC Canyon Extended Cab	2012	1.00	0.60	0.75	10
Geo Metro Convertible	1993	0.67	0.67	0.67	6
HUMMER H3T Crew Cab	2010	0.83	1.00	0.91	5
Honda Odyssey Minivan	2012	0.83	0.56	0.67	9
Honda Odyssey Minivan	2007	0.62	0.83	0.71	6
Honda Accord Coupe	2012	1.00	1.00	1.00	4
Honda Accord Sedan	2012	1.00	0.92	0.96	12
Hyundai Veloster Hatchback	2012	1.00	0.83	0.91	6
Hyundai Santa Fe SUV	2012	1.00	0.91	0.95	11
Hyundai Tucson SUV	2012	1.00	1.00	1.00	9
Hyundai Veracruz SUV	2012	0.70	0.78	0.74	9
Hyundai Sonata Hybrid Sedan	2012	1.00	0.75	0.86	4
Hyundai Elantra Sedan	2007	0.43	0.43	0.43	7
Hyundai Accent Sedan	2012	0.60	0.75	0.67	4
Hyundai Genesis Sedan	2012	1.00	1.00	1.00	7
Hyundai Sonata Sedan	2012	1.00	0.85	0.92	13
Hyundai Elantra Touring Hatchback	2012	0.93	1.00	0.96	13
Hyundai Azera Sedan	2012	0.83	0.83	0.83	6
Infiniti G Coupe IPL	2012	0.88	0.78	0.82	9
Infiniti QX56 SUV	2011	0.86	1.00	0.92	6
Isuzu Ascender SUV	2008	0.90	0.90	0.90	10
Jaguar XK XKR	2012	1.00	0.62	0.77	8
Jeep Patriot SUV	2012	0.86	0.75	0.80	8
Jeep Wrangler SUV	2012	0.88	1.00	0.93	7
Jeep Liberty SUV	2012	1.00	0.60	0.75	5
Jeep Grand Cherokee SUV	2012	0.86	0.67	0.75	9
Jeep Compass SUV	2012	0.75	0.75	0.75	8
Lamborghini Reventon Coupe	2008	0.89	0.89	0.89	9
Lamborghini Aventador Coupe	2012	0.75	0.75	0.75	4
Lamborghini Gallardo LP 570-4 Superleggera	2012	1.00	1.00	1.00	8
Lamborghini Diablo Coupe	2001	0.67	0.86	0.75	7
Land Rover Range Rover SUV	2012	0.88	1.00	0.93	14
Land Rover LR2 SUV	2012	1.00	0.89	0.94	9
Lincoln Town Car Sedan	2011	1.00	1.00	1.00	6
MINI Cooper Roadster Convertible	2012	1.00	0.50	0.67	10
Maybach Landaulet Convertible	2012	0.67	1.00	0.80	6
Mazda Tribute SUV	2011	0.71	1.00	0.83	5
McLaren MP4-12C Coupe	2012	0.88	0.88	0.88	8
Mercedes-Benz 300-Class Convertible	1993	0.83	1.00	0.91	10
Mercedes-Benz C-Class Sedan	2012	0.75	1.00	0.86	6
Mercedes-Benz SL-Class Coupe	2009	0.83	0.83	0.83	6
Mercedes-Benz E-Class Sedan	2012	0.67	0.67	0.67	9
Mercedes-Benz S-Class Sedan	2012	0.88	0.57	0.67	7
Mercedes-Benz Sprinter Van	2012	0.71	0.50	0.59	10
Mitsubishi Lancer Sedan	2012	0.82	0.90	0.86	10
Nissan Leaf Hatchback	2012	0.86	1.00	0.92	6
Nissan NV Passenger Van	2012	1.00	1.00	1.00	8
Nissan Juke Hatchback	2012	0.67	1.00	0.80	2
Nissan 240SX Coupe	1998	0.71	0.71	0.71	7
Plymouth Neon Coupe	1999	1.00	0.78	0.88	9
Porsche Panamera Sedan	2012	1.00	0.90	0.95	10
Ram C/V Cargo Van Minivan	2012	0.86	1.00	0.92	6
Rolls-Royce Phantom Drophead Coupe Convertible	2012	0.83	0.83	0.83	6
Rolls-Royce Ghost Sedan	2012	0.50	0.67	0.57	6
Rolls-Royce Phantom Sedan	2012	1.00	0.44	0.62	9
Scion XD Hatchback	2012	1.00	0.86	0.92	7
Spyker C8 Convertible	2009	0.71	0.71	0.71	7
Spyker C8 Coupe	2009	0.78	0.78	0.78	9
Suzuki Aerio Sedan	2007	1.00	0.60	0.75	5
Suzuki Kizashi Sedan	2012	1.00	1.00	1.00	7
Suzuki SX4 Hatchback	2012	1.00	1.00	1.00	7
Suzuki SX4 Sedan	2012	1.00	0.73	0.84	11
Tesla Model S Sedan	2012	0.56	0.71	0.63	7
Toyota Sequoia SUV	2012	1.00	1.00	1.00	5
Toyota Camry Sedan	2012	0.89	0.89	0.89	9
Toyota Corolla Sedan	2012	0.88	0.73	0.76	11
Toyota 4Runner SUV	2012	1.00	0.80	0.89	10
Volkswagen Golf Hatchback	2012	1.00	0.60	0.75	5
Volkswagen Golf Hatchback	1991	1.00	0.67	0.80	9
Volkswagen Beetle Hatchback	2012	0.86	0.75	0.80	8
Volvo C30 Hatchback	2012	1.00	0.78	0.88	9
Volvo 240 Sedan	1993	1.00	0.92	0.96	12
Volvo XC90 SUV	2007	0.89	1.00	0.94	8
smart fortwo Convertible	2012	1.00	1.00	1.00	8

accuracy		0.81	1600
macro avg	0.82	0.81	0.80
weighted avg	0.84	0.81	0.81

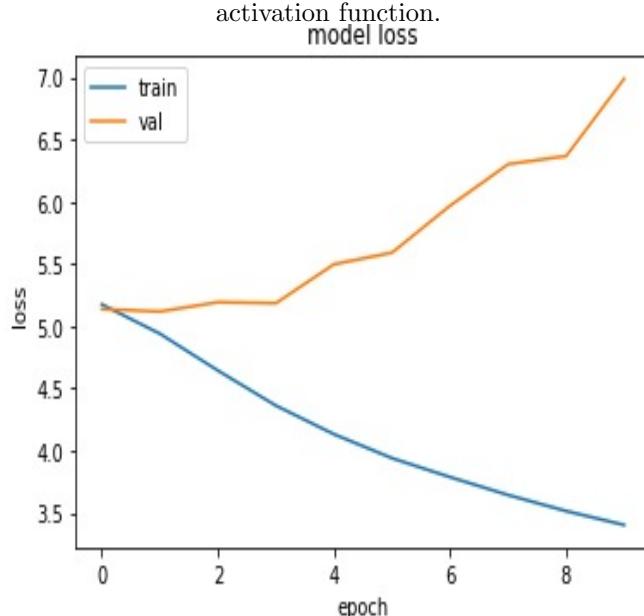
## 2.2.4 END-TO-END-CNN

### 2.2.4.1 Design

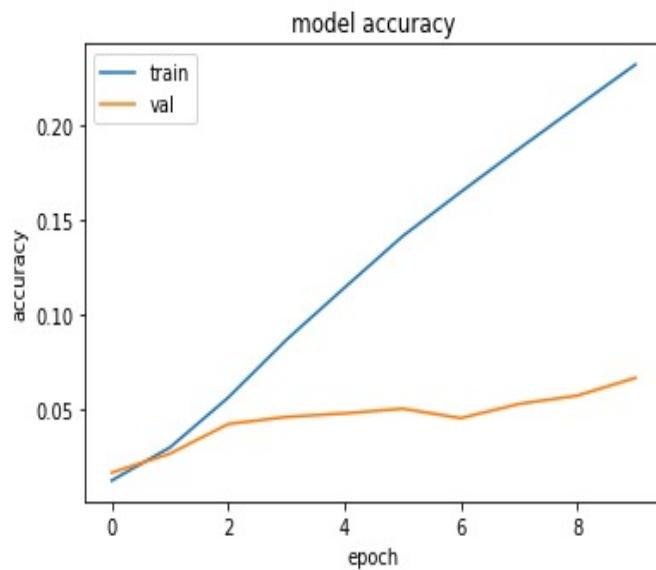
In the End To End CNN approach we build from scratch a Convolutional Neural Network model. A Convolutional Neural Network has the ability to extract this feature and use it for our classification. This ability is called feature extraction which is a method that uses a filtering pooling layers. The filtering layer is basically a matrix with the same deepness of our image target that checks each section in the image with the convolutional method, which is a multiplication of the cells of both matrices: the filter matrix in the image and the section matrix that the filtering is currently on, then we do a summary of all the cells. Also, we can do this with many filters as we like. The layers of pooling takes the maximum cell value of the section the pooling matrix is currently computing and it can have striding to skip sections. After the feature extraction there is the flatten method which creates a vector of our matrix output, which is basically a label representing our image. Then, there are fully connected layers that are used for the classification itself. We created a the feature extraction layer. Then, we added the flatten layer and the dense layers and we also added the last layer that has 196 neurons that uses the softmax function for the probability classification of the input image. We also added between the dense layers a dropout layer. Dropout is a regularization technique used in neural networks to prevent overfitting, which occurs when a model learns the noise in the training data rather than the underlying pattern. This is done in a stochastic manner, such that the set of units that are dropped out is different for each training example. After compiling the model we added the hyper parameters such as number of batches, number of epochs and learning rate. Also we added a callback of early stopping which is used for avoiding overfitting and having a better model performance because it stops the training when the model is not improving.

#### 2.2.4.2 First Experiment

In our first experiment, we paid more attention to our CNN architecture. We had different number of filters and size per convolutional layer, different number of Max pooling layers, a different number of convolutional layers. We had the flatten layer after the feature extraction and different architecture of the Fully Connected layers used for the classification of the input image, which are different number of dense hidden layers and neurons per layer and different activation function method for each dense layer. We used: 4 convolutional layers, one had 32 filters with kernel size of 3, then a convolutional layer with 32 filters and a kernel size of 3, a convolutional layer of 16 filters and a kernel size of 3 and then a convolutional layer of 8 filter with a kernel size of 3. Between each convolutional layer we had a MaxPooling layer. Then we have the flatten layer, A dense layer with 80 neurons, a dense layer with 40 neurons and last layer of 196 neurons as the number of classes we have, with the Softmax activation function. Each dense layer has the Relu activation function.



Model Loss Graph



Model Accuracy Graph

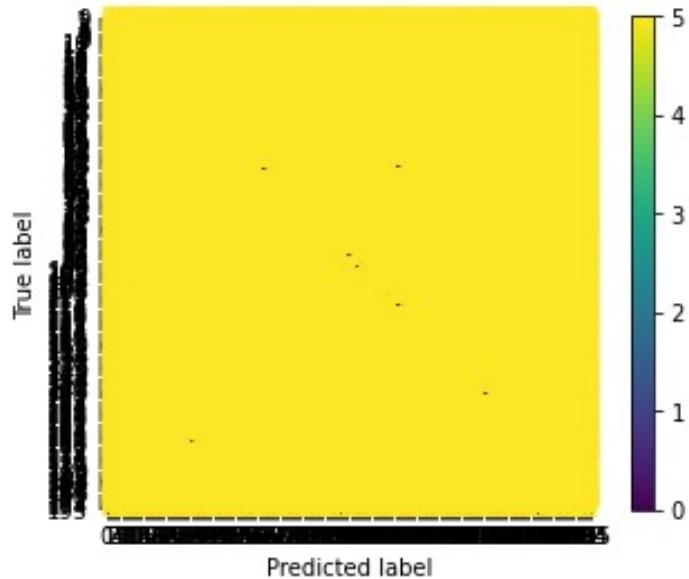
### Confusion Matrix:

```
[[2 0 0 ... 0 0 0]
 [0 0 0 ... 0 0 0]
 [0 0 1 ... 0 0 1]
 ...
 [0 0 0 ... 0 0 0]
 [0 0 0 ... 0 0 0]
 [0 0 0 ... 0 0 2]]
```

Accuracy: 6%

Balanced Accuracy: 6%

Confusion Matrix



Confusion Matrix As Table

	precision	recall	f1-score	support
AM General Hummer SUV 2000	0.17	0.17	0.17	12
Acura RL Sedan 2012	0.00	0.00	0.00	5
Acura TL Sedan 2012	0.17	0.28	0.18	5
Acura TL Type-S 2008	0.00	0.00	0.00	8
Acura TSX Sedan 2012	0.00	0.00	0.00	6
Acura Integra Type R 2001	0.14	0.10	0.12	10
Acura ZDX Hatchback 2012	0.00	0.00	0.00	7
Aston Martin V8 Vantage Convertible 2012	0.00	0.00	0.00	7
Aston Martin V8 Vantage Coupe 2012	0.00	0.00	0.00	13
Aston Martin Virage Convertible 2012	0.00	0.00	0.00	9
Aston Martin Virage Coupe 2012	0.09	0.14	0.11	7
Audi RS 4 Convertible 2008	0.00	0.00	0.00	4
Audi A5 Coupe 2012	1.00	0.14	0.25	7
Audi TTS Coupe 2012	0.00	0.00	0.00	5
Audi R8 Coupe 2012	0.00	0.00	0.00	9
Audi V8 Sedan 1994	0.09	0.12	0.11	8
Audi 100 Sedan 1994	0.00	0.00	0.00	10
Audi 100 Wagon 1994	0.00	0.00	0.00	5
Audi TT Hatchback 2011	0.11	0.10	0.11	10
Audi S6 Sedan 2011	0.00	0.00	0.00	9
Audi S5 Convertible 2012	0.07	0.07	0.07	14
Audi S5 Coupe 2012	0.00	0.00	0.00	8
Audi S4 Sedan 2012	0.00	0.00	0.00	4
Audi S4 Sedan 2007	0.00	0.00	0.00	9
Audi TT RS Coupe 2012	0.00	0.00	0.00	9
BMW ActiveHybrid 5 Sedan 2012	0.00	0.00	0.00	10
BMW 1 Series Convertible 2012	0.00	0.00	0.00	8
BMW 1 Series Coupe 2012	0.00	0.00	0.00	12
BMW 3 Series Sedan 2012	0.13	0.25	0.17	8
BMW 3 Series Wagon 2012	0.00	0.00	0.00	13
BMW 6 Series Convertible 2007	0.00	0.00	0.00	11
BMW X5 SUV 2007	0.00	0.00	0.00	9
BMW X6 SUV 2012	0.00	0.00	0.00	4
BMW M3 Coupe 2012	0.00	0.00	0.00	10
BMW M5 Sedan 2010	0.00	0.00	0.00	7
BMW M6 Convertible 2010	0.04	0.10	0.05	10
BMW X3 SUV 2012	0.00	0.00	0.00	6
BMW Z4 Convertible 2012	0.00	0.00	0.00	12
Bentley Continental Supersports Conv. Convertible 2012	0.00	0.00	0.00	9

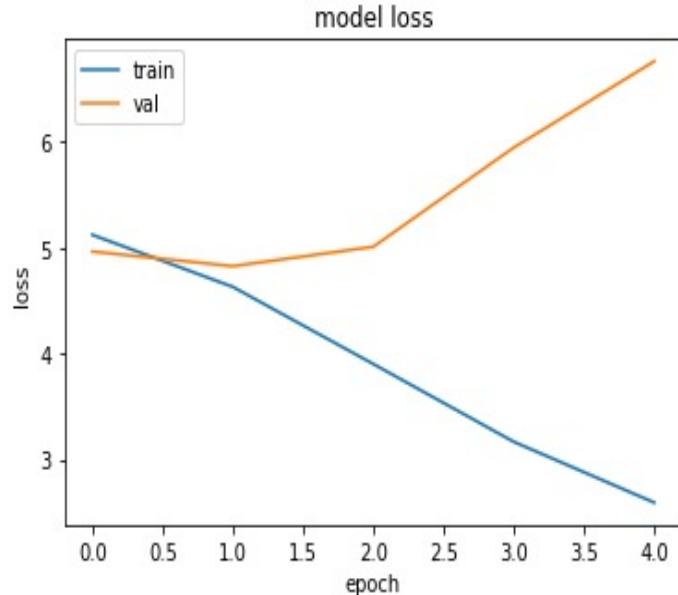
Bentley Arnage Sedan 2009	0.08	0.17	0.11	6
Bentley Mulsanne Sedan 2011	0.00	0.00	0.00	7
Bentley Continental GT Coupe 2012	0.00	0.00	0.00	9
Bentley Continental GT Coupe 2007	0.25	0.07	0.11	14
Bentley Continental Flying Spur Sedan 2007	0.00	0.00	0.00	6
Bugatti Veyron 16.4 Convertible 2009	0.00	0.00	0.00	8
Bugatti Veyron 16.4 Coupe 2009	0.00	0.00	0.00	5
Buick Regal GS 2012	0.00	0.00	0.00	6
Buick Rainier SUV 2007	0.00	0.00	0.00	9
Buick Verano Sedan 2012	0.00	0.00	0.00	7
Buick Enclave SUV 2012	0.00	0.00	0.00	8
Cadillac CTS-V Sedan 2012	0.17	0.12	0.14	8
Cadillac SRX SUV 2012	0.06	0.10	0.07	10
Cadillac Escalade EXT Crew Cab 2007	0.11	0.29	0.16	7
Chevrolet Silverado 1500 Hybrid Crew Cab 2012	0.14	0.14	0.14	7
Chevrolet Corvette Convertible 2012	0.00	0.00	0.00	5
Chevrolet Corvette Ron Fellows Edition Z06 2007	0.00	0.00	0.00	7
Chevrolet Traverse SUV 2012	0.00	0.00	0.00	5
Chevrolet Camaro Convertible 2012	0.00	0.00	0.00	11
Chevrolet HHR SS 2010	0.00	0.00	0.00	6
Chevrolet Impala Sedan 2007	0.00	0.00	0.00	12
Chevrolet Tahoe Hybrid SUV 2012	0.10	0.12	0.11	8
Chevrolet Sonic Sedan 2012	0.17	0.12	0.14	8
Chevrolet Express Cargo Van 2007	0.33	0.14	0.20	7
Chevrolet Avalanche Crew Cab 2012	0.18	0.33	0.23	9
Chevrolet Cobalt SS 2010	0.25	0.20	0.22	5
Chevrolet Malibu Hybrid Sedan 2010	0.09	0.14	0.11	7
Chevrolet TrailBlazer SS 2009	0.00	0.00	0.00	7
Chevrolet Silverado 2500HD Regular Cab 2012	0.00	0.00	0.00	7
Chevrolet Silverado 1500 Classic Extended Cab 2007	0.20	0.11	0.14	9
Chevrolet Express Van 2007	0.14	0.20	0.17	5
Chevrolet Monte Carlo Coupe 2007	0.50	0.09	0.15	11
Chevrolet Malibu Sedan 2007	0.00	0.00	0.00	9
Chevrolet Silverado 1500 Extended Cab 2012	0.00	0.00	0.00	7
Chevrolet Silverado 1500 Regular Cab 2012	0.25	0.20	0.22	10
Chrysler Aspen SUV 2009	0.00	0.00	0.00	14
Chrysler Sebring Convertible 2010	0.00	0.00	0.00	7
Chrysler Town and Country Minivan 2012	0.14	0.25	0.18	8
Chrysler 300 SRT-8 2010	0.00	0.00	0.00	8
Chrysler Crossfire Convertible 2008	0.00	0.00	0.00	7
Chrysler PT Cruiser Convertible 2008	0.00	0.00	0.00	9
Daewoo Nubira Wagon 2002	0.00	0.00	0.00	12
Dodge Caliber Wagon 2012	0.17	0.11	0.13	9
Dodge Caliber Wagon 2007	0.00	0.00	0.00	8
Dodge Calavera Minivan 1997	0.12	0.09	0.11	11
Dodge Ram Pickup 3500 Crew Cab 2010	0.00	0.00	0.00	11
Dodge Ram Pickup 3500 Quad Cab 2009	0.50	0.12	0.20	8
Dodge Sprinter Cargo Van 2009	0.00	0.00	0.00	5
Dodge Journey SUV 2012	0.06	0.08	0.07	12
Dodge Dakota Crew Cab 2010	0.00	0.00	0.00	7
Dodge Dakota Club Cab 2007	0.17	0.10	0.12	10
Dodge Magnum Wagon 2008	0.00	0.00	0.00	4
Dodge Challenger SRT8 2011	0.00	0.00	0.00	4
Dodge Durango SUV 2012	0.00	0.00	0.00	9
Dodge Durango SUV 2007	0.00	0.00	0.00	8
Dodge Charger Sedan 2012	0.12	0.20	0.15	10
Dodge Charger SRT-8 2009	0.00	0.00	0.00	13
Eagle Talon Hatchback 1998	0.09	0.10	0.10	10
FIAT 500 Abarth 2012	0.30	0.25	0.43	4
FIAT 500 Convertible 2012	0.00	0.00	0.00	9
Ferrari FF Coupe 2012	0.07	0.14	0.10	7
Ferrari California Convertible 2012	0.13	0.40	0.20	10
Ferrari 458 Italia Convertible 2012	0.20	0.08	0.12	12
Ferrari 458 Italia Coupe 2012	0.25	0.14	0.18	7
Fisker Karma Sedan 2012	0.00	0.00	0.00	13
Ford F-450 Super Duty Crew Cab 2012	0.00	0.00	0.00	4
Ford Mustang Convertible 2007	0.00	0.00	0.00	8
Ford Freestar Minivan 2007	0.00	0.00	0.00	7
Ford Expedition EL SUV 2009	0.00	0.00	0.00	6
Ford Edge SUV 2012	0.08	0.08	0.08	13
Ford Ranger SuperCab 2011	0.00	0.00	0.00	9
Ford GT Coupe 2006	0.00	0.00	0.00	8
Ford F-150 Regular Cab 2012	0.18	0.29	0.14	7
Ford F-150 Regular Cab 2007	0.17	0.16	0.12	10
Ford E-Series Sedan 2007	0.33	0.10	0.15	10
Ford E-Series Wagon 2012	0.00	0.00	0.00	5
Ford Fiesta Sedan 2012	0.00	0.00	0.00	11
GMC Terrain SUV 2012	0.14	0.11	0.12	9
GMC Savana Van 2012	0.24	0.38	0.29	13
GMC Yukon Hybrid SUV 2012	0.00	0.00	0.00	7
GMC Acadia SUV 2012	0.17	0.09	0.12	11
GMC Canyon Extended Cab 2012	0.25	0.12	0.17	8
Geo Metro Convertible 1993	0.40	0.33	0.36	6
HUMMER H3T Crew Cab 2010	0.00	0.00	0.00	4
HUMMER H2 SUT Crew Cab 2009	0.00	0.00	0.00	12
Honda Odyssey Minivan 2012	0.00	0.00	0.00	9
Honda Odyssey Minivan 2007	0.00	0.00	0.00	6

Honda Accord Coupe 2012	0.00	0.00	0.00	4
Honda Accord Sedan 2012	0.00	0.00	0.00	12
Hyundai Veloster Hatchback 2012	0.00	0.00	0.00	6
Hyundai Santa Fe SUV 2012	0.00	0.00	0.00	11
Hyundai Tucson SUV 2012	0.08	0.09	0.08	11
Hyundai Veracruz SUV 2012	0.00	0.00	0.00	8
Hyundai Sonata Hybrid Sedan 2012	0.00	0.00	0.00	5
Hyundai Elantra Sedan 2007	0.00	0.00	0.00	8
Hyundai Accent Sedan 2012	0.00	0.00	0.00	4
Hyundai Genesis Sedan 2012	0.00	0.00	0.00	7
Hyundai Sonata Sedan 2012	0.00	0.00	0.00	13
Hyundai Elantra Touring Hatchback 2012	0.17	0.08	0.11	13
Hyundai Azera Sedan 2012	0.00	0.00	0.00	6
Infiniti G Coupe IP 2012	0.11	0.11	0.11	9
Infiniti QX56 SUV 2011	0.09	0.17	0.12	6
Isuzu Ascender SUV 2008	0.00	0.00	0.00	10
Jaguar XK XKR 2012	0.00	0.00	0.00	7
Jeep Patriot SUV 2012	0.00	0.00	0.00	8
Jeep Wrangler SUV 2012	0.17	0.29	0.21	7
Jeep Liberty SUV 2012	0.00	0.00	0.00	7
Jeep Grand Cherokee SUV 2012	0.00	0.00	0.00	9
Jeep Compass SUV 2012	0.08	0.12	0.10	8
Lamborghini Reventon Coupe 2008	0.00	0.00	0.00	10
Lamborghini Aventador Coupe 2012	0.00	0.00	0.00	4
Lamborghini Gallardo LP 570-4 Superleggera 2012	0.33	0.29	0.31	7
Lamborghini Diablo Coupe 2001	0.11	0.14	0.12	7
Land Rover Range Rover SUV 2012	0.18	0.20	0.19	15
Land Rover LR2 SUV 2012	0.00	0.00	0.00	9
Lincoln Town Car Sedan 2011	0.00	0.00	0.00	6
MINI Cooper Roadster Convertible 2012	0.07	0.10	0.08	10
Maybach Landaulet Convertible 2012	0.00	0.00	0.00	6
Mazda Tribute SUV 2011	0.00	0.00	0.00	5
McLaren MP4-12C Coupe 2012	0.40	0.29	0.33	7
Mercedes-Benz 300-Class Convertible 1993	0.00	0.00	0.00	10
Mercedes-Benz C-Class Sedan 2012	0.00	0.00	0.00	6
Mercedes-Benz SL-Class Coupe 2009	0.00	0.00	0.00	6
Mercedes-Benz E-Class Sedan 2012	0.00	0.00	0.00	9
Mercedes-Benz S-Class Sedan 2012	0.00	0.00	0.00	7
Mercedes-Benz Sprinter Van 2012	0.11	0.18	0.14	11
Mitsubishi Lancer Sedan 2012	0.00	0.00	0.00	10
Nissan Leaf Hatchback 2012	0.00	0.00	0.00	5
Nissan NV Passenger Van 2012	0.00	0.00	0.00	7
Nissan Juke Hatchback 2012	0.00	0.00	0.00	2
Nissan 240SX Coupe 1998	0.00	0.00	0.00	7
Plymouth Neon Coupe 1999	0.00	0.00	0.00	9
Porsche Panamera Sedan 2012	0.00	0.00	0.00	10
Ram C/V Cargo Van Minivan 2012	0.40	0.29	0.33	7
Rolls-Royce Phantom Drophead Coupe Convertible 2012	0.00	0.00	0.00	6
Rolls-Royce Ghost Sedan 2012	0.14	0.33	0.20	6
Rolls-Royce Phantom Sedan 2012	0.00	0.00	0.00	8
Scion xD Hatchback 2012	0.12	0.12	0.12	8
Spyker C8 Convertible 2009	0.00	0.00	0.00	6
Spyker C8 Coupe 2009	0.12	0.11	0.12	9
Suzuki Aerio Sedan 2007	0.08	0.20	0.11	5
Suzuki Kizashi Sedan 2012	0.00	0.00	0.00	6
Suzuki SX4 Hatchback 2012	0.00	0.00	0.00	7
Suzuki SX4 Sedan 2012	0.00	0.00	0.00	11
Tesla Model S Sedan 2012	0.00	0.00	0.00	7
Toyota Sequoia SUV 2012	0.17	0.20	0.18	5
Toyota Camry Sedan 2012	0.00	0.00	0.00	9
Toyota Corolla Sedan 2012	0.00	0.00	0.00	10
Toyota 4Runner SUV 2012	0.00	0.00	0.00	10
Volkswagen Golf Hatchback 2012	0.00	0.00	0.00	5
Volkswagen Golf Hatchback 1991	0.00	0.00	0.00	9
Volkswagen Beetle Hatchback 2012	0.08	0.12	0.10	8
Volvo C30 Hatchback 2012	0.00	0.00	0.00	9
Volvo 240 Sedan 1993	0.00	0.00	0.00	11
Volvo XC90 SUV 2007	0.00	0.00	0.00	8
smart fortwo Convertible 2012	0.07	0.25	0.11	8
accuracy			0.06	1600
macro avg	0.06	0.06	0.05	1600
weighted avg	0.07	0.06	0.06	1600

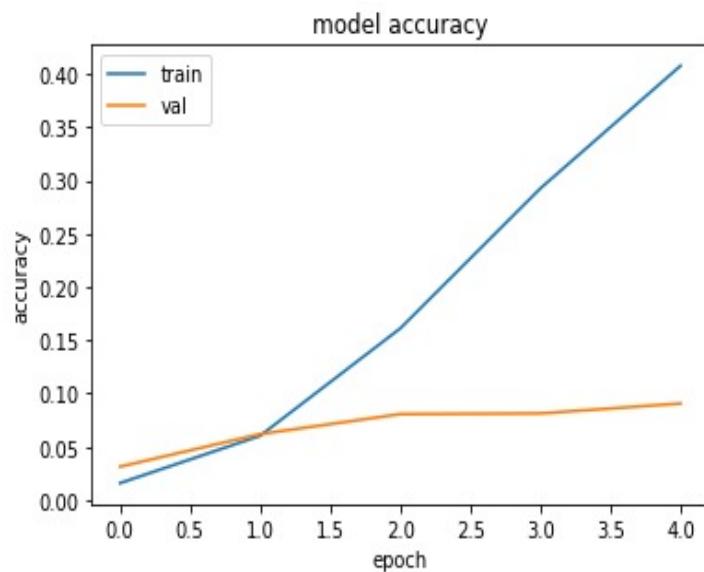
#### 2.2.4.3 Second Experiment

In our second experiment, we paid more attention to the hyper parameters of our CNN model. We used the same architecture of the best model and we changed the hyper parameters we use to train our model. The hyper parameters we changed were the number of batches, number of epochs and the learning rate. We

used: learning of rate 0.001, 40 number of batches and 5 number of epochs.



Model Loss Graph



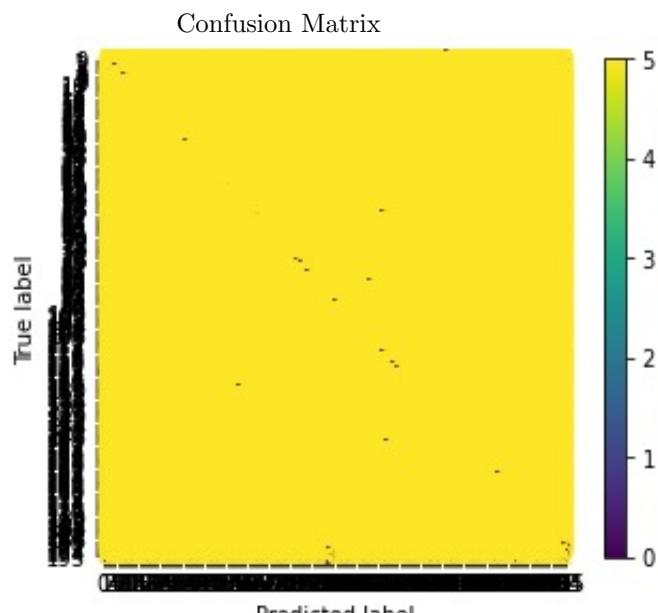
Model Accuracy Graph

**Confusion Matrix:**

```
[[1 0 0 ... 0 0 0]
 [0 1 0 ... 0 1 0]
 [0 0 0 ... 0 0 0]
 ...
 [0 0 0 ... 2 0 0]
 [0 0 0 ... 0 3 0]
 [0 0 0 ... 0 0 2]]
```

**Accuracy: 10%**

**Balanced Accuracy: 10%**



Confusion Matrix As Table

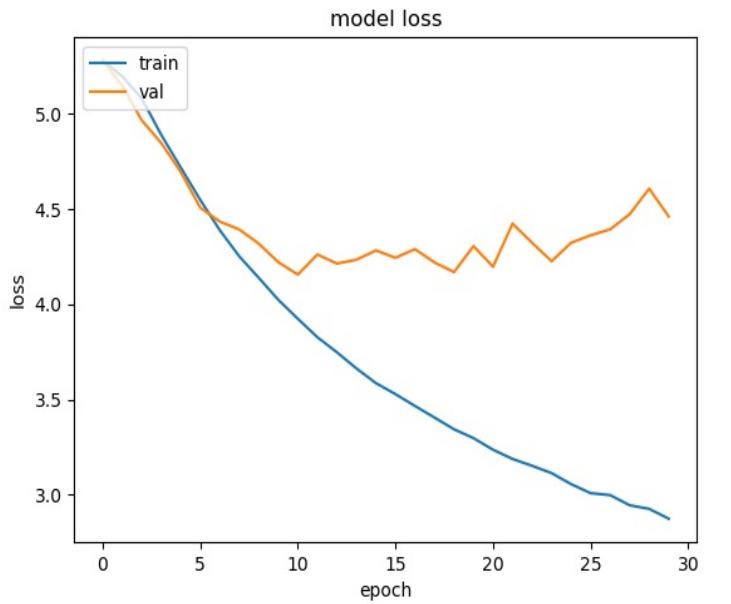
		precision	recall	f1-score	support
AM General	Hummer SUV 2000	0.14	0.08	0.11	12
Acura	RL Sedan 2012	0.12	0.20	0.15	5
Acura	TL Sedan 2012	0.00	0.00	0.00	5
Acura	TL Type-S 2008	0.10	0.12	0.11	8
Acura	TSX Sedan 2012	0.14	0.17	0.15	6
Acura	Integra Type R 2001	0.19	0.27	0.22	11
Acura	ZDX Hatchback 2012	0.00	0.00	0.00	7
Aston Martin	V8 Vantage Coupe 2012	0.00	0.00	0.00	7
Aston Martin	V8 Vantage Coupe 2012	0.02	0.15	0.10	13
Aston Martin	Virage Convertible 2012	0.75	0.33	0.46	9
Aston Martin	Virage Coupe 2012	0.25	0.14	0.19	7
Audi	RS 4 Convertible 2008	0.12	0.25	0.17	4
Audi	A5 Coupe 2012	0.00	0.00	0.00	7
Audi	TTS Coupe 2012	0.00	0.00	0.00	5
Audi	R8 Coupe 2012	0.00	0.00	0.00	9
Audi	V8 Sedan 1994	0.00	0.00	0.00	8
Audi	100 Sedan 1994	0.06	0.10	0.07	10
Audi	100 Wagon 1994	0.00	0.00	0.00	6
Audi	T4 Hatchback 2011	0.00	0.00	0.00	10
Audi	S6 Sedan 2011	0.00	0.00	0.00	8
Audi	S5 Convertible 2012	0.00	0.00	0.00	14
Audi	S5 Coupe 2012	0.00	0.00	0.00	7
Audi	S4 Sedan 2012	0.12	0.25	0.17	4
Audi	S4 Sedan 2007	0.00	0.00	0.00	9
Audi	TT RS Coupe 2012	0.15	0.20	0.17	10
BMW	ActiveHybrid 5 Sedan 2012	0.33	0.18	0.24	11
BMW	1 Series Convertible 2012	0.00	0.00	0.00	7
BMW	1 Series Coupe 2012	0.40	0.17	0.24	12
BMW	3 Series Sedan 2012	0.20	0.12	0.15	8
BMW	3 Series Wagon 2012	0.20	0.08	0.11	13
BMW	6 Series Convertible 2007	0.00	0.00	0.00	10
BMW	X5 SUV 2007	0.06	0.10	0.07	10
BMW	X6 SUV 2012	0.00	0.00	0.00	4
BMW	M3 Coupe 2012	0.00	0.00	0.00	9
BMW	M5 Sedan 2010	0.00	0.00	0.00	7
BMW	M6 Convertible 2010	0.23	0.27	0.25	11
BMW	X3 SUV 2012	0.00	0.00	0.00	6
BMW	Z4 Convertible 2012	0.00	0.00	0.00	11
Bentley	Continental Supersports Conv. Convertible 2012	0.20	0.10	0.13	10
Bentley	Arnage Sedan 2009	0.00	0.00	0.00	6
Bentley	Mulsanne Sedan 2011	0.00	0.00	0.00	7
Bentley	Continental GT Coupe 2012	0.00	0.00	0.00	9
Bentley	Continental Gt Coupe 2007	0.00	0.00	0.00	13
Bentley	Continental Flying Spur Sedan 2007	0.20	0.17	0.18	6
Bugatti	Veyron 16.4 Convertible 2009	0.00	0.00	0.00	8
Bugatti	Veyron 16.4 Coupe 2009	0.00	0.00	0.00	5
Buick	Regal GS 2012	0.00	0.00	0.00	6
Buick	Rainier SUV 2007	0.17	0.18	0.12	18
Buick	Verano Sedan 2012	0.00	0.00	0.00	7
Buick	Enclave SUV 2012	0.20	0.12	0.15	8
Cadillac	CTS-V Sedan 2012	0.06	0.12	0.08	8
Cadillac	SRX SUV 2012	0.14	0.09	0.11	11
Cadillac	Escalade EXT Crew Cab 2007	0.31	0.50	0.38	8
Chevrolet	Silverado 1500 Hybrid Crew Cab 2012	0.00	0.00	0.00	7
Chevrolet	Corvette Convertible 2012	0.00	0.00	0.00	5
Chevrolet	Corvette Ron Fellows Edition Z06 2007	0.00	0.00	0.00	7
Chevrolet	Corvette Traverse SUV 2012	0.00	0.00	0.00	5
Chevrolet	Camaro Convertible 2012	0.00	0.00	0.00	11
Chevrolet	Camaro SS 2010	0.00	0.00	0.00	5
Chevrolet	Impala Sedan 2007	0.00	0.00	0.00	11
Chevrolet	Tahoe Hybrid SUV 2012	0.00	0.00	0.00	8
Chevrolet	Sonic Sedan 2012	0.12	0.12	0.12	8
Chevrolet	Express Cargo Van 2007	0.29	0.29	0.29	7
Chevrolet	Avalanche Crew Cab 2012	0.22	0.40	0.29	10
Chevrolet	Cobalt SS 2010	0.12	0.33	0.18	6
Chevrolet	Malibu Hybrid Sedan 2010	0.07	0.14	0.09	7
Chevrolet	TrailBlazer SS 2009	0.00	0.00	0.00	6
Chevrolet	Silverado 2500HD Regular Cab 2012	0.00	0.00	0.00	7
Chevrolet	Silverado 1500 Classic Extended Cab 2007	0.00	0.00	0.00	5
Chevrolet	Colorado Regular Cab 2007	0.02	0.09	0.29	5
Chevrolet	Monte Carlo Coupe 2007	0.08	0.09	0.09	11
Chevrolet	Malibu Sedan 2007	0.04	0.11	0.06	9
Chevrolet	Silverado 1500 Extended Cab 2012	0.11	0.17	0.13	6
Chevrolet	Silverado 1500 Regular Cab 2012	0.25	0.29	0.27	7
Chevrolet	Aspen SUV 2009	0.08	0.07	0.08	14
Crysler	Sebring Convertible 2010	0.00	0.00	0.00	7
Crysler	Town and Country Minivan 2012	0.00	0.00	0.00	8
Crysler	300 SRT-8 2010	0.09	0.12	0.11	8
Crysler	Crossfire Convertible 2008	0.00	0.00	0.00	8
Crysler	PT Cruiser Convertible 2008	0.00	0.00	0.00	9
Daimler	Maybach Wagon 2002	0.00	0.00	0.00	12
Dodge	Caliber Wagon 2012	0.00	0.16	0.10	10
Dodge	Caliber Wagon 2007	0.25	0.38	0.39	8
Dodge	Caravan Minivan 1997	0.18	0.18	0.18	11
Dodge	Ram Pickup 3500 Crew Cab 2010	0.25	0.09	0.13	11
Dodge	Ram Pickup 3500 Quad Cab 2009	0.43	0.38	0.40	8
Dodge	Sprinter Cargo Van 2009	0.00	0.00	0.00	5
Dodge	Journey SUV 2012	0.20	0.08	0.11	13
Dodge	Dakota Crew Cab 2010	0.25	0.12	0.17	8
Dodge	Dakota Club Cab 2007	0.12	0.20	0.15	10
Dodge	Magnum Wagon 2008	0.05	0.25	0.08	4

Dodge Challenger SRT8 2011	0.00	0.00	0.00	4
Dodge Durango SUV 2012	0.00	0.00	0.00	9
Dodge Durango SUV 2007	0.08	0.12	0.10	8
Dodge Charger Sedan 2012	0.04	0.09	0.06	11
Dodge Charger SRT-8 2009	0.00	0.00	0.00	13
Eagle Talon Hatchback 1998	0.00	0.00	0.00	10
FIAT 500 Abarth 2012	0.60	1.00	0.75	3
FIAT 500 Convertible 2012	0.17	0.22	0.19	9
Ferrari FF Coupe 2012	0.00	0.00	0.00	7
Ferrari California Convertible 2012	0.00	0.00	0.00	10
Ferrari 458 Italia Convertible 2012	0.00	0.00	0.00	12
Ferrari 458 Italia Coupe 2012	0.00	0.00	0.00	7
Fisker Karma Sedan 2012	0.07	0.08	0.07	12
Ford F-450 Super Duty Crew Cab 2012	0.20	0.50	0.29	4
Ford Mustang Convertible 2007	0.00	0.00	0.00	7
Ford Freestar Minivan 2007	0.00	0.00	0.00	6
Ford Expedition EL SUV 2009	0.00	0.00	0.00	6
Ford Edge SUV 2012	0.50	0.08	0.13	13
Ford Ranger SuperCab 2011	0.17	0.11	0.13	9
Ford GT Coupe 2006	0.00	0.00	0.00	8
Ford F-150 Regular Cab 2012	0.17	0.29	0.21	7
Ford F-150 Regular Cab 2007	0.00	0.00	0.00	10
Ford Focus Sedan 2007	0.00	0.00	0.00	9
Ford E-Series Wagon Van 2012	0.00	0.00	0.00	5
Ford Fiesta Sedan 2012	0.18	0.17	0.17	12
GMC Terrain SUV 2012	0.14	0.11	0.12	9
GMC Savana Van 2012	0.36	0.38	0.37	13
GMC Yukon Hybrid SUV 2012	0.20	0.29	0.24	7
GMC Acadia SUV 2012	0.00	0.00	0.00	10
GMC Canyon Extended Cab 2012	0.12	0.22	0.15	9
Geo Metro Convertible 1993	0.27	0.43	0.33	7
HUMMER H3T Crew Cab 2010	0.20	0.25	0.22	4
HUMMER H2 SUT Crew Cab 2009	0.75	0.27	0.40	11
Honda Odyssey Minivan 2012	0.00	0.00	0.00	9
Honda Odyssey Minivan 2007	0.33	0.17	0.22	6
Honda Accord Coupe 2012	0.00	0.00	0.00	4
Honda Accord Sedan 2012	0.29	0.18	0.22	11
Hyundai Veloster Hatchback 2012	0.25	0.33	0.29	6
Hyundai Santa Fe SUV 2012	0.12	0.10	0.11	10
Hyundai Tucson SUV 2012	0.00	0.00	0.00	10
Hyundai Veracruz SUV 2012	0.00	0.00	0.00	9
Hyundai Sonata Hybrid Sedan 2012	0.00	0.00	0.00	4
Hyundai Elantra Sedan 2007	0.00	0.00	0.00	7
Hyundai Accent Sedan 2012	0.20	0.25	0.22	4
Hyundai Genesis Sedan 2012	0.25	0.14	0.18	7
Hyundai Sonata Sedan 2012	0.33	0.08	0.13	12
Hyundai Elantra Touring Hatchback 2012	0.33	0.00	0.12	13
Hyundai Elantra Sedan 2012	0.00	0.00	0.00	7
Infiniti G Coupe IPL 2012	0.00	0.00	0.00	0
Infiniti QX56 SUV 2011	0.09	0.17	0.12	6
Isuzu Ascender SUV 2008	0.00	0.00	0.00	10
Jaguar XK XKR 2012	0.00	0.00	0.00	7
Jeep Patriot SUV 2012	0.00	0.00	0.00	8
Jeep Wrangler SUV 2012	0.22	0.29	0.25	7
Jeep Liberty SUV 2012	0.00	0.00	0.00	5
Jeep Grand Cherokee SUV 2012	0.00	0.00	0.00	9
Jeep Compass SUV 2012	0.20	0.25	0.22	8
Lamborghini Reventon Coupe 2008	0.14	0.09	0.11	11
Lamborghini Aventador Coupe 2012	0.00	0.00	0.00	4
Lamborghini Gallardo LP 570-4 Superleggera 2012	0.00	0.00	0.00	7
Lamborghini Diablo Coupe 2001	0.18	0.29	0.22	7
Land Rover Range Rover 2012	0.12	0.07	0.09	14
Land Rover LR2 SUV 2012	0.00	0.11	0.11	9
Lincoln Town Car Sedan 2011	0.00	0.00	0.00	6
MINI Cooper Roadster Convertible 2012	0.00	0.00	0.00	10
Maybach Landaulet Convertible 2012	0.00	0.00	0.00	6
Mazda Tribute SUV 2011	0.17	0.20	0.18	5
McLaren MP4-12C Coupe 2012	0.00	0.00	0.00	7
Mercedes-Benz 300-Class Convertible 1993	0.00	0.00	0.00	10
Mercedes-Benz C-Class Sedan 2012	0.00	0.00	0.00	6
Mercedes-Benz SL-Class Coupe 2009	0.33	0.29	0.31	7
Mercedes-Benz E-Class Sedan 2012	0.09	0.11	0.10	9
Mercedes-Benz S-Class Sedan 2012	0.00	0.00	0.00	7
Mercedes-Benz Sprinter Van 2012	0.17	0.22	0.19	9
Mitsubishi Lancer Sedan 2012	0.21	0.27	0.24	11
Nissan Leaf Hatchback 2012	0.11	0.20	0.14	5
Nissan NV Passenger Van 2012	0.00	0.00	0.00	8
Nissan Juke Hatchback 2012	0.00	0.00	0.00	2
Nissan 240SX Hatchback 1998	0.00	0.00	0.00	7
Plymouth Neon Coupe 1999	0.00	0.00	0.00	9
Porsche Panamera Sedan 2012	0.13	0.18	0.15	11
Ram C/V Cargo Van Minivan 2012	0.00	0.00	0.00	6
Rolls-Royce Phantom Drophead Coupe Convertible 2012	0.00	0.00	0.00	7
Rolls-Royce Ghost Sedan 2012	0.00	0.00	0.00	6
Rolls-Royce Phantom Sedan 2012	0.00	0.00	0.00	8
Scion xD Hatchback 2012	0.17	0.12	0.14	8
Spyker C8 Convertible 2009	0.12	0.17	0.14	6
Spyker C8 Coupe 2009	0.40	0.25	0.31	8
Suzuki Aerio Sedan 2007	0.50	0.20	0.29	5
Suzuki Kizashi Sedan 2012	0.00	0.00	0.00	6
Suzuki SX4 Hatchback 2012	0.00	0.00	0.00	7
Suzuki SX4 Sedan 2012	0.10	0.09	0.10	11

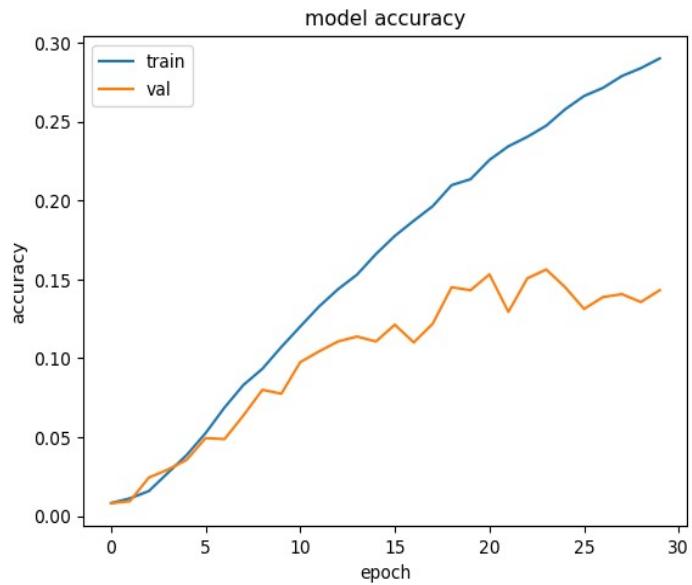
Tesla Model S Sedan 2012	0.00	0.00	0.00	7
Toyota Sequoia SUV 2012	0.25	0.20	0.22	5
Toyota Camry Sedan 2012	0.09	0.11	0.10	9
Toyota Corolla Sedan 2012	0.00	0.00	0.00	10
Toyota 4Runner SUV 2012	0.10	0.10	0.10	10
Volkswagen Golf Hatchback 2012	0.00	0.00	0.00	5
Volkswagen Golf Hatchback 1991	0.22	0.22	0.22	9
Volkswagen Beetle Hatchback 2012	0.00	0.00	0.00	9
Volvo C30 Hatchback 2012	0.17	0.33	0.22	12
Volvo 240 Sedan 1993	0.20	0.18	0.19	11
Volvo XC90 SUV 2007	0.25	0.38	0.30	8
smart fortwo Convertible 2012	0.14	0.25	0.18	8
accuracy			0.10	1600
macro avg	0.10	0.10	0.10	1600
weighted avg	0.11	0.10	0.10	1600

#### 2.2.4.4 Best model Results and Metrics

Our best model includes some pooling, dropout, conv2d and dense layers. we used the relu activation function method to all convolutional layers and kernel size is 3 and padding argument was default value of valid. So, our model consist of 5 conv2d layers so that after each conv2d layer there is dropout layer and maxpooling also After the convolutional neural network stage we added flatten layer and then three dense layer with 256 neurons and the last layer had 196 neurons like the number of classes. When we fitted the model we added callback as Early Stopping with validation accuracy monitor with max mode and patience two.



Model Loss Graph



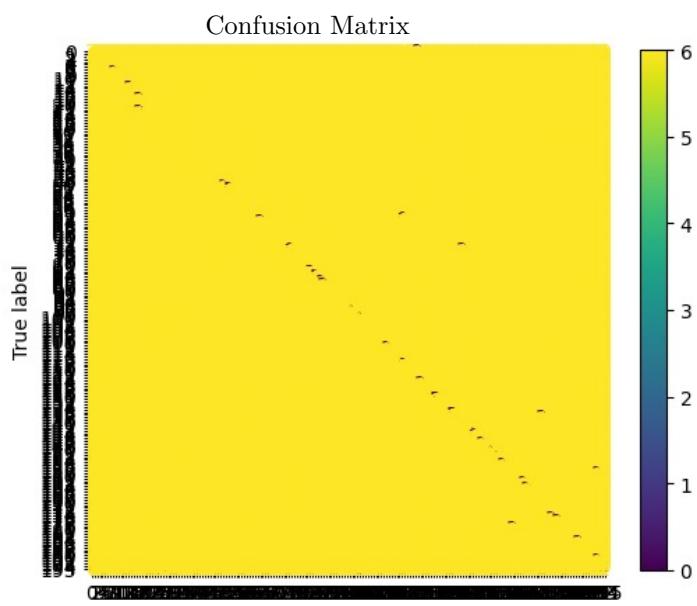
Model Accuracy Graph

**Confusion Matrix:**

```
[[2 0 0 ... 0 0 0]
 [0 0 0 ... 0 0 0]
 [0 0 0 ... 0 0 0]
 ...
 [0 0 0 ... 1 1 0]
 [0 0 0 ... 0 2 0]
 [0 0 0 ... 0 0 2]]
```

**Accuracy:** 14%

**Balanced Accuracy:** 15%



		precision	recall	f1-score	support		
AM General	Hummer SUV	2000	0.33	0.18	0.24	11	
Acura	RL Sedan	2012	0.00	0.00	0.00	5	
Acura	TL Sedan	2012	0.00	0.00	0.00	5	
Acura	TL Type-S	2008	0.00	0.00	0.00	8	
Acura	TSX Sedan	2012	0.29	0.40	0.33	5	
Acura	Integra Type R	2001	0.00	0.00	0.00	10	
Acura	ZDX Hatchback	2012	0.00	0.00	0.00	7	
Aston Martin	V8 Vantage	2012	0.05	0.07	0.07	7	
Aston Martin	Vantage Coupe	2012	0.23	0.23	0.23	13	
Aston Martin	Virage Convertible	2012	0.00	0.00	0.00	9	
Aston Martin	Virage Coupe	2012	0.12	0.29	0.17	7	
Audi	RS 4 Convertible	2008	0.00	0.00	0.00	4	
Audi	A5 Coupe	2012	0.00	0.00	0.00	7	
Audi	TTS Coupe	2012	0.00	0.00	0.00	5	
Audi	R8 Coupe	2012	0.12	0.33	0.18	9	
Audi	V8 Sedan	1994	0.00	0.00	0.00	8	
Audi	100 Sedan	1994	0.12	0.18	0.14	10	
Audi	100 Wagon	1994	0.11	0.17	0.13	6	
Audi	TT Hatchback	2011	0.14	0.33	0.19	9	
Audi	S6 Sedan	2011	0.00	0.00	0.00	8	
Audi	S5 Convertible	2012	0.00	0.00	0.00	14	
Audi	S5 Coupe	2012	0.00	0.00	0.00	8	
Audi	S4 Sedan	2012	0.00	0.00	0.00	4	
Audi	S4 Sedan	2007	0.00	0.00	0.00	9	
Audi	TT RS Coupe	2012	0.08	0.10	0.09	10	
BMW	ActiveHybrid 5	Sedan	2012	0.12	0.18	0.14	10
BMW	1 Series Convertible	2012	0.00	0.00	0.00	7	
BMW	1 Series Coupe	2012	0.49	0.17	0.24	12	
BMW	3 Series Sedan	2012	0.00	0.00	0.00	8	
BMW	3 Series Wagon	2012	0.14	0.08	0.10	13	
BMW	6 Series Convertible	2007	0.00	0.00	0.00	11	
BMW	X5 SUV	2007	0.20	0.10	0.13	10	
BMW	X6 SUV	2012	0.12	0.25	0.17	4	
BMW	M3 Coupe	2012	0.00	0.00	0.00	10	
BMW	M6 Convertible	2010	0.07	0.10	0.08	10	
BMW	X3 SUV	2012	0.14	0.14	0.14	7	
BMW	Z4 Convertible	2012	0.00	0.00	0.00	14	
Bentley	Continental Supersports Conv.	Convertible	2012	0.00	0.00	0.00	9
Bentley	Arnage Sedan	2009	0.29	0.29	0.29	7	
Bentley	Mulsanne Sedan	2011	0.00	0.00	0.00	7	
Bentley	Continental GT Coupe	2012	0.10	0.11	0.11	9	
Bentley	Continental GT Coupe	2007	0.17	0.08	0.11	13	
Bentley	Continental Flying Spur Sedan	2007	0.20	0.25	0.22	8	
Bugatti	Veyron 16.4 Convertible	2009	0.17	0.12	0.14	8	
Bugatti	Veyron 16.4 Coupe	2009	0.00	0.00	0.00	6	
Buick	Regal GS	2012	0.11	0.14	0.12	7	
Buick	Regal GS	2007	0.25	0.11	0.15	9	
Buick	Verano Sedan	2012	0.00	0.00	0.00	6	
Buick	Enclave SUV	2012	0.25	0.12	0.17	8	
Cadillac	CTS-V Sedan	2012	0.13	0.25	0.17	8	
Cadillac	SRX SUV	2012	0.11	0.10	0.11	10	
Cadillac	Escalade EXT Crew Cab	2007	0.29	0.71	0.42	7	
Chevrolet	Silverado 1500 Hybrid Crew Cab	2012	0.00	0.00	0.00	7	
Chevrolet	Corvette Convertible	2012	0.00	0.00	0.00	5	
Chevrolet	Corvette ZR1	2012	0.33	0.12	0.18	8	
Chevrolet	Corvette Ron Fellows Edition Z06	2007	0.12	0.14	0.13	7	
Chevrolet	Traverse SUV	2012	0.00	0.00	0.00	5	
Chevrolet	Camaro Convertible	2012	0.00	0.00	0.00	11	
Chevrolet	Camaro SS	2010	0.17	0.17	0.17	6	
Chevrolet	Impala Sedan	2007	0.50	0.08	0.14	12	
Chevrolet	Tahoe Hybrid SUV	2012	0.00	0.00	0.00	8	
Chevrolet	Sonic Sedan	2012	0.25	0.12	0.17	8	
Chevrolet	Express Cargo Van	2007	0.00	0.00	0.00	7	
Chevrolet	Avalanche Crew Cab	2012	0.50	0.33	0.40	9	
Chevrolet	Cobalt SS	2010	0.00	0.00	0.00	5	
Chevrolet	Malibu Hybrid Sedan	2010	0.00	0.00	0.00	7	
Chevrolet	TrailBlazer SS	2009	0.00	0.00	0.00	6	
Chevrolet	Silverado 2500HD Regular Cab	2012	0.00	0.00	0.00	6	
Chevrolet	Silverado 1500 Classic Extended Cab	2007	0.00	0.00	0.00	6	
Chevrolet	Express Cargo Van	2007	0.15	0.20	0.22	5	
Chevrolet	Monte Carlo Coupe	2007	0.00	0.00	0.00	11	
Chevrolet	Malibu Sedan	2007	0.11	0.11	0.11	9	
Chevrolet	Silverado 1500 Extended Cab	2012	0.17	0.14	0.15	7	
Chevrolet	Silverado 1500 Regular Cab	2012	0.11	0.12	0.12	8	
Chrysler	Aspen SUV	2009	0.33	0.46	0.39	13	
Chrysler	Sebring Convertible	2010	0.00	0.00	0.00	7	
Chrysler	Town and Country Minivan	2012	0.25	0.11	0.15	9	
Chrysler	300 SRT-8	2010	0.15	0.25	0.19	8	
Chrysler	Crossfire Convertible	2008	0.18	0.33	0.24	6	
Chrysler	PT Cruiser	2008	0.12	0.10	0.11	10	
Dodge	Nubira Wagon	2002	0.00	0.00	0.00	12	
Dodge	Caliber Wagon	2012	0.33	0.22	0.27	9	
Dodge	Caliber Wagon	2007	0.19	0.38	0.25	8	
Dodge	Caravan Minivan	1997	0.33	0.18	0.24	11	
Dodge	Ram Pickup 3500 Crew Cab	2010	0.42	0.42	0.42	12	
Dodge	Ram Pickup 3500 Quad Cab	2009	0.33	0.25	0.29	8	
Dodge	Sprinter Cargo Van	2009	0.30	0.50	0.37	6	
Dodge	Journey SUV	2012	0.18	0.25	0.21	12	
Dodge	Dakota Crew Cab	2010	0.29	0.22	0.25	9	
Dodge	Dakota Club Cab	2007	0.00	0.00	0.00	9	
Dodge	Magnum Wagon	2008	0.00	0.00	0.00	4	
Dodge	Challenger SRT8	2011	0.00	0.00	0.00	4	

Dodge Durango SUV	2012	0.25	0.10	0.14	10
Dodge Durango SUV	2007	0.00	0.00	0.00	8
Dodge Charger Sedan	2012	0.10	0.10	0.10	10
Dodge Charger SRT-8	2009	0.00	0.00	0.00	13
Eagle Talon Hatchback	1998	0.14	0.11	0.12	9
FIAT 500 Abarth	2012	0.67	1.00	0.80	4
FIAT 500 Convertible	2012	0.00	0.00	0.00	9
Ferrari FF Coupe	2012	0.06	0.14	0.09	7
Ferrari California Convertible	2012	0.22	0.40	0.29	10
Ferrari 458 Italia Convertible	2012	0.00	0.00	0.00	12
Ferrari 458 Italia Coupe	2012	0.00	0.00	0.00	7
Fisker Karma Sedan	2012	0.20	0.08	0.11	13
Ford F-450 Super Duty Crew Cab	2012	0.00	0.00	0.00	4
Ford Mustang Convertible	2007	0.00	0.00	0.00	7
For Freestar Minivan	2007	0.17	0.17	0.17	6
Ford Expedition EL SUV	2009	0.22	0.29	0.25	7
Ford Edge SUV	2012	0.12	0.08	0.10	12
Ford Ranger SuperCab	2011	0.33	0.22	0.27	9
Ford GT Coupe	2006	0.00	0.00	0.00	10
Ford F-150 Regular Cab	2012	0.21	0.43	0.29	7
Ford F-150 Regular Cab	2007	0.33	0.20	0.25	10
Ford Focus Sedan	2007	0.00	0.00	0.00	9
Ford E-Series Wagon Van	2012	0.20	0.40	0.27	5
Ford Fiesta Sedan	2012	0.08	0.09	0.08	11
GMC Terrain SUV	2012	0.29	0.25	0.27	8
GMC Savana Van	2012	0.27	0.46	0.34	13
GMC Yukon Hybrid SUV	2012	0.50	0.29	0.36	7
GMC Acadia SUV	2012	0.00	0.00	0.00	10
GMC Canyon Extended Cab	2012	0.25	0.10	0.14	10
Geo Metro Convertible	1993	0.25	0.33	0.29	6
HUMMER H3T Crew Cab	2010	0.00	0.00	0.00	5
HUMMER H2 SUT Crew Cab	2009	0.12	0.08	0.10	12
Honda Odyssey Minivan	2012	0.27	0.33	0.30	9
Honda Odyssey Minivan	2007	0.14	0.33	0.20	6
Honda Accord Coupe	2012	0.00	0.00	0.00	4
Honda Accord Sedan	2012	0.17	0.09	0.12	11
Hyundai Veloster Hatchback	2012	0.25	0.17	0.20	6
Hyundai Santa Fe SUV	2012	0.17	0.20	0.18	10
Hyundai Tucson SUV	2012	0.50	0.50	0.50	10
Hyundai Veracruz SUV	2012	0.25	0.11	0.15	9
Hyundai Sonata Hybrid Sedan	2012	0.00	0.00	0.00	4
Hyundai Elantra Sedan	2007	0.00	0.00	0.00	7
Hyundai Accent Sedan	2012	0.00	0.00	0.00	4
Hyundai Genesis Sedan	2012	0.05	0.14	0.07	7
Hyundai Sonata Sedan	2012	0.50	0.38	0.43	13
Hyundai Elantra Touring Hatchback	2012	0.00	0.00	0.00	12
Hyundai Santa Sedan	2012	0.22	0.33	0.27	6
Infiniti G Coupe IPL	2012	0.00	0.00	0.00	9
Infiniti QX56 SUV	2011	0.06	0.17	0.09	6
Isuzu Ascender SUV	2008	0.14	0.10	0.12	10
Jaguar XK XKR	2012	0.05	0.12	0.07	8
Jeep Patriot SUV	2012	0.50	0.50	0.50	8
Jeep Wrangler SUV	2012	0.60	0.86	0.71	7
Jeep Grand Cherokee SUV	2012	0.05	0.11	0.10	9
Jeep Compass SUV	2012	0.35	0.38	0.38	8
Lamborghini Reventon Coupe	2008	0.00	0.00	0.00	9
Lamborghini Aventador Coupe	2012	0.00	0.00	0.00	4
Lamborghini Gallardo LP 570-4 Superleggera	2012	0.88	0.50	0.62	8
Lamborghini Diablo Coupe	2001	0.40	0.29	0.33	7
Land Rover Range Rover SUV	2012	0.44	0.27	0.33	15
Land Rover LR2 SUV	2012	0.00	0.00	0.00	9
Lincoln Town Car Sedan	2011	0.17	0.17	0.17	6
MINI Cooper Roadster Convertible	2012	0.50	0.30	0.37	10
Maybach Landaulet Convertible	2012	0.29	0.33	0.31	6
Mazda RX-8	2011	0.05	0.20	0.13	5
McLaren MP4-12C Coupe	2012	0.00	0.00	0.00	8
Mercedes-Benz 300-Class Convertible	1993	0.00	0.00	0.00	10
Mercedes-Benz C-Class Sedan	2012	0.00	0.00	0.00	6
Mercedes-Benz SL-Class Coupe	2009	0.25	0.17	0.20	6
Mercedes-Benz E-Class Sedan	2012	0.10	0.11	0.11	9
Mercedes-Benz S-Class Sedan	2012	0.00	0.00	0.00	7
Mercedes-Benz Sprinter Van	2012	0.33	0.30	0.32	10
Mitsubishi Lancer Sedan	2012	0.14	0.10	0.12	10
Nissan Leaf Hatchback	2012	0.25	0.33	0.29	6
Nissan NV Passenger Van	2012	0.05	0.12	0.15	8
Nissan Juke Hatchback	2012	0.00	0.00	0.00	2
Nissan 240SX Coupe	1998	0.10	0.14	0.12	7
Plymouth Neon Coupe	1999	0.00	0.00	0.00	9
Porsche Panamera Sedan	2012	0.18	0.22	0.20	9
Ram C/V Cargo Van Minivan	2012	0.67	0.29	0.40	7
Rolls-Royce Phantom Drophead Coupe Convertible	2012	0.17	0.17	0.17	6
Rolls-Royce Ghost Sedan	2012	0.20	0.33	0.25	6
Rolls-Royce Phantom Sedan	2012	0.11	0.11	0.11	9
Scion xB Convertible	2009	0.35	0.38	0.40	8
Spyker C8 Spyder	2009	0.08	0.17	0.11	6
Suzuki Aerio Sedan	2007	0.00	0.00	0.00	5
Suzuki Kizashi Sedan	2012	0.00	0.00	0.00	7
Suzuki SX4 Hatchback	2012	0.00	0.00	0.00	7
Suzuki SX4 Sedan	2012	0.00	0.00	0.00	11
Tesla Model S Sedan	2012	0.08	0.14	0.11	7
Toyota Sequoia SUV	2012	0.30	0.60	0.40	5
Toyota Camry Sedan	2012	0.00	0.00	0.00	9

Toyota Corolla Sedan 2012	0.05	0.10	0.07	10
Toyota 4Runner SUV 2012	0.40	0.20	0.27	10
Volkswagen Golf Hatchback 2012	0.12	0.20	0.15	5
Volkswagen Golf Hatchback 1991	0.10	0.12	0.11	8
Volkswagen Beetle Hatchback 2012	0.08	0.12	0.10	8
Volvo C30 Hatchback 2012	0.21	0.30	0.25	10
Volvo 240 Sedan 1993	0.14	0.09	0.11	11
Volvo XC90 SUV 2007	0.17	0.25	0.20	8
smart fortwo Convertible 2012	0.50	0.25	0.33	8
accuracy			0.14	1600
macro avg	0.15	0.15	0.14	1600
weighted avg	0.15	0.14	0.14	1600

#### 2.2.4.5 Best model Results and Metrics

### 3 Discussion

In summary, We learned from the first approach, the Transfer Learning, that using an already built model, can and most of the time will help significantly instead of trying to build the CNN model from scratch. With this approach we can use a pre-built model that experts created and make small changes in the architecture to solve similar problems. For example, we didn't have to think about how many convolutional layers we need to have because the experts that built the model already did that for us. We learned from the second approach, the Image Retrieval(KNN), that algorithms can give the same performance of an ANN. In this approach instead of having an artificial neural network for classification of the flattened input image. We can use a simple algorithm like KNN and it may give the same performance as an actual artificial neural network we use after the feature extraction. This approach saves us a lot of time because we didn't need to experiment with the number of fully connected layers, their number of neurons and also their activation functions. We learned from the third approach, the End To End CNN, that created from scratch a CNN model is very difficult for hard problems like we have in this project. We had to make many experiments in this approach in order to find the right architecture which took a lot of time and effort. After we ran the experiments related to the first and third approaches we understood from the first experiment which was more focused in the CNN architecture itself that not always having more convolutional layers can give us better performance. We learned from the lectures a term about

receptive fields which means that the inside layers can see bigger pictures than the previous convolutional layers. Also it can affect badly on our algorithm because the more layers we have, we take a look on unnecessary pixels such as background pixels. After we ran the second experiment related to the first and third approaches which was more focused on the hyper parameters, we learned that having more epochs should cause over fitting, and the learning rate is dependable on the epochs because when we have a small learning rate, getting to the minimal loss will take a lot of epochs and we needed to find the balance between them. We also learned that the batch size controls the accuracy of the estimate of the error gradient when training neural networks. The experiments related to the second approach, the Image Retrieval(KNN), were very technical and fast to execute.

## 4 Code

Colab project