

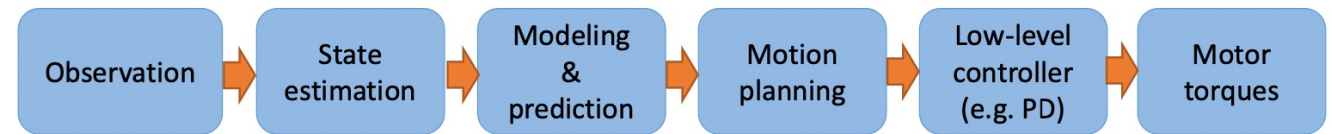


Behavioral cloning on a self driving car

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The Idea

- Learning from pixels
- End to end trained neural network using CNN
- Autonomous driving by mapping camera images to steering angle



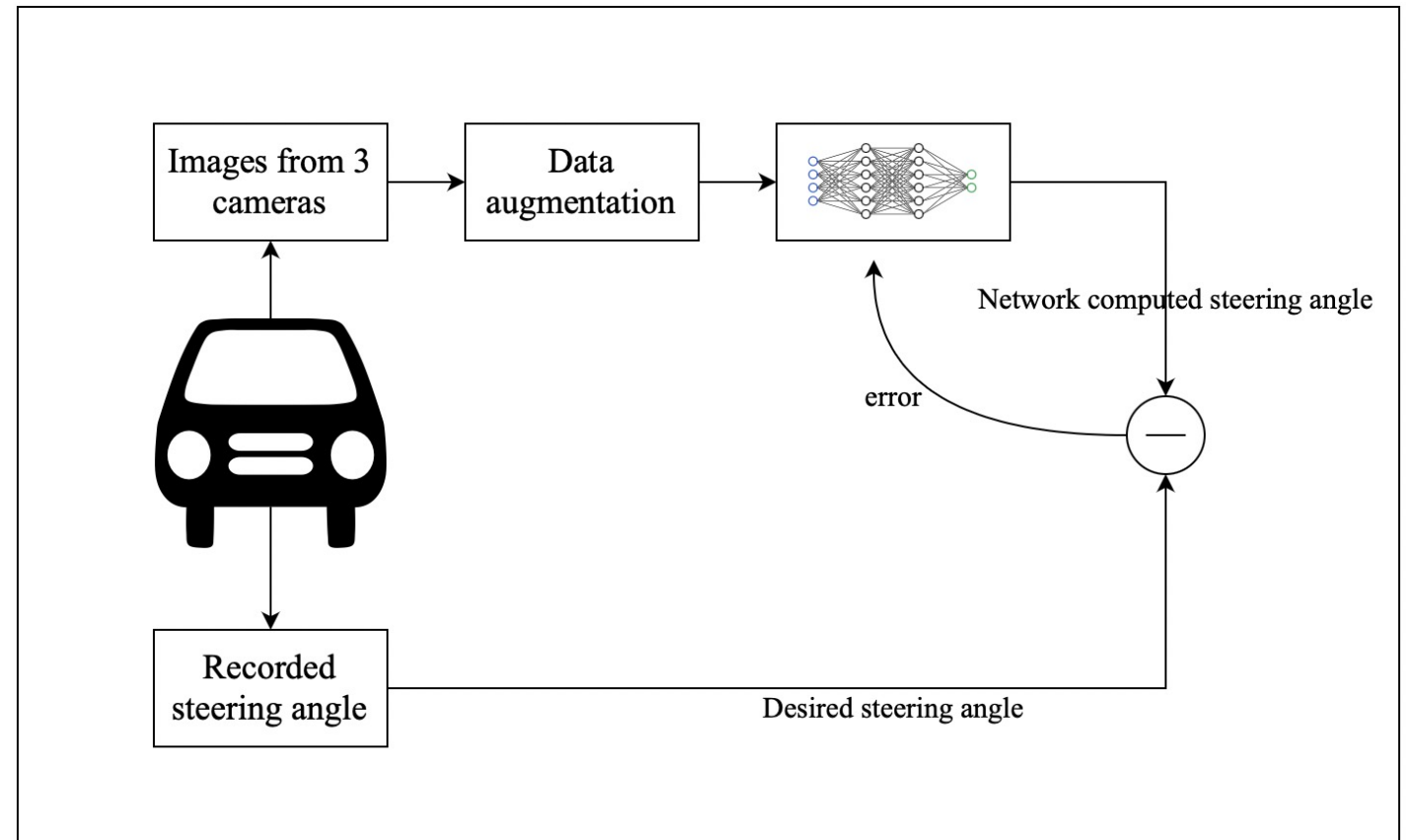
(a) Standard robotics control approach



(b) End-to-end deep learning approach

Approach

- Step 1: Collecting data
 - Data augmentation
 - Corner cases
- Step 2: Training CNN
 - NVIDIA Model
- Step 3: Driving autonomously



ANGLE

-2.30°

Mode: Autonomous

0	1	0	30.1901
0	1	0	30.1903
-0.1	1	0	30.1883
-0.25	1	0	30.1756
-0.45	1	0	30.1521
-0.65	1	0	30.1275
0	1	0	30.1743
0	1	0	30.1868
0	1	0	30.1897

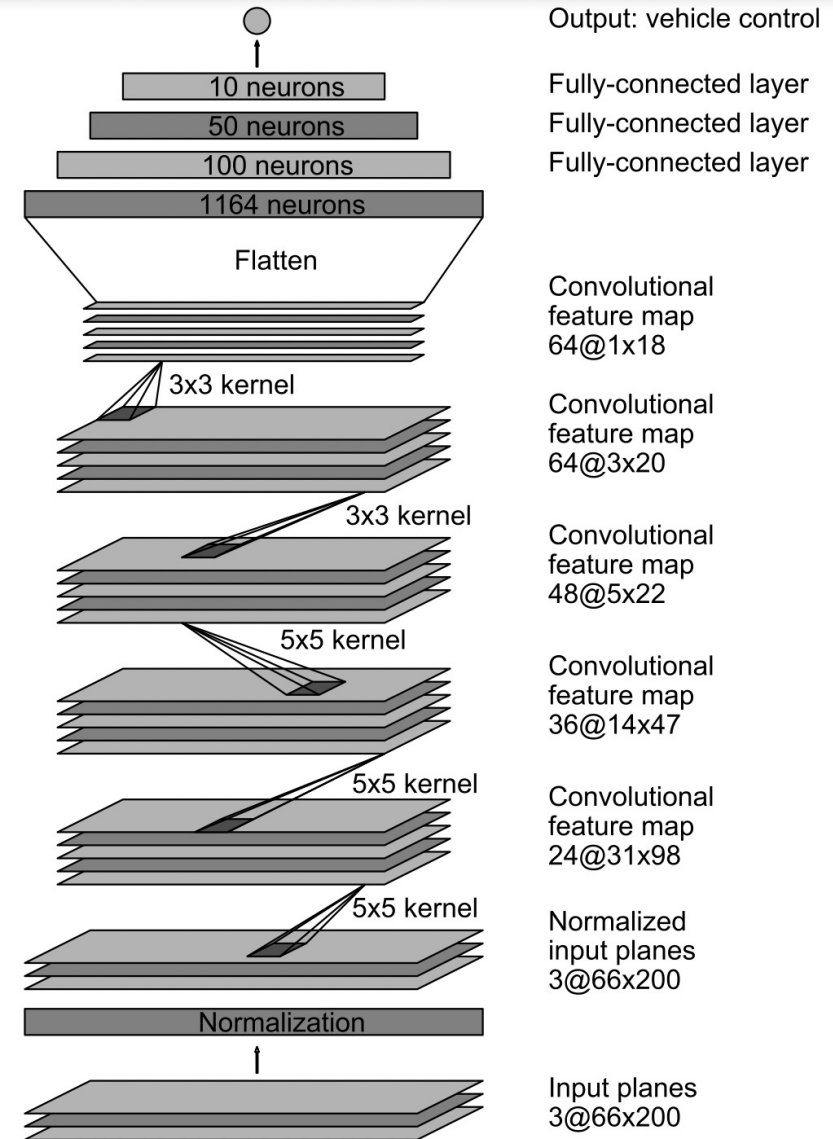
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center_2020_06_08_02_39_24_917.jpg	center_2020_06_08_02_39_24_986.jpg	center_2020_06_08_02_39_25_057.jpg
center_2020_06_08_02_39_25_125.jpg	center_2020_06_08_02_39_25_193.jpg	center_2020_06_08_02_39_25_264.jpg
center_2020_06_08_02_39_25_331.jpg	center_2020_06_08_02_39_25_406.jpg	center_2020_06_08_02_39_25_482.jpg
center_2020_06_08_02_39_25_552.jpg	center_2020_06_08_02_39_25_624.jpg	center_2020_06_08_02_39_25_691.jpg
center_2020_06_08_02_39_25_766.jpg	center_2020_06_08_02_39_25_838.jpg	center_2020_06_08_02_39_25_912.jpg
center_2020_06_08_02_39_25_980.jpg	center_2020_06_08_02_39_26_053.jpg	center_2020_06_08_02_39_26_127.jpg
center_2020_06_08_02_39_26_202.jpg	center_2020_06_08_02_39_26_276.jpg	center_2020_06_08_02_39_26_345.jpg
center_2020_06_08_02_39_26_417.jpg	center_2020_06_08_02_39_26_490.jpg	center_2020_06_08_02_39_26_554.jpg
center_2020_06_08_02_39_26_628.jpg	center_2020_06_08_02_39_26_703.jpg	center_2020_06_08_02_39_26_773.jpg
center_2020_06_08_02_39_26_845.jpg	center_2020_06_08_02_39_26_921.jpg	center_2020_06_08_02_39_26_992.jpg
center_2020_06_08_02_39_27_069.jpg	center_2020_06_08_02_39_27_145.jpg	center_2020_06_08_02_39_27_213.jpg
center_2020_06_08_02_39_27_283.jpg	center_2020_06_08_02_39_27_352.jpg	center_2020_06_08_02_39_27_424.jpg
center_2020_06_08_02_39_27_496.jpg	center_2020_06_08_02_39_27_574.jpg	center_2020_06_08_02_39_27_643.jpg
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center_2020_06_08_02_39_27_942.jpg	center_2020_06_08_02_39_28_016.jpg	center_2020_06_08_02_39_28_094.jpg
center_2020_06_08_02_39_28_169.jpg	center_2020_06_08_02_39_28_243.jpg	center_2020_06_08_02_39_28_314.jpg
center_2020_06_08_02_39_28_385.jpg	center_2020_06_08_02_39_28_454.jpg	center_2020_06_08_02_39_28_532.jpg
center_2020_06_08_02_39_28_610.jpg	center_2020_06_08_02_39_28_677.jpg	center_2020_06_08_02_39_28_745.jpg
center_2020_06_08_02_39_28_815.jpg	center_2020_06_08_02_39_28_885.jpg	center_2020_06_08_02_39_28_957.jpg

9.21

MPH

Architecture and Tools

- NVIDIA model
- CNN using Keras



Approach

- Reading the data
- Splitting the data into training, testing and validation samples
- Data Augmentation:
 - a) Image flipping
 - b) Steering angle negation
- Histogram
- Cropping the images to remove unwanted variables
- Resampling of the data to the mean
- Normalize image data



Specifications

- Library: Keras API of tensorflow
- Optimizer: Adam, SGD, RMSprop
- Activation function: ReLu
- Loss function: MSE

Optimizer	Epoch	Learning rate	MSE Train	MSE Val	Car performance	Comments
Adam	20	10 ⁻⁴	8.21e-04	0.0248	Lap not completed	Overfitting
	10	10 ⁻⁴	0.0042	0.0233	Lap not completed	Overfitting
	5	10 ⁻⁴	0.0095	0.0236	Lap completed with good performance	-
	5	10 ⁻³	0.0102	0.0208	Lap not completed	Aggressive Turns
	10	10 ⁻³	0.0057	0.0219	Lap not completed	Aggressive Turns
	50	10 ⁻³	6.1e-04	0.0228	Lap not completed	Aggressive Turns
SGD	5	10 ⁻⁴	0.0523	0.0677	Lap not completed	Could not converge
	10	10 ⁻⁴	0.0517	0.0677	Lap not completed	Could not converge
	50	10 ⁻⁴	0.0480	0.0630	Lap not completed	Could not converge
RMSprop	5	10 ⁻⁴	0.0089	0.0234	Lap completed with average performance	-
	10	10 ⁻³	0.0054	0.0203	Lap not completed	Overfitting

Advantages & Limitations

- Smaller networks
- Maximum system performance
- Better performance with unclear visual guidance
- No lane detection
- Non-deterministic
- Camera dependent (no depth information)
- Combination with other algorithms (eg: LiDAR)



References

End to End learning for self driving cars:

<https://images.nvidia.com/content/tegra/automotive/images/2016/solutions/pdf/end-to-end-dl-using-px.pdf>