
Object Detection and Orientation Estimation for Autonomous Driving

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Keywords: [computer vision, object detection, object orientation estimation, autonomous driving]

Instructions

Your midway report should be 4 pages long (excluding references) and include the following:

- Project title and list of group members (please follow the given template).
- **Introduction (1 – 1½ pages):** Problem and literature overview; how your idea fits into the existing work. If you already had an elaborate proposal, you may borrow this part from there, but try to make it as focused and concise as possible. If your proposal did not include enough background information, please make sure this section fills that gap (this will also save you time on preparing the final report).
- **Methods (1½ – 2 pages):** If you are developing a new method / model / architecture, this section should contain all the math, derivations, formal details, illustrations (if necessary). If you are proving theorems, assumptions and theorem formulations should be here. If your project is application driven, this section should highlight important aspects of the application and details on how your methodology addresses those.
- **Preliminary Results (½ – 1 page):** Please include experimental results you have obtained by the deadline. We expect you to have at least implemented and tested a major part of your models (maybe on some toy data) and run a few baselines. Describe how the current results align with your expectations. You may include the details on how you mined / prepared the data, if it is an important aspect of the project.
- **Final plan (½ page):** The adjusted plan for the next steps (in terms of methodology, experiments, data collection, etc.)

Additional notes

If you have changed or adjusted your project plan significantly (compared to what you have proposed), please provide a brief note on this in a subsection of the introduction.

Grading rubric

Total weight: 25% of the project grade (i.e., 10% of the course grade).

- Introduction & literature survey (10%)
- Methods (40%)
- Preliminary results (20%)
- Plan of the next steps (20%)
- Quality of writing (10%)

1 Introduction

1.1 Problem Overview

Nowadays cameras are available onboard of almost every new car produced in the last few years. Computer vision provides a very cost effective solution not only to improve safety, but also to one of the holy grails of AI, fully autonomous self-driving cars. In this project we are planning to use deep neural networks to solve the object detection and object orientation estimation problems for autonomous driving.

There are lots of potential challenges that we need to solve for example, due to the weather, road conditions and car location, images from the car cameras will have a high-variety, which requires high robustness for our model. And besides the classical object detection task, we want to further estimate the 3D orientation from the 2D images. Last, but not least our system need to produce a good result within a limited runtime in order to be used in practise.

1.2 Dataset

The dataset that we are planning to use is the KITTI Vision Benchmark Suite [1]. It's developed for use in mobile robotics and autonomous driving research. So it contains several novel challenging benchmarks for the tasks of stereo, optical flow, visual odometry/SLAM and 3D object detection. In our project, we mainly focus on the object detection and orientation estimation task. The corresponding benchmark ¹ consists of 7481 training images and 7518 test images, comprising a total of 80,256 labeled objects (up to 15 cars and 30 pedestrians are visible per image). All images are color and saved as png.

[Dataset statistics](http://www.cvlibs.net/datasets/kitti/eval_object.php)

1.3 Evaluation

For evaluation, the benchmark is split into three parts: First, we need to evaluate the classical 2D object detection by measuring performance using the well established average precision (AP) metric as described in [2]. Detections are iteratively assigned to ground truth labels starting with the largest overlap, measured by bounding box intersection over union. True positives are required to overlap by more than 50% and multiple detections of the same object are counted as false positives.

Second, we assess the performance of jointly detecting objects and estimating their 3D orientation using a novel measure which is called the average orientation similarity (AOS) [1] and is defined as:

$$AOC = \frac{1}{11} \sum_{r \in \{0, 0.1, \dots, 1\}} \max_{\tilde{r}: \tilde{r} \geq r} s(\tilde{r}) \quad (1)$$

Here, $r = \frac{TP}{TP+FN}$ is the PASCAL object detection recall, where detected 2D bounding boxes are correct if they overlap by at least 50% with a ground truth bounding box. The orientation similarity $s \in [0, 1]$ at recall r is a normalized $([0..1])$ variant of the cosine similarity defined as

$$s(r) = \frac{1}{|D(r)|} \sum_{i \in D(r)} \frac{1 + \cos \Delta_{theta}^{(i)}}{2} \delta_i \quad (2)$$

where $D(r)$ denotes the set of all object detections at recall rate r and $\Delta_{theta}^{(i)}$ is the difference in angle between estimated and ground truth orientation of detection i . To penalize multiple detections which explain a single object, we set $\delta_i = 1$ if detection i has been assigned to a ground truth bounding box (overlaps by at least 50%) and $\delta_i = 0$ if it has not been assigned.

Finally, we will also evaluate pure classification (16 bins for cars) and regression (continuous orientation) performance on the task of 3D object orientation estimation in terms of orientation similarity.

¹http://www.cvlibs.net/datasets/kitti/eval_object.php

1.4 Related work

Traditional methods for object detection usually utilize image features, such as SIFT and HOG. We investigated three methods utilizing deep convolutional network in object detection.

1.5 R-CNN: Rich feature hierarchies for accurate object detection and semantic segmentation

The first challenge for object detection is how to implement localizing within an image. The new method proposed in this paper[3] combines CNN with region proposals. So it is called R-CNN. The general detection process is to extract about 2000 region proposals for each input image. Then utilize CNN to compute a fixed length feature for each region proposal. Finally utilize linear SVM to classify each region.

The second challenge is how to train a large CNN using limited labeled data. This paper proposed to pre-train CNN on a large auxiliary data set, then continually train on a small data set. This method significantly improved the accuracy of objection detection compared with feature learning models. But training is expensive in space and time, and detection is also slow at test time.

1.6 Fast R-CNN

This paper[4] talked about how to train a detection network faster. R-CNN is very slow because it extracts feature for each region proposal and there are many duplicate computations. The process could be faster if we share computation.

This paper proposed to modify R-CNN's architecture by taking an image and multiple regions of interests as input. Region proposal method usually depends on Selective Search. Each region of interest is pooled into a fixed-size feature map and fully connected layers are used to extract features. There two output vectors: softmax probabilities and per-class bounding-box regression offsets. The second one is to reduce mislocalization.

1.7 Faster R-CNN: Towards Real-Time Object Detection with Region Proposal Networks

Fast-CNN achieves near real-time rates using very deep networks, when ignoring the time spent on region proposals. Select Search takes about 2 seconds per image on the CPU. Faster R-CNN[5] adds a fully convolutional network to compute region proposals directly. Then use the same detector on the proposed regions as what Fast R-CNN does.

1.8 Yolo

2 Methods

3 Results

3.1 Object Detection Using Yolo

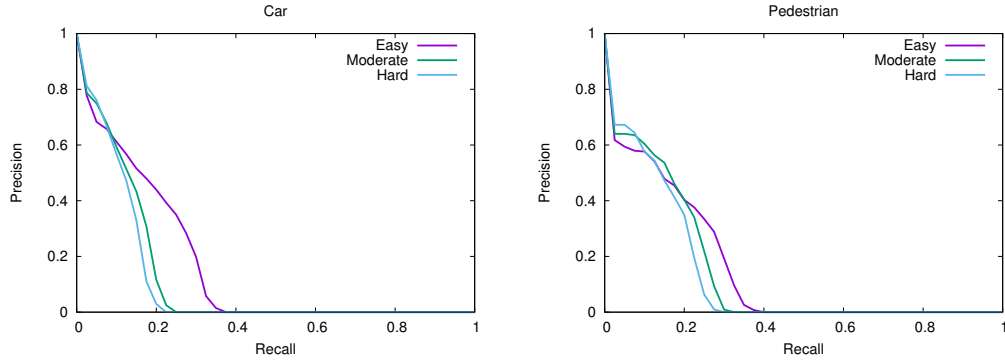


Figure 1: Using a Pre-Trained Yolo Model

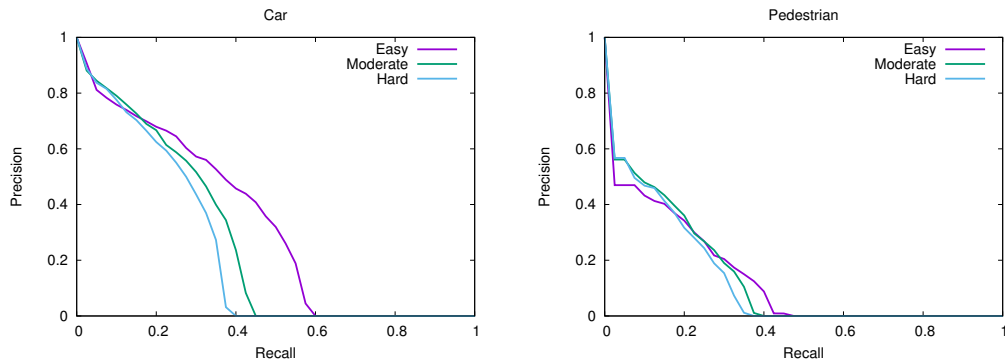


Figure 2: Using a Tiny Yolo Model Trained on Our Dataset

3.2 Object Detection Using Faster-RCNN

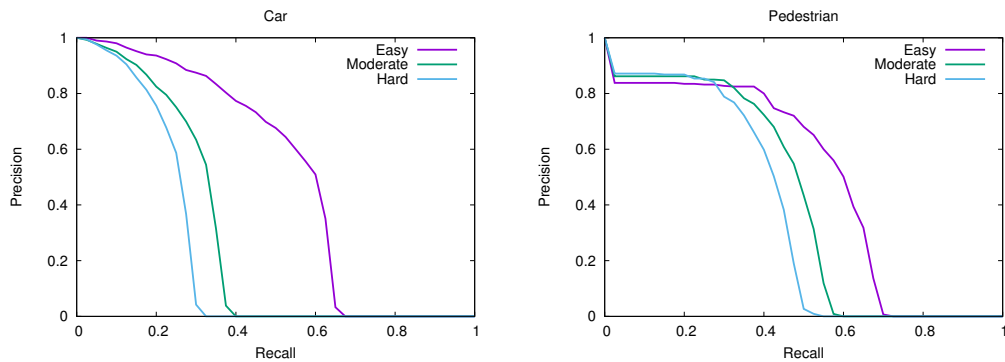


Figure 3: Using a Pre-Trained Faster-RCNN Model

3.3 Average Precision

Method	Easy	Moderate	Hard
Pre-Trained Yolo	0.204438	0.155358	0.145101
Yolo Tiny	0.344293	0.291823	0.257863
Pre-Trained Faster-RCNN	0.522754	0.309875	0.248554

Table 1: AP on Car Detection

Method	Easy	Moderate	Hard
Pre-Trained Yolo	0.197457	0.183323	0.175022
Yolo Tiny	0.187898	0.184558	0.176187
Pre-Trained Faster-RCNN	0.498992	0.429862	0.377569

Table 2: AP on Pedestrian Detection

4 Project Plan

We plan to implement 2D object detection using faster R-CNN by the second milestone. After that, we will focus on 3D object detection. We may also try YOLO[6] method and see if there are any improvement. Detailed plan depends on time and compute power.

References

- [1] Andreas Geiger, Philip Lenz, and Raquel Urtasun. Are we ready for autonomous driving? the kitti vision benchmark suite. In *Conference on Computer Vision and Pattern Recognition (CVPR)*, 2012.
- [2] M Everingham, L Van Gool, CKI Williams, J Winn, and A Zisserman. The pascal visual object classes challenge 2011 (voc 2011) results (2011). In URL <http://www.pascal-network.org/challenges/VOC/voc2011/workshop/index.html>, 2010.
- [3] Trevor Darrell Jitendra Malik Ross Girshick, Jeff Donahue. Rich feature hierarchies for accurate object detection and semantic segmentation. In *Conference on Computer Vision and Pattern Recognition(CVPR)*, 2014.
- [4] Ross Girshick. Fast r-cnn. In *IEEE International Conference on Computer Vision (ICCV)*, 2015.
- [5] Ross Girshick Jian Su Shaoqing Ren, Kaiming He. Faster r-cnn: Towards real-time object detection with region proposal networks. In *IEEE International Conference on Computer Vision (ICCV)*, 2015.
- [6] Ross Girshick Ali Farhadi Joseph Redmon, Santosh Divvala. You only look once: Unified, real-time object detection. In *arXiv preprint arXiv:1506.02640*, 2015.