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Assignment

Machine Learning assessment - Report

Hardware information:

- Memory: 12 GB RAM
- Disk Memory: 62 GB
- Processor: Intel core i7-7500U CPU @2.70GHz x 4
- OS : Ubuntu 16.04 LTS
- Development Environment: PyCharm Edu 2017.3

GitHub repository: *https://github.com/amrita95/YOLO*

Section 1:

Github user y22ma modifies Darknet source code in order to train YOLO using Udacity's data. In this section, you should clone y22ma's project in your own GitHub repository, and then build the project on your machine.

I cloned the repository in my local directory from the attached link and checked out the branch, *udacity*. I chose one of the yolo architecture from the ./cfg folder and loaded the corresponding weights from the */bin* folder. The following command runs the algorithm on the test images.

```
./flow --model cfg/v1/yolo-full.cfg --load bin/yolo-full.weights --json False
```

The test images are stored in the *./test* and the resulting output images with the bounding boxes gets stored in the *./test/out.* In order to train on a dataset by loading a certain pre-trained weight, the command is

```
./flow --model cfg/v1/yolo-full.cfg --load bin/yolo-full.weights --dataset
<dataset directory> --annotation <annotation file directory> --train
```

If we are to train the model from the scratch the --load has to be dropped from the above command. There were a few changes that were done since the version of tensorflow in my system was different from what is required. The syntax of few of the functions like *tf.concat*, *tf.multiply* had to be changed. The following are the changes that were made:

File Name	Line number	Changes
net/ops/convolution.py	88	key='param_initializers'
net/vanilla/train.py	27,28	Tf.mul -- > tf.multiply
net/yolo.py	62,68,72,85	Tf.concat - syntax change Tf.mul -- > tf.multiply

Section 2:

Train the network using Udacity's dataset.

To train on a new dataset, *--dataset* argument of *./flow* has to be set to the location of the udacity dataset. Y22ma's udacity branch of the repository has the udacity cfg file for 5 classes. The annotation file udacity.csv is parsed using a new function provided in the udacity branch /utils/udacity_voc_csv.py. The following command starts the training.

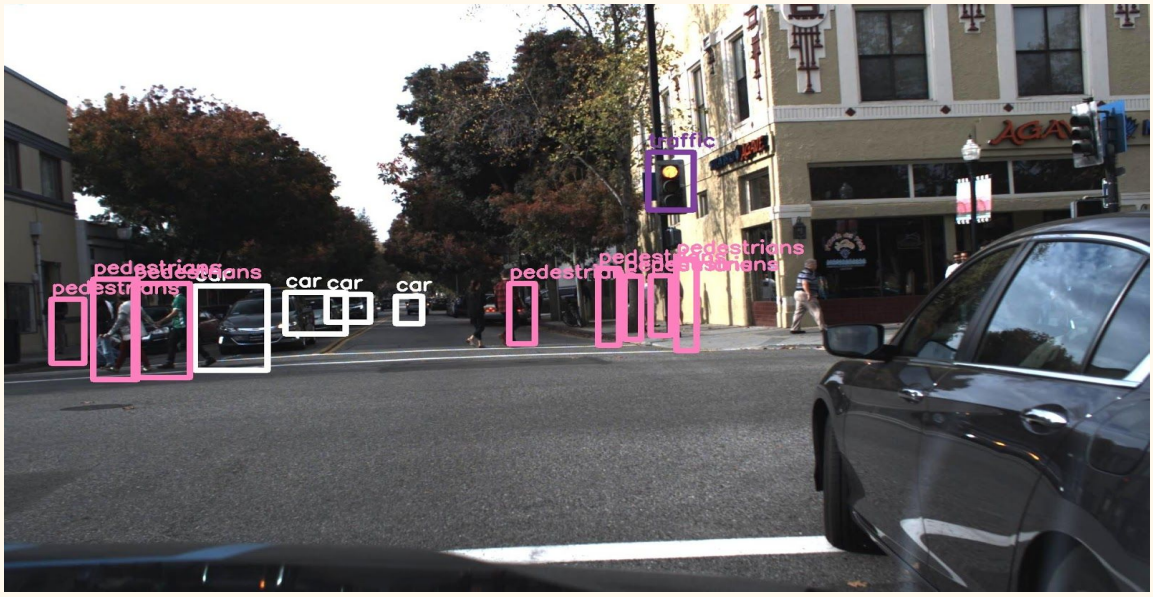
./flow --model cfg/tiny-yolo-udacity.cfg --load 9707 --dataset <dataset directory> --annotation <csv file directory> --train

I loaded the weights from a checkpoint that was provided by y22ma and trained the network starting from the step 8987. To train from the beginning, I tried to overfit the model with a dataset of 5-6 images and the loss drastically reduced from ~100 to ~8. The loss doesn't reach 0 since there was a noise that was augmented to the images. This step is just to check if the whole system is working fine. But it has to run for at least 8000-9000 steps, before it can produce a meaningful bounding box.

The YOLO network model that I used is the one that was provided in the repository in the file ./cfg/tiny-yolo-udacity.cfg. The architecture consisted of 9 convolutional layers, where each of the convolutional layer is followed by a max pooling layer except for the last 2 convolutional layers. The leaky ReLU is used as the activation function for all the layers except for the last layer where linear activation has been used. The screenshot attached below shows the architecture of the network in the tiny-yolo-udacity.cfg.

```
Building net ...
Source | Train? | Layer description                | Output size
-------+--------+----------------------------------+---------------
       |        | input                            | (?, 416, 416, 3)
 Init  |  Yep!  | conv 3x3p1_1  +bnorm  leaky      | (?, 416, 416, 16)
 Load  |  Yep!  | maxp 2x2p0_2                     | (?, 208, 208, 16)
 Init  |  Yep!  | conv 3x3p1_1  +bnorm  leaky      | (?, 208, 208, 32)
 Load  |  Yep!  | maxp 2x2p0_2                     | (?, 104, 104, 32)
 Init  |  Yep!  | conv 3x3p1_1  +bnorm  leaky      | (?, 104, 104, 64)
 Load  |  Yep!  | maxp 2x2p0_2                     | (?, 52, 52, 64)
 Init  |  Yep!  | conv 3x3p1_1  +bnorm  leaky      | (?, 52, 52, 128)
 Load  |  Yep!  | maxp 2x2p0_2                     | (?, 26, 26, 128)
 Init  |  Yep!  | conv 3x3p1_1  +bnorm  leaky      | (?, 26, 26, 256)
 Load  |  Yep!  | maxp 2x2p0_2                     | (?, 13, 13, 256)
 Init  |  Yep!  | conv 3x3p1_1  +bnorm  leaky      | (?, 13, 13, 512)
 Load  |  Yep!  | maxp 2x2p0_1                     | (?, 13, 13, 512)
 Init  |  Yep!  | conv 3x3p1_1  +bnorm  leaky      | (?, 13, 13, 1024)
 Init  |  Yep!  | conv 3x3p1_1  +bnorm  leaky      | (?, 13, 13, 1024)
 Init  |  Yep!  | conv 1x1p0_1    linear           | (?, 13, 13, 50)
-------+--------+----------------------------------+---------------
```

The training, if started with randomly initialized weights takes a lot of time and iterations (~8000) to converge. My PC ran out of memory with 600 steps and after 16 hours training, since I had saved the model for every 1000 data(800MB each). Training with pretrained weights (weights stored after ~9000 steps) gave a training loss ~8 in each steps later and moving average loss was also approximately around 9 . The screenshot below shows the training performance of the algorithm on udacity dataset loading the pre-trained weights. An example of the output image is shown below.



After ~9000 training steps, the bounding boxes are considerable and it can be improved even more by training it for more number of steps until the loss converges.

Section 3:

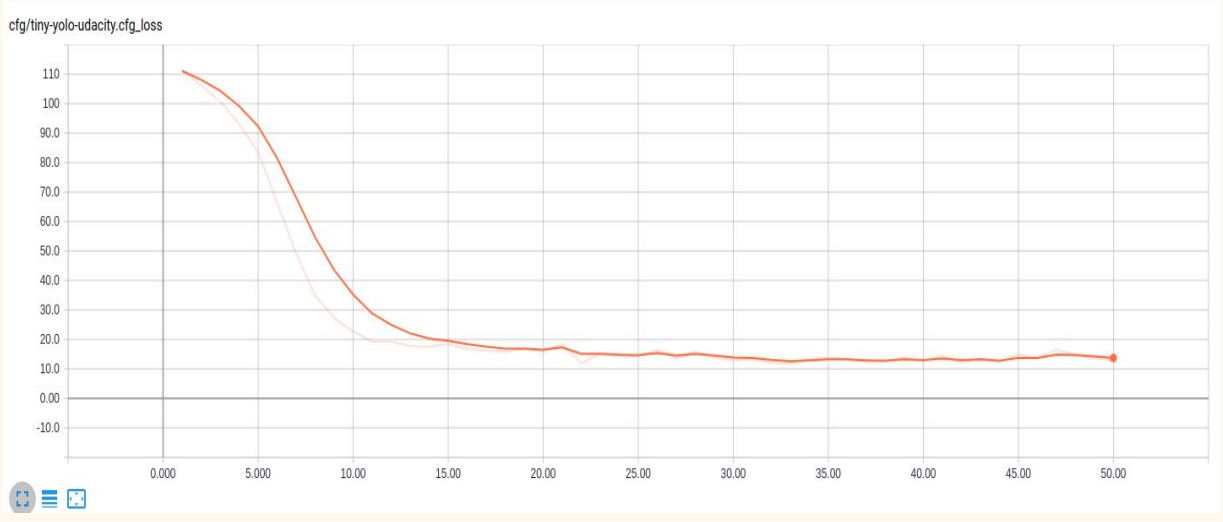
Provide more performance metrics. Tensorboard plotting is a good method to monitor the training. When running the detector, there are several ways to evaluate the performance.

TENSORBOARD:

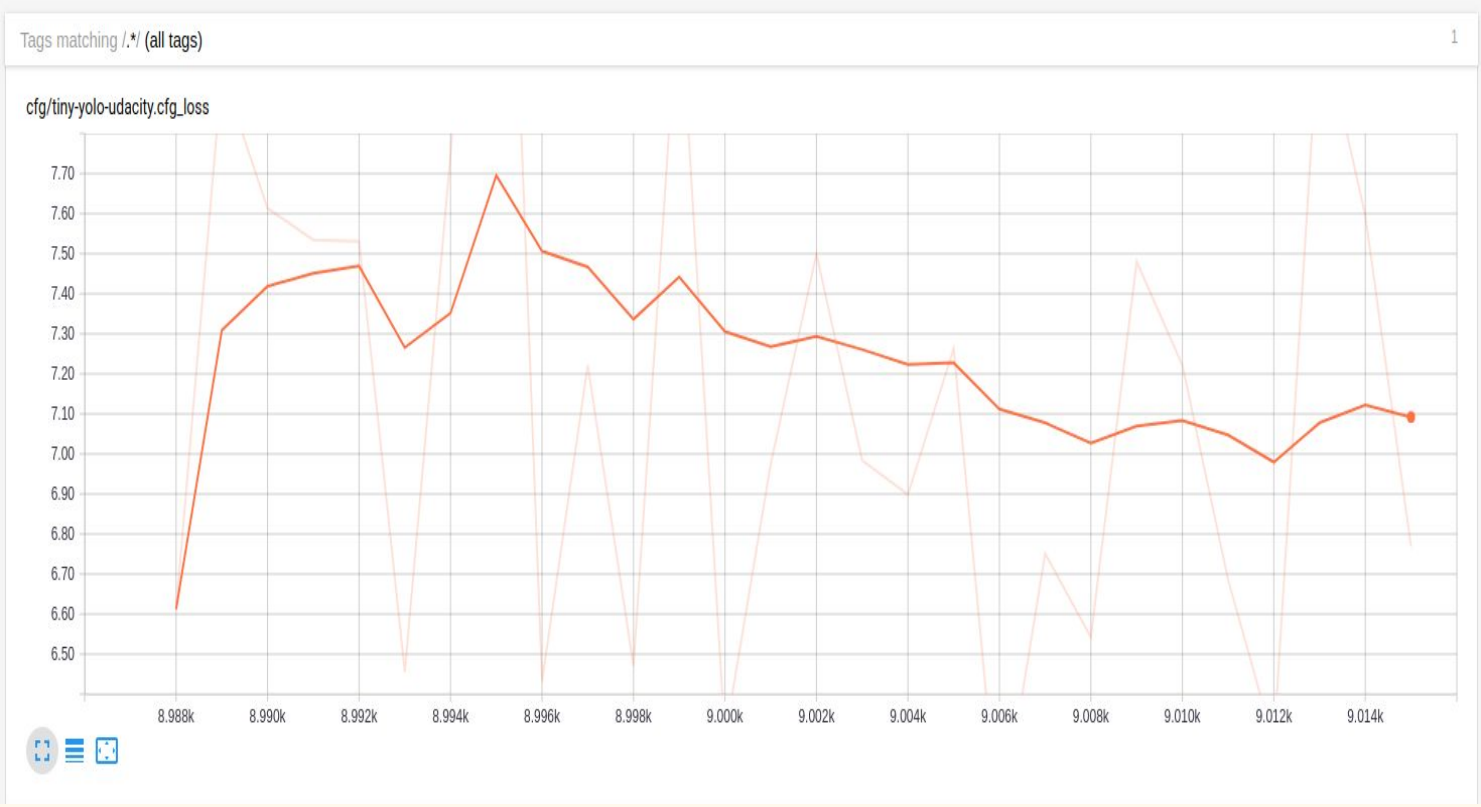
In order to add the tensorboard support to monitor the loss, I have modified the source code(/net/yolov2/train.py Line:107) by adding tf.summary.scalar ops to the node that gives loss as the output. Tf.summary.merge_all( ) will produce a serialized summary protobuf object and with the summary data at each step. Finally, to write it to the disk, I have passed the protobuf object to tf.summary.FileWriter( ). These modifications can be seen at line 95 of the file net/build.py. I have also included a new argument --summary where you give the location to which the summary has to be stored. This can be called from the command line and the modification has been done in the file /flow. After storing, we can run the tensorboard using the following command.

tensorboard --logdir = <summary directory>

The following screenshot is the plot of the loss value plotted against the number of training steps, from the tensorboard. This loss value is actually from the model that was trained to overfit the small dataset(~5 images) in order to check if the network is working fine. The loss value has dropped from 112 to ~13 in just 50 iterations.



On the other hand, the plot of the loss value for a model loaded with pre trained weights, is oscillatory around the loss value of ~7.5 after 8900 iterations.



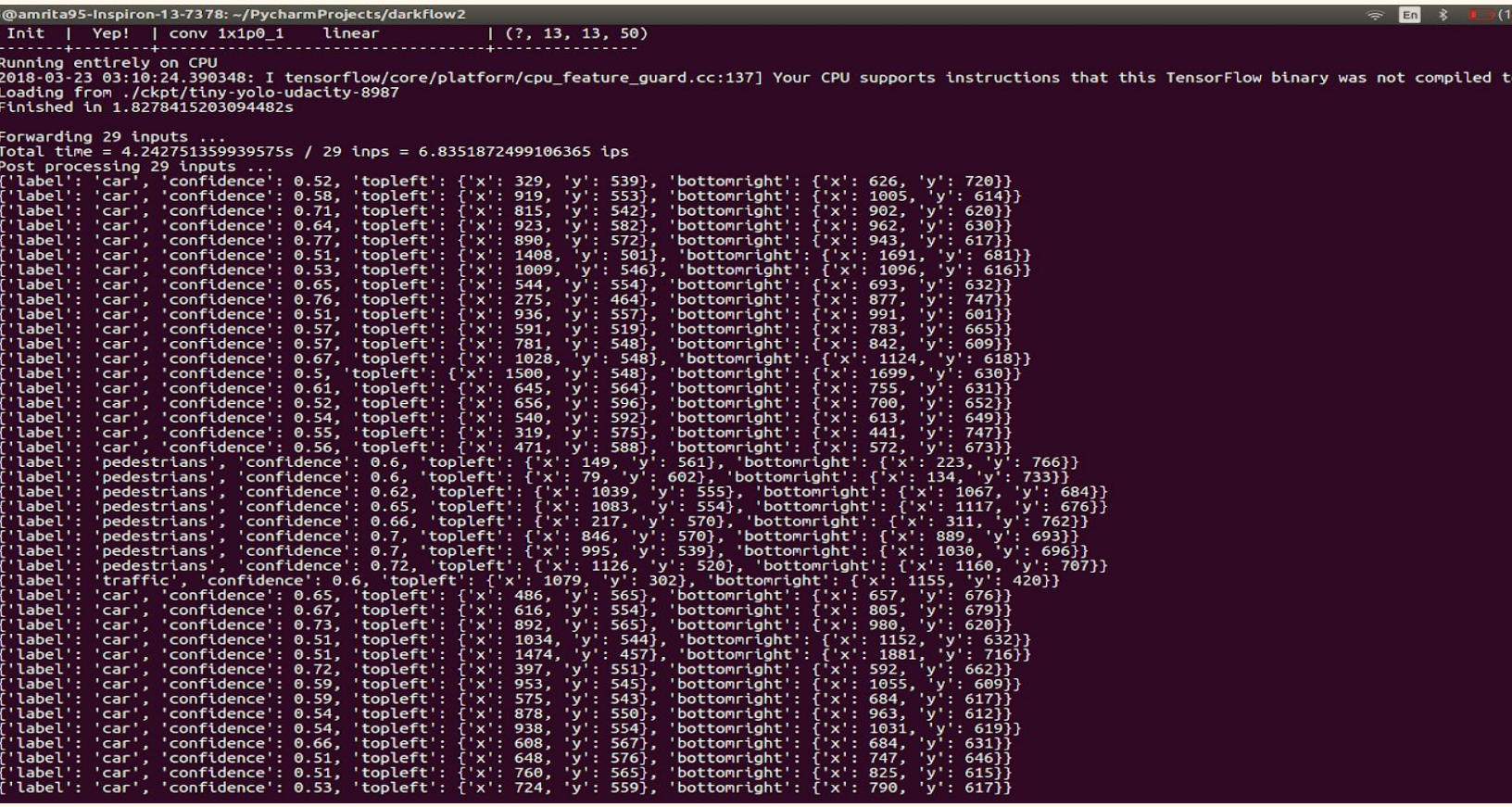
JSON:

I have modified the code */net/yolov2/test.py* in order to output the JSON for each image and saved the JSON as a *text* file in the directory */test/out* . I have also modified the file /flow in order to add a parameter --json of boolean type. When this parameter is set to true, the JSON output will be shown and it will be saved.

The following command will run the detector and will also save and the JSON is displayed as an output along with it. Here --load 9707 denotes the loading of weights from a checkpoint saved at 9707th step.

```
./flow --model cfg/tiny-yolo-udacity.cfg --load 9707 --json True
```

The following screenshot shows the JSON output for each of image in the */test* folder.

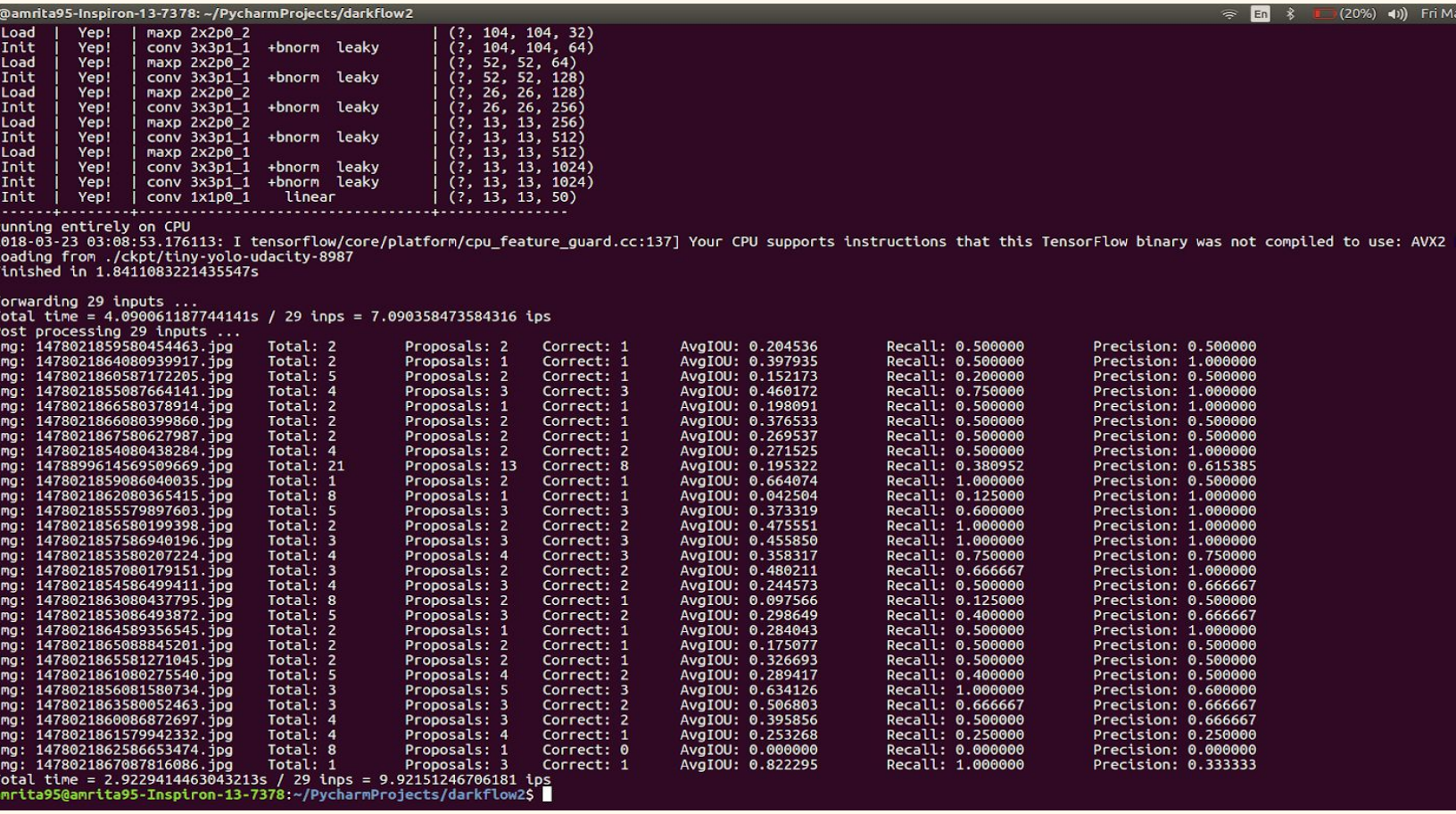


Additional Key Performance Indicators (KPI):

I have modified the */net/yolov2/test.py* file and also added a new file in the *utils* directory */utils/additionalKPI.py*. The new file contains the code, which calculates the number of actual bounding boxes in each image (Total), the number of bounding boxes predicted by the network (Proposal) and also the number of predicted boxes which are correct by thresholding on the IOU of the predicted and actual bounding box(Correct). Now the recall and precision for each of the image can be found as correct/total and correct/predicted respectively. The average IOU is average of all the IOUs that are taken between predicted and actual bounding boxes in a single image. I have a also added a boolean feature in */flow* to output these values whenever that parameter is set true. The command to display the KPIs is as follows.

```
./flow --model cfg/tiny-yolo-udacity.cfg --load 9707 --json False --kpi True
```

The screenshot below shows the new KPIs for the test images.

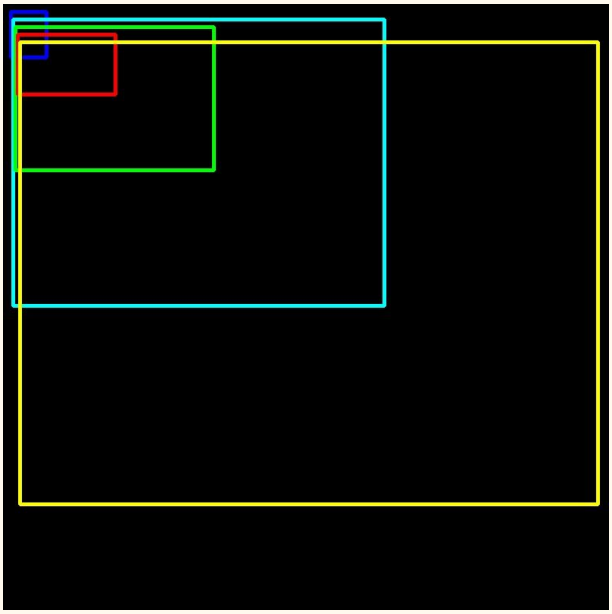


Section 4:

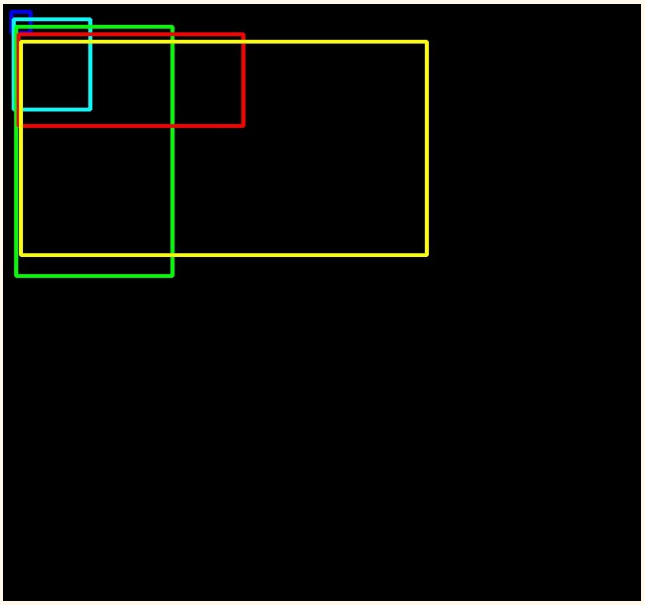
YOLO uses pre-calculated anchor box in the training. The original YOLO's anchor boxes are calculated from VOC 2007 dataset using K-mean cluster algorithm.

To find the anchor boxes, I have first extracted the width and height of all the bounding boxes present in the images of udacity dataset and applied K-means algorithm using width and height as the feature. I took the number of clusters to be 5, one for each class in the udacity dataset. I have included a new file for finding the anchor boxes (*/utils/kmeans_anchor.py)*. The following is a representation of the anchor boxes found using k-means. Based on

intuition, as we can see the anchor boxes derived from VOC dataset would perform better than the udacity anchor boxes.



Udacity Anchor boxes



VOC dataset anchor boxes

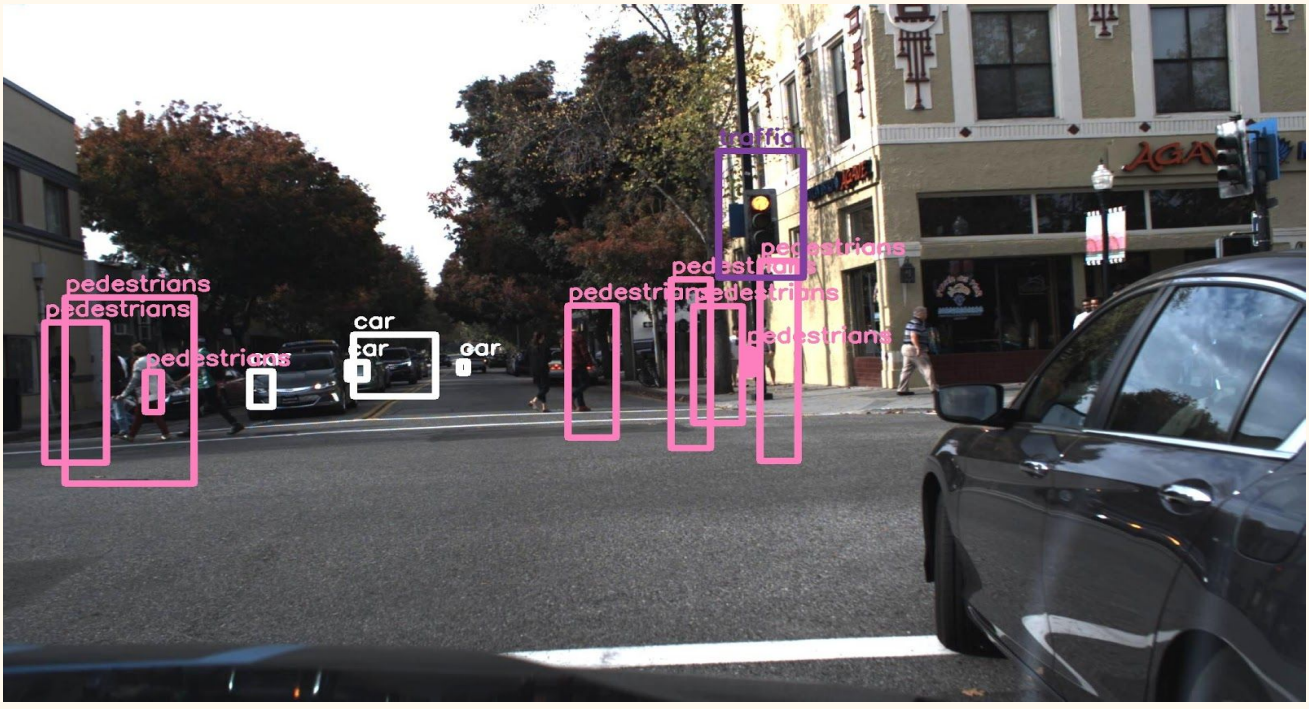
After fitting the K-means model on the udacity dataset, the centre points of each of the clusters are assumed to be the width and height of the anchor boxes. These were then converted to the scale of 13 x 13 in order to be provided to the network. The anchor box data is provided in the table below.

	Width	*Height*
Anchor box 1	*1.79455642*	*2.19526107*
Anchor box 2	*8.7824603*	*6.90141213*
Anchor box 3	*24.54700779*	*20.62964766*
Anchor box 4	*15.78625389*	*12.48136682*
Anchor box 5	*4.68438428*	*3.74576042*

The performance of the detector using the new anchor boxes is shown below in the screenshot. The output produced by the network using the new anchor boxes is shown in the second image below.

```
amrita95@amrita95-Inspiron-13-7378: ~/PycharmProjects/darkflow2
 Load  |  Yep!  | maxp 2x2p0_2                    | (?, 104, 104, 32)
 Init  |  Yep!  | conv 3x3p1_1  +bnorm  leaky     | (?, 104, 104, 64)
 Load  |  Yep!  | maxp 2x2p0_2                    | (?, 52, 52, 64)
 Init  |  Yep!  | conv 3x3p1_1  +bnorm  leaky     | (?, 52, 52, 128)
 Load  |  Yep!  | maxp 2x2p0_2                    | (?, 26, 26, 128)
 Init  |  Yep!  | conv 3x3p1_1  +bnorm  leaky     | (?, 26, 26, 256)
 Load  |  Yep!  | maxp 2x2p0_2                    | (?, 13, 13, 256)
 Init  |  Yep!  | conv 3x3p1_1  +bnorm  leaky     | (?, 13, 13, 512)
 Load  |  Yep!  | maxp 2x2p0_1                    | (?, 13, 13, 512)
 Init  |  Yep!  | conv 3x3p1_1  +bnorm  leaky     | (?, 13, 13, 1024)
 Init  |  Yep!  | conv 3x3p1_1  +bnorm  leaky     | (?, 13, 13, 1024)
 Init  |  Yep!  | conv 1x1p0_1    linear          | (?, 13, 13, 50)
-------+--------+---------------------------------+--------------
Running entirely on CPU
2018-03-23 19:47:32.312492: I tensorflow/core/platform/cpu_feature_guard.cc:137] Your CPU supports instructions that this TensorFlow binary was not compiled to use:
Loading from ./ckpt/tiny-yolo-udacity-anchr-8987
Finished in 1.962388277053833s

Forwarding 29 inputs ...
Total time = 3.759228229522705s / 29 inps = 7.714349390189065 ips
Post processing 29 inputs ...
Img: 1478021859580454463.jpg    Total: 2        Proposals: 3    Correct: 1      AvgIOU: 0.315675        Recall: 0.500000        Precision: 0.333333
Img: 1478021864080939917.jpg    Total: 2        Proposals: 2    Correct: 1      AvgIOU: 0.225689        Recall: 0.500000        Precision: 0.500000
Img: 1478021860587172205.jpg    Total: 5        Proposals: 2    Correct: 1      AvgIOU: 0.090593        Recall: 0.200000        Precision: 0.500000
Img: 1478021855087664141.jpg    Total: 4        Proposals: 4    Correct: 2      AvgIOU: 0.204120        Recall: 0.500000        Precision: 0.500000
Img: 1478021866580378914.jpg    Total: 2        Proposals: 2    Correct: 0      AvgIOU: 0.264709        Recall: 0.000000        Precision: 0.000000
Img: 1478021866080399860.jpg    Total: 2        Proposals: 3    Correct: 1      AvgIOU: 0.430863        Recall: 0.500000        Precision: 0.333333
Img: 1478021867580627987.jpg    Total: 2        Proposals: 3    Correct: 0      AvgIOU: 0.235409        Recall: 0.000000        Precision: 0.000000
Img: 1478021854080438284.jpg    Total: 4        Proposals: 4    Correct: 2      AvgIOU: 0.247876        Recall: 0.500000        Precision: 0.500000
Img: 1478899614569509669.jpg    Total: 21       Proposals: 13   Correct: 2      AvgIOU: 0.115300        Recall: 0.095238        Precision: 0.153846
Img: 1478021859086040035.jpg    Total: 1        Proposals: 3    Correct: 1      AvgIOU: 0.473086        Recall: 1.000000        Precision: 0.333333
Img: 1478021862080365415.jpg    Total: 8        Proposals: 2    Correct: 0      AvgIOU: 0.038014        Recall: 0.000000        Precision: 0.000000
Img: 1478021855579897603.jpg    Total: 5        Proposals: 5    Correct: 1      AvgIOU: 0.199913        Recall: 0.200000        Precision: 0.200000
Img: 1478021856580199398.jpg    Total: 2        Proposals: 4    Correct: 1      AvgIOU: 0.508046        Recall: 0.500000        Precision: 0.250000
Img: 1478021857586940196.jpg    Total: 3        Proposals: 4    Correct: 1      AvgIOU: 0.337282        Recall: 0.333333        Precision: 0.250000
Img: 1478021853580207224.jpg    Total: 4        Proposals: 4    Correct: 2      AvgIOU: 0.271471        Recall: 0.500000        Precision: 0.500000
Img: 1478021857080179151.jpg    Total: 3        Proposals: 4    Correct: 1      AvgIOU: 0.330809        Recall: 0.333333        Precision: 0.250000
Img: 1478021854586499411.jpg    Total: 4        Proposals: 5    Correct: 1      AvgIOU: 0.283357        Recall: 0.250000        Precision: 0.200000
Img: 1478021863080437795.jpg    Total: 8        Proposals: 3    Correct: 1      AvgIOU: 0.042265        Recall: 0.125000        Precision: 0.333333
Img: 1478021853086493872.jpg    Total: 5        Proposals: 4    Correct: 1      AvgIOU: 0.165943        Recall: 0.200000        Precision: 0.250000
Img: 1478021864589356545.jpg    Total: 2        Proposals: 2    Correct: 1      AvgIOU: 0.263546        Recall: 0.500000        Precision: 0.500000
Img: 1478021865088845201.jpg    Total: 2        Proposals: 3    Correct: 1      AvgIOU: 0.269990        Recall: 0.500000        Precision: 0.333333
Img: 1478021865581271045.jpg    Total: 2        Proposals: 3    Correct: 1      AvgIOU: 0.256260        Recall: 0.500000        Precision: 0.333333
Img: 1478021861080275540.jpg    Total: 5        Proposals: 3    Correct: 1      AvgIOU: 0.107540        Recall: 0.200000        Precision: 0.333333
Img: 1478021856081580734.jpg    Total: 3        Proposals: 7    Correct: 2      AvgIOU: 0.424500        Recall: 0.666667        Precision: 0.285714
Img: 1478021863580052463.jpg    Total: 3        Proposals: 4    Correct: 2      AvgIOU: 0.255273        Recall: 0.666667        Precision: 0.500000
Img: 1478021860086872697.jpg    Total: 4        Proposals: 4    Correct: 1      AvgIOU: 0.187312        Recall: 0.250000        Precision: 0.250000
Img: 1478021861579942332.jpg    Total: 4        Proposals: 3    Correct: 1      AvgIOU: 0.164226        Recall: 0.250000        Precision: 0.333333
Img: 1478021862586653474.jpg    Total: 8        Proposals: 1    Correct: 0      AvgIOU: 0.000000        Recall: 0.000000        Precision: 0.000000
Img: 1478021867087816086.jpg    Total: 1        Proposals: 3    Correct: 0      AvgIOU: 0.216924        Recall: 0.000000        Precision: 0.000000
Total time = 2.8425841331481934s / 29 inps = 10.20198475810184 ips
amrita95@amrita95-Inspiron-13-7378:~/PycharmProjects/darkflow2$
```



Section 5:

Can you improve the network to get a better result?

1. To improve the object detection, I tried increasing the resolution of the image. This improved the precision of the detection, and the network was able to predict smaller objects with more precision. I implemented this as a modification in the cfg file ./cfg/tiny-yolo-udacity.cfg by changing the values of height and width from 416 to 608 or 832 (or any multiples of 32). The KPIs after the change is shown in the screenshot below.

```
Forwarding 29 inputs ...
Total time = 17.915765047073364s / 29 inps = 1.6186861082294282 ips
Post processing 29 inputs ...
Img: 1478021859580454463.jpg    Total: 2        Proposals: 5    Correct: 1      AvgIOU: 0.178796        Recall: 0.500000        Precision: 0.200000
Img: 1478021864080939917.jpg    Total: 2        Proposals: 2    Correct: 2      AvgIOU: 0.800348        Recall: 1.000000        Precision: 1.000000
Img: 1478021860587172205.jpg    Total: 5        Proposals: 3    Correct: 0      AvgIOU: 0.115062        Recall: 0.000000        Precision: 0.000000
Img: 1478021855087664141.jpg    Total: 4        Proposals: 3    Correct: 1      AvgIOU: 0.128645        Recall: 0.250000        Precision: 0.333333
Img: 1478021866580378914.jpg    Total: 2        Proposals: 6    Correct: 2      AvgIOU: 0.660984        Recall: 1.000000        Precision: 0.333333
Img: 1478021866080399860.jpg    Total: 2        Proposals: 4    Correct: 2      AvgIOU: 0.774210        Recall: 1.000000        Precision: 0.500000
Img: 1478021867580627987.jpg    Total: 2        Proposals: 3    Correct: 2      AvgIOU: 0.465384        Recall: 1.000000        Precision: 0.666667
Img: 1478021854080438284.jpg    Total: 4        Proposals: 4    Correct: 2      AvgIOU: 0.353844        Recall: 0.500000        Precision: 0.500000
Img: 1478899614569509669.jpg    Total: 21       Proposals: 7    Correct: 4      AvgIOU: 0.091149        Recall: 0.190476        Precision: 0.571429
Img: 1478021859086040035.jpg    Total: 1        Proposals: 6    Correct: 1      AvgIOU: 0.692903        Recall: 1.000000        Precision: 0.166667
Img: 1478021862080365415.jpg    Total: 8        Proposals: 3    Correct: 2      AvgIOU: 0.152844        Recall: 0.250000        Precision: 0.666667
Img: 1478021855579897603.jpg    Total: 5        Proposals: 4    Correct: 3      AvgIOU: 0.363031        Recall: 0.600000        Precision: 0.750000
Img: 1478021856580199398.jpg    Total: 2        Proposals: 4    Correct: 2      AvgIOU: 0.532471        Recall: 1.000000        Precision: 0.500000
Img: 1478021857586940196.jpg    Total: 3        Proposals: 2    Correct: 2      AvgIOU: 0.333627        Recall: 0.666667        Precision: 1.000000
Img: 1478021853580207224.jpg    Total: 4        Proposals: 7    Correct: 2      AvgIOU: 0.299466        Recall: 0.500000        Precision: 0.285714
Img: 1478021857080179151.jpg    Total: 3        Proposals: 3    Correct: 3      AvgIOU: 0.629527        Recall: 1.000000        Precision: 1.000000
Img: 1478021854586499411.jpg    Total: 4        Proposals: 3    Correct: 2      AvgIOU: 0.268172        Recall: 0.500000        Precision: 0.666667
Img: 1478021863080437795.jpg    Total: 8        Proposals: 3    Correct: 2      AvgIOU: 0.101607        Recall: 0.250000        Precision: 0.666667
Img: 1478021853086493872.jpg    Total: 5        Proposals: 4    Correct: 1      AvgIOU: 0.146627        Recall: 0.200000        Precision: 0.250000
Img: 1478021864589356545.jpg    Total: 2        Proposals: 3    Correct: 2      AvgIOU: 0.450589        Recall: 1.000000        Precision: 0.666667
Img: 1478021865088845201.jpg    Total: 2        Proposals: 3    Correct: 2      AvgIOU: 0.566301        Recall: 1.000000        Precision: 0.666667
Img: 1478021865581271045.jpg    Total: 2        Proposals: 5    Correct: 2      AvgIOU: 0.743762        Recall: 1.000000        Precision: 0.400000
Img: 1478021861080275540.jpg    Total: 5        Proposals: 5    Correct: 1      AvgIOU: 0.273671        Recall: 0.200000        Precision: 0.200000
Img: 1478021856081580734.jpg    Total: 3        Proposals: 2    Correct: 2      AvgIOU: 0.437341        Recall: 0.666667        Precision: 1.000000
Img: 1478021863580052463.jpg    Total: 3        Proposals: 3    Correct: 3      AvgIOU: 0.578902        Recall: 1.000000        Precision: 1.000000
Img: 1478021860086872697.jpg    Total: 4        Proposals: 3    Correct: 1      AvgIOU: 0.212242        Recall: 0.250000        Precision: 0.333333
Img: 1478021861579942332.jpg    Total: 4        Proposals: 4    Correct: 1      AvgIOU: 0.221056        Recall: 0.250000        Precision: 0.250000
Img: 1478021862586653474.jpg    Total: 8        Proposals: 5    Correct: 4      AvgIOU: 0.250552        Recall: 0.500000        Precision: 0.800000
Img: 1478021867087816086.jpg    Total: 1        Proposals: 5    Correct: 1      AvgIOU: 0.592133        Recall: 1.000000        Precision: 0.200000
Total time = 6.419684410095215s / 29 inps = 4.51735601743854 ips
```

The output of one image is shown below. As we can see, the network was able to predict even a car that was very far away with high precision.

2. Other suggestions to improve the performance (which I haven't tried out) are:

- Increase the resolution of the network before training of the model. This would possibly improve the precision but the training consumed more time than expected. (ran only 400 iterations in 12 hours in my laptop). This improvement is again related to changing the height and width of the input in the .cfg file that we are using.
- Augment more data in the training dataset, with different scales, rotation, lighting setup etc. Also, augment data with no objects of concern (negative examples) where you want your network to predict nothing.