

# CarMatch

*A singular* car buying solution

Thomas Noriega

# Car Buying is for Experts



CARVANA

Find My Car

Trade-In

Financing

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## THE **NEW** WAY TO BUY A CAR

Delivery to Your Door | 7-Day Test Own

HOW IT WORKS



SEARCH OUR 9,950 CARS

Select **BODYSTYLE(S)**



SEDAN



SUV



PICKUP



MINI-VAN



HATCHBACK



CONVERTIBLE



COUPE



WAGON

Select **PRICE RANGE**

< \$15K

\$15K-20K

\$20K-25K

\$25K-30K

\$30K-35K

> \$35K

FIND MY NEXT CAR


# Car Buying is for Experts

Need to know **exactly** what you want

THE **NEW** WAY TO BUY A CAR

Delivery to Your Door | 7-Day Test Drive

SEARCH OUR 9,950 CARS

 I want... (ex. Audi A5)

Select BODYSTYLE(S)



SEDAN



SUV



PICKUP



MINI-VAN



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WAGON

Select PRICE RANGE

< \$15K

\$15K-20K

\$20K-25K

\$25K-30K

\$30K-35K

> \$35K

FIND MY NEXT CAR

# Car Buying is for Experts

Need to know **several constraints**

Select **BODYSTYLE(S)**



SEDAN



SUV



PICKUP



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CONVERTIBLE



COUPE



WAGON

Select **PRICE RANGE**

< \$15K

\$15K-20K

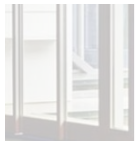
\$20K-25K

\$25K-30K

\$30K-35K

> \$35K

FIND MY NEXT CAR



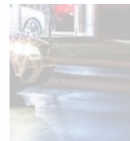
HATCHBACK

CONVERTIBLE

COUPE

WAGON

FIND MY NEXT CAR



# CarMatch

**Just needs a *single, understandable* input**

users don't need to be experts to browse  
listings

websites can reduce friction and increase  
customer conversion

# Inception 2D Neural Network

Modified and progressively fine-tuned to classify  
**196 different car classes**

- No feature extraction
- Minimal pre-processing
- Could be trained on a small dataset

# Dataset

Each class a unique combination of:



**MAKE:** Dodge

**MODEL:** RAM 3500

**YEAR:** 2009

Approximately **80 photos/class** (~16,000 photos total)

[http://ai.stanford.edu/~jkrause/cars/car\\_dataset.html](http://ai.stanford.edu/~jkrause/cars/car_dataset.html)

# Multiple Angles





# Variable Quality



# Validation on Test Set

Top-1 accuracy: 77.1%

Top-5 accuracy: 94.8%

# Validation on Test Set

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Top-5 accuracy: 94.8%

So if the user just wants to identify the uploaded car they almost certainly will

# Validation on Test Set

Top-1 accuracy: 77.1%

Top-5 accuracy: 94.8%

So if the user just wants to identify the uploaded car they almost certainly will

But results are most useful if they also ***look like the submitted photo***

**Input: sedan**

**output: sedans**



**Input: sedan**



**output: sedan-like**



# Similarity Validation

Incorrect ID: 5.2%

# Similarity Validation

Incorrect ID: 5.2%

Correct ID





# Similarity Validation

Incorrect ID: 5.2%

Correct ID AND styles



# Similarity Validation

Incorrect ID: 5.2%

Correct ID AND styles: 15.8%



# Similarity Validation

Incorrect ID: 5.2%

Correct ID AND styles: 15.8%

Correct ID AND wrong styles: 79.0%



# How to improve the results

Instead of absolute top-5 ranking

Algorithm that balances

- 1) most represented **body-styles**  
and
- 2) the **highest confidence** results

# Improved results by 4x

Correct ID AND styles:

New algorithm: 71.4% (vs. 15.5%)

Correct ID AND wrong styles:

New algorithm: 21.5% (vs. 79.0%)

4x  
improvement

Incorrect ID:

New algorithm: 7.1% (vs. 5.2%)

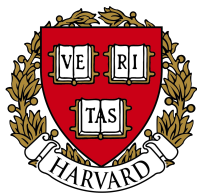
1.4x  
compromise

**And that's how CarMatch**

gives customers more results, more easily

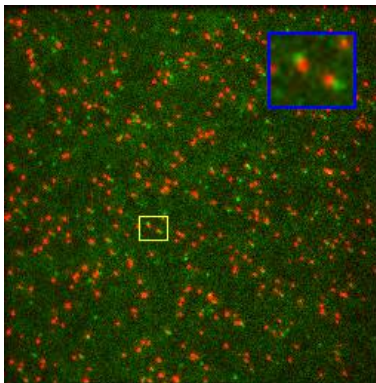
helps websites sell more cars

# Thomas Noriega



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# **SUPPLEMENTAL SLIDES**



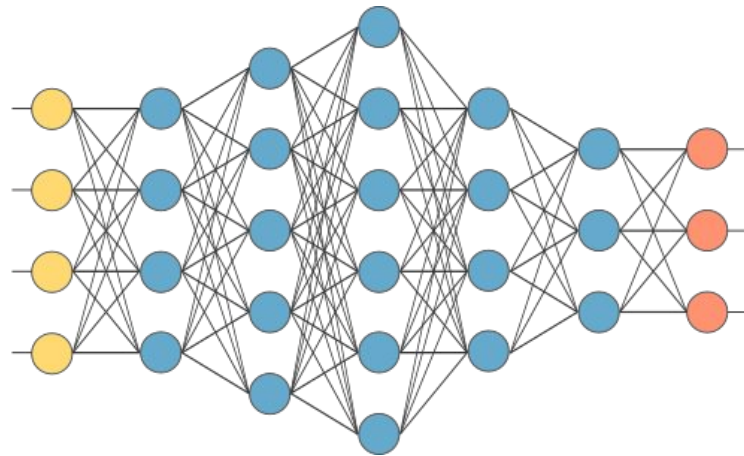
# Training



training set



in-memory  
augmentation

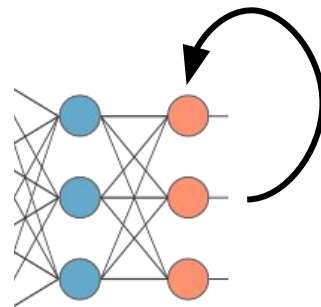
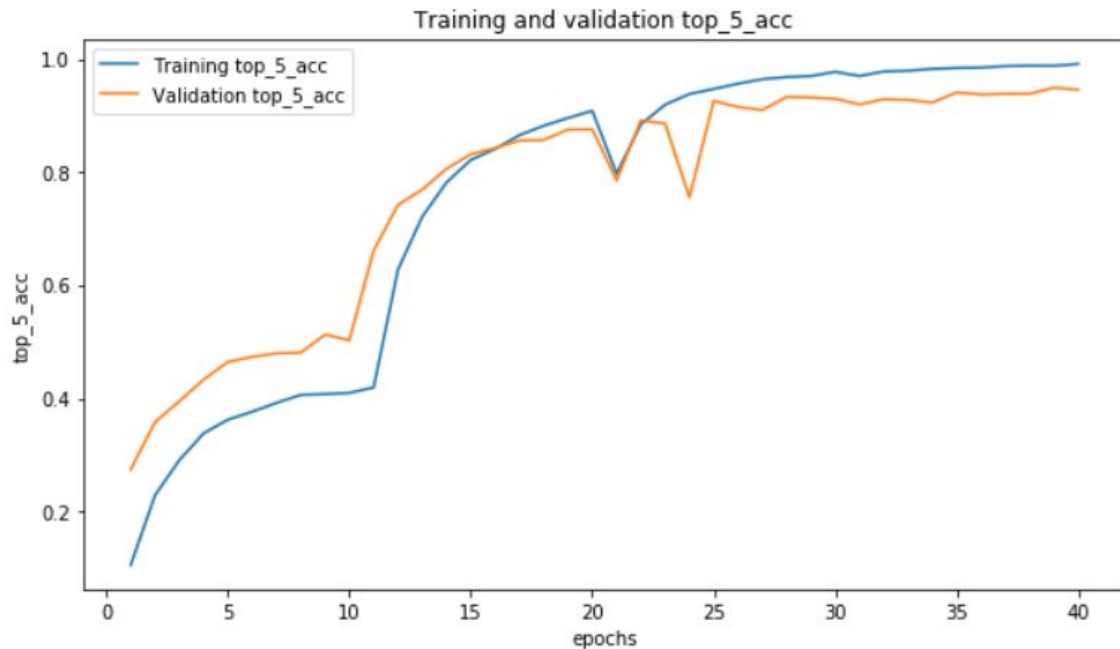


Pre-trained GoogleNet (Inception)  
**2D convolutional neural network**

# Training



training set



al network  
tion layer

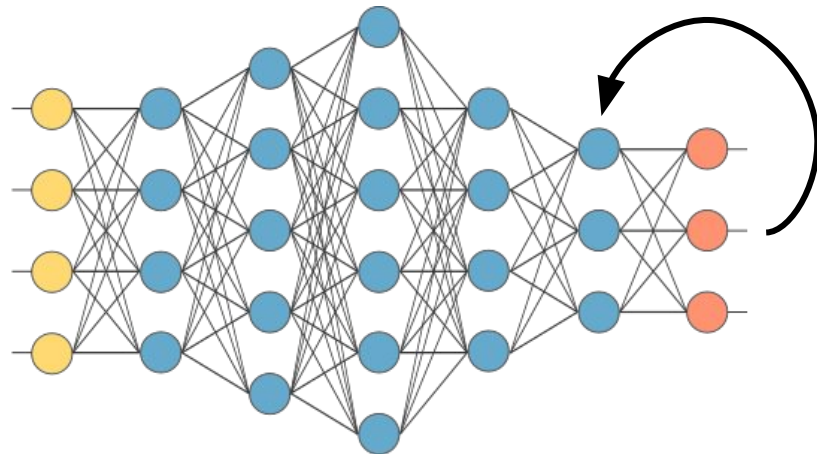
# Training



training set



in-memory  
augmentation



2D convolutional neural network  
**progressive fine-tuning**

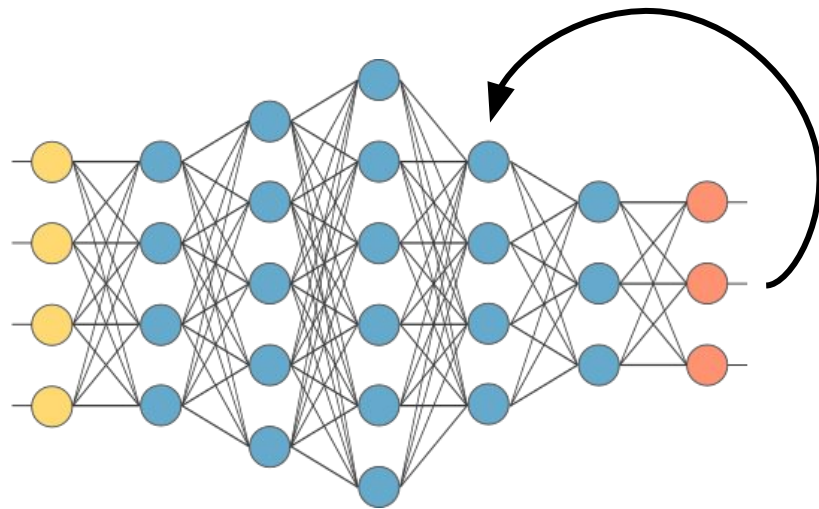
# Training



training set



in-memory  
augmentation



2D convolutional neural network  
**progressive fine-tuning**

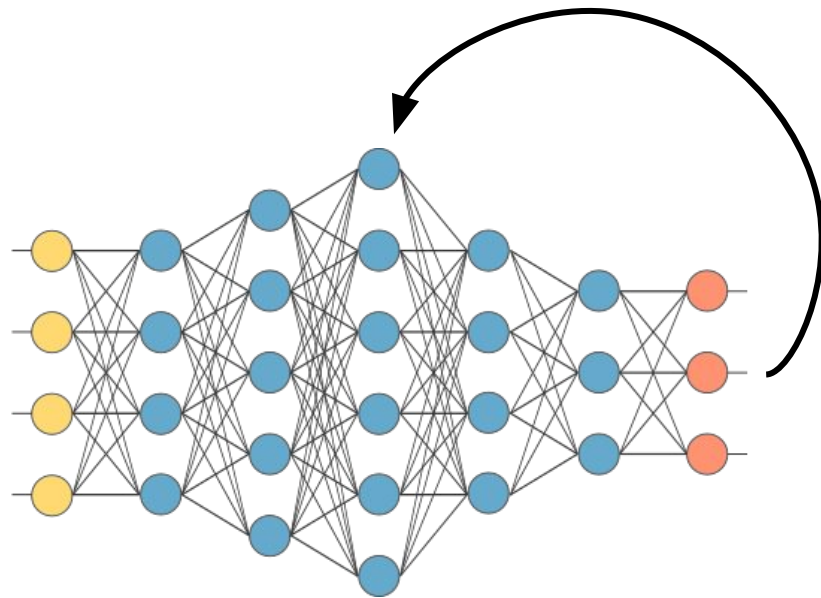
# Training



training set

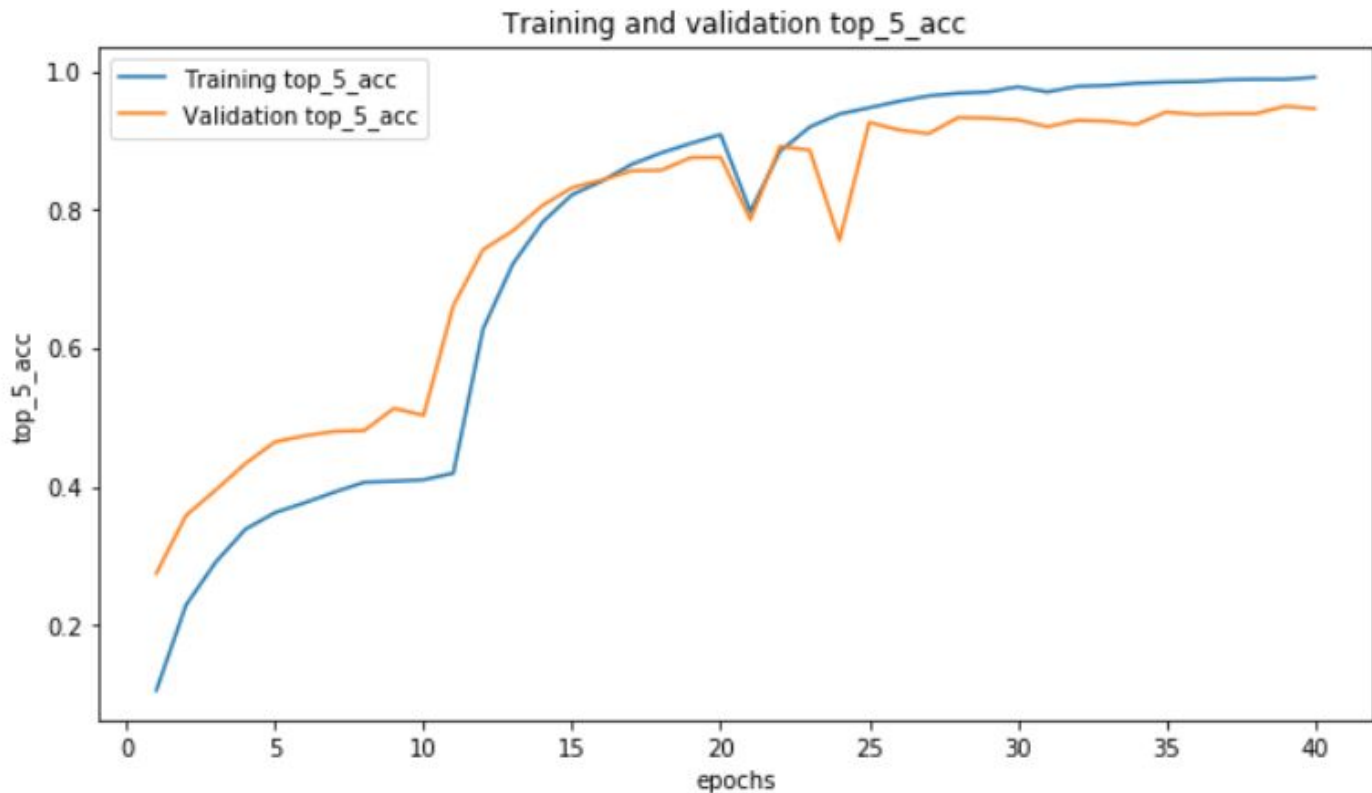


in-memory  
augmentation

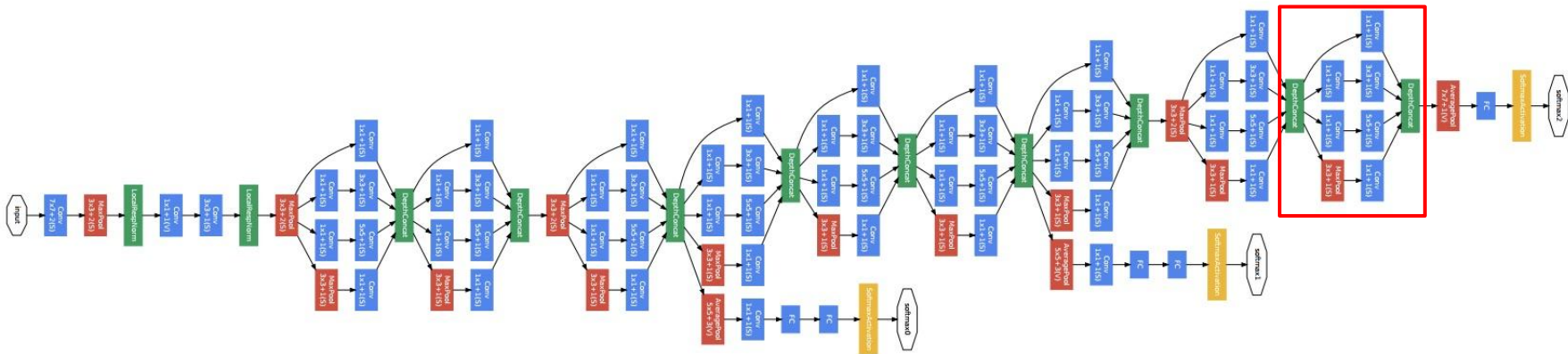
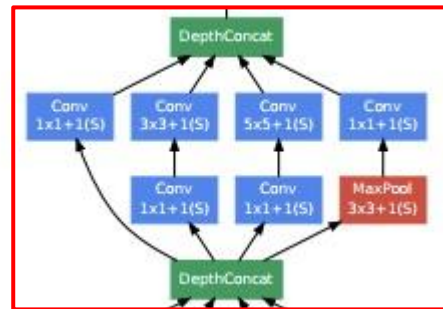


2D convolutional neural network  
**progressive fine-tuning**

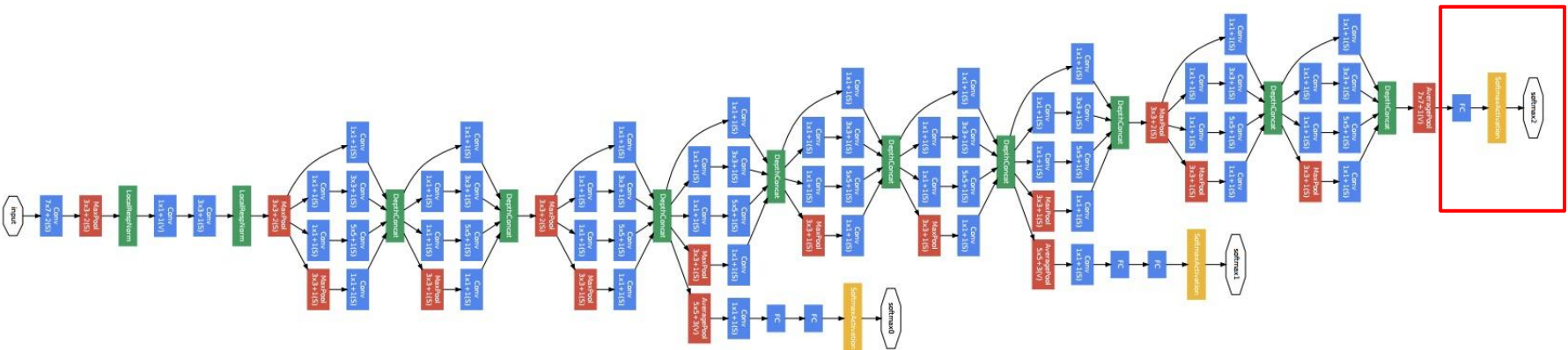
# Training/Validation Curves



# Inception Model



# Modify







# Why such high wrong style results?

Top-5 ignores probability assignments:



0.85



0.10



0.02



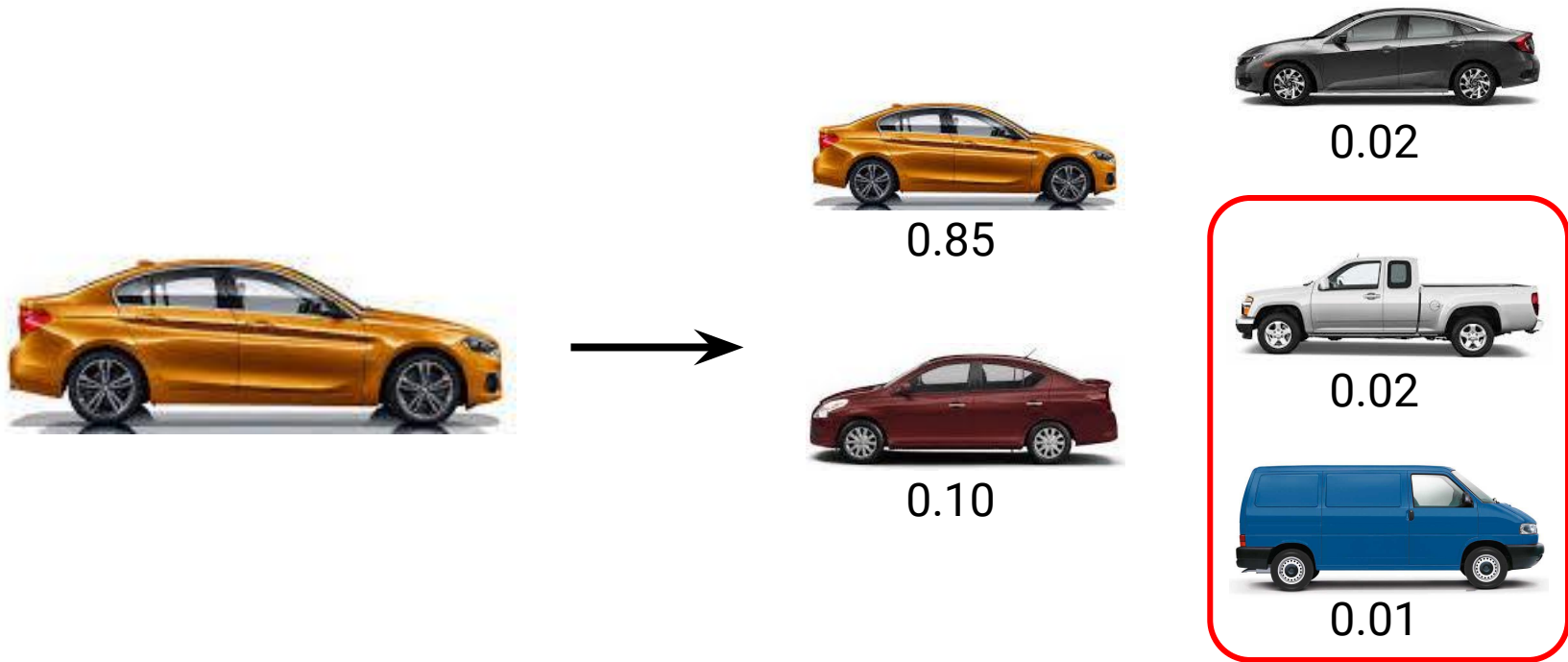
0.02



0.01

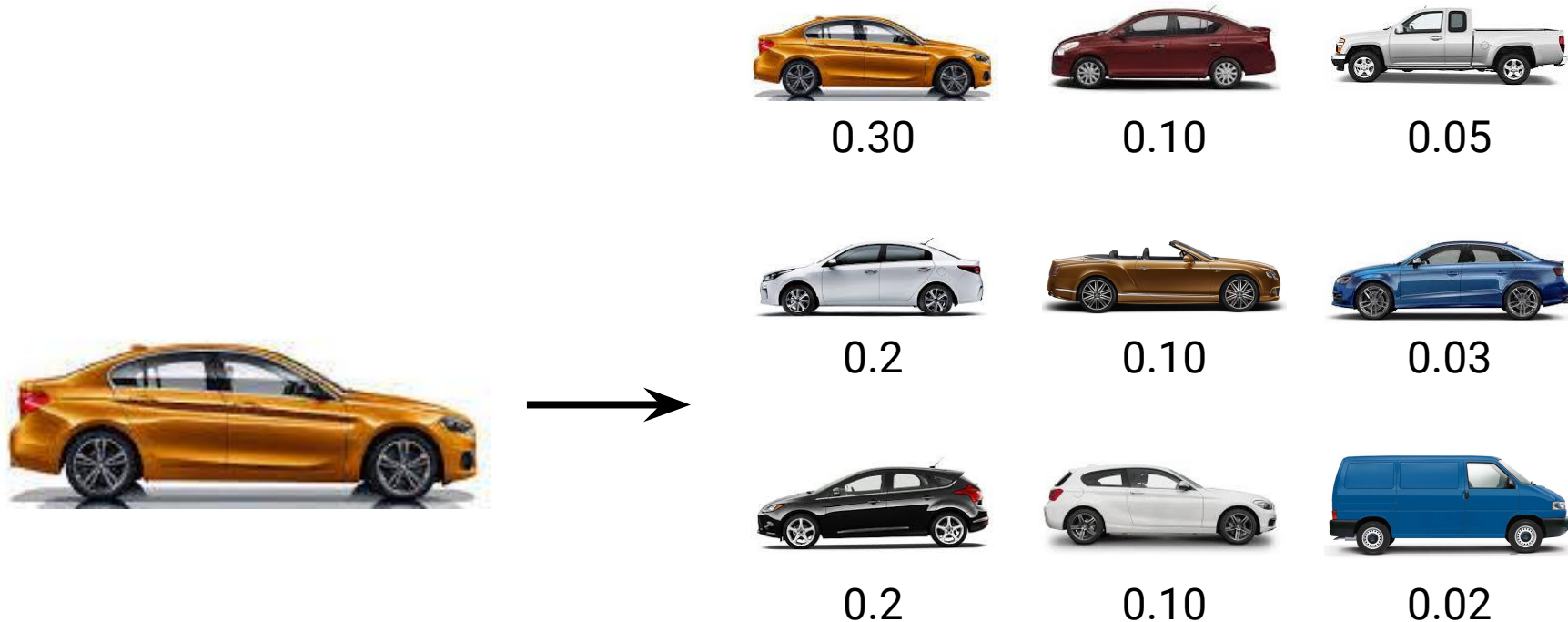
# Why such high wrong style results?

Top-5 ignores probability assignments:



# How to improve the results

1) Start with all predictions



# How to improve the results

- 1) Start with all predictions
- 2) Consider predictions with 95% confidence



0.30



0.10



0.05



0.2



0.10



0.03



0.2



0.10



0.02

# How to improve the results

- 1) Start with all predictions
- 2) Consider predictions with 95% confidence
- 3) Limit to top-2 body-styles



0.30



0.10



0.05



0.2



0.10



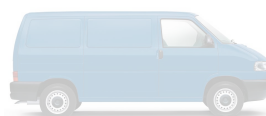
0.03



0.2



0.10



0.02

# How to improve the results

- 1) Start with all predictions
- 2) Consider predictions with 95% confidence
- 3) Limit to top-2 body-styles
- 4) Present top-5 remaining results



0.30



0.10



0.05



0.2



0.10



0.03



0.2



0.10



0.02