Predicting a vehicles speed using dashcam footage

A deep learning approach

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Table of content

The "comma ai speed challenge"[1]

Motivation

- Here are some motivational words needed

Data collection:

- "comma ai speed challenge" provides two videos:
    - Train video: 24000 frames, shoot at 20 frames per second, including ground truths
    - Test video: 10798 frames, shoot at 20 frames per second, no ground truths, used to applications
- Split train video after 80% with hard cut off (ability the generalize), to get train and test datasets

Initial assumptions

- Use mean squared error (MSE) as a performance measure
- How to evaluate a prediction? Assumptions:
    - MSE ≤ 10: good
    - MSE ≤ 5: better
    - MSE ≤ 3: correct

[1] https://github.com/commaai/speedchallenge

Preprocessing

- Frame size of $(640, 480, 3)$ pixels
- Cut off last 60 pixels, to remove black frame inside the car
- Sample down the frame to half its size, due to computational limitations

IMAGES with arrows are needed

Optical flow using "Farneback pyramid method" [2]

- Global method to solve the optical flow equation

$$\partial_x f \cdot V_x + \partial_y f \cdot V_y + \partial_t f = 0$$

  for an image sequence $(f_t)_t$ with $f_t : \Omega \to \mathbb{R}^3$, for all t, and the (dense) flow field $V : \Omega \to \mathbb{R}^2, \omega \mapsto (V_x(\omega), V_y(\omega))$.
- Uses a downsampling pyramid, to solve the equation for different resolutions of the image
- Parameters for the Farneback method

$$\begin{aligned}
\text{pyramid levels} &:= 3 \\
\text{pyramid scaling} &:= 0.5 \\
\text{window size} &:= 6 \\
\text{pixel neighborhood size} &:= 5 \\
\text{SD of the gaussian filter} &:= 1.1
\end{aligned}$$

- Result: **Flow field with** $(160, 105, 3)$ **pixels**

Visualization of the flow field

- Flow field is a two-dimensional vector field
- RGB representation via
  - Transform flow field into polar coordinates $(V_x, V_y) \rightarrow (r, \varphi)$
  - Normalize magnitudes r for third channel
  - Values of the second channel are set to 255
  - Multiply angle φ by factor $\frac{180}{2\pi}$ for first channel
- Sample down the size again, to speed up the training

IMAGE REQUIRED

Convolutional neural network and initial architecture

Method selection

- Speed prediction is a **non-linear regression** task $\rightsquigarrow$ Neural network
- Use convolution layers to perform feature extraction $\rightsquigarrow$ **convolutional neural network** (CNN)

Initial architecture

- Paper of NVIDIA work group [1] of a CNN for self-driving cars
- Enough complexity and layers to handle the task and lots of possibilities to fine-tune it
  IMAGE OF THE MODEL
- Initial results with the raw model: MSE of under 3 on the training set and around 18-20 on the testing set
  $\Rightarrow$ Improvements needed

Batch Normalization, Dropout layers, activation function and pooling

- Batch normalization to speed up the training [3]
- Initial activation function: $\mathrm{ReLu} : \mathbb{R} \to \mathbb{R}_0^+, x \mapsto \max\{0, x\}$, still MSE over 15 on the testing set
  $\Rightarrow$ Overfitting problems
- Found paper about dropout layers [4] to reduce overfit, build in one with dropout probability $p = 0.5$
- Solve problems of dead neurons using

$$\mathrm{leakyReLU} : \mathbb{R} \to \mathbb{R}, x \mapsto \begin{cases} x, x \geq 0 \\ c \cdot x, x < 0 \end{cases}$$

  with $c = 0.01$, MSE of around 12 on the testing set

Problems

We identified three possible problems for poor results

1. Too complex model, as initially used for autonomous driving or insufficient amount of information put into the model
2. Problems with different brightnesses/illumination changes in the frames, therefore unstable calculations of the optical flow
3. Too ambiguous splitting, as the training and testing datasets represent totally different road traffic scenarios in the road traffic

IMAGE OF THE SPEED DISTRIBUTION

Possible solutions

1. **Simplify model**: pooling layers (maximum and average pooling) to get more compression

   Siamese approach: put flow field and raw frame into the model or put two consecutive frames into the model
2. **Add additional noise**: add noise before computing the optical flow filed, to get more invariance regarding illumination changes
3. **Different splitting**: get better ratio between different scenarios, by using a splitting bases on the different road traffic situations in the video

Literature I

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