Image Processing & Computer Vision Coursework Report

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1. The Viola-Jones Object Detector

Ground Truth and Visualization

This part using green boxes to visualize possible faces detected by Viola-Jones detector. For the ground truth value, which were obtained by direct observation and manually annotation, is bounded in the red boxes.

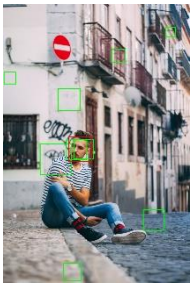


Figure 1: NoEntry1.jpg

Figure 2: NoEntry2.jpg

Figure 3: NoEntry4.jpg

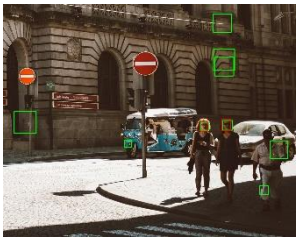


Figure 4: NoEntry11.jpg

Figure 5: NoEntry5.jpg

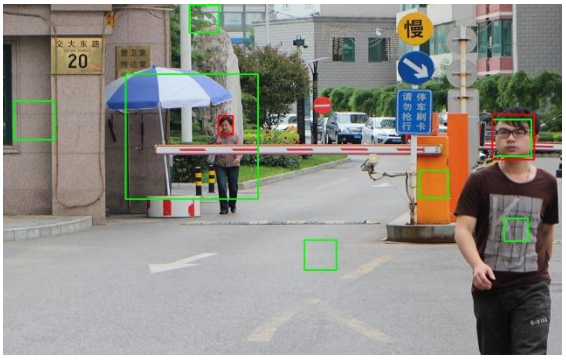


Figure 6: NoEntry7.jpg

There is a ground truth which I think is a frontal face on the left-hand side in Figure 6.

IOU, TPR, F1 Score

The intersection over union (IOU) which is a numeric metric for the overlapping area are used to measure the accuracy of Viola-Jones detector. If the IOU exceed certain value, then we think this is a correct detection. Here I choose the threshold of IOU at 40%.

True positive rate (TPR) is the number of correct detections over ground truth value. And F1 score is calculated by the following formula. It is also a measure of accuracy of test and take the false positive and false negative into account.

$$F_1 = 2 \cdot \frac{\mathrm{precision} \cdot \mathrm{recall}}{\mathrm{precision} + \mathrm{recall}} = \frac{\mathrm{TP}}{\mathrm{TP} + \frac{1}{2}(\mathrm{FP} + \mathrm{FN})}$$

Figure 7: F1 score

Test	TPR (%)	F1 Score
NoEntry0.jpg	-	-
NoEntry1.jpg	100	0.364
NoEntry2.jpg	100	0.250
NoEntry3.jpg	-	-
NoEntry4.jpg	100	0.324
NoEntry5.jpg	100	0.333
NoEntry6.jpg	-	-
NoEntry7.jpg	50	0.250
NoEntry8.jpg	-	-
NoEntry9.jpg	-	-
NoEntry10.jpg	-	-
NoEntry11.jpg	100	0.364
NoEntry12.jpg	-	-
NoEntry13.jpg	-	-
NoEntry14.jpg	-	-
NoEntry15.jpg	-	-

Table 1: faces

Since the calculation of TPR is dependent on number of ground truth. When there are no faces in the image, ground truth number equals zero, TPR therefore becomes meaningless by dividing 0. ‘NoEntry7.jpg’ does reach 100% TPR in the table because of low IOU between the left-hand face and ground truth faces. However, it is always possible for every detection task to reach 100% TPR by lowering the threshold of IOU and enlarging the bounding box. In general, F1 score is more reliable to be the metric in this task.

2. Building & Testing my Detector

Training Performance

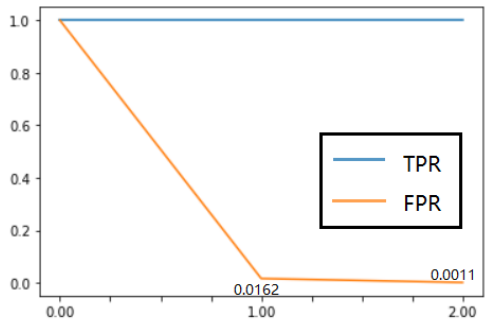


Figure 8

Here is the plot of TPR & FPR for each training stage. It can be seen from the graph that the TPR of Viola-Jones detector always keeps at 100%, while the FPR rate drops dramatically at each stage.

Testing Performance

The following table records the training performance for my Viola-Jones detector.

Picture	Number Detected	TPR	F1 Score
NoEntry0	51	1	0.0754717
NoEntry1	24	1	0.08
NoEntry2	29	1	0.0666667
NoEntry3	14	1	0.25
NoEntry4	39	1	0.097561
NoEntry5	41	0.25	0.097561
NoEntry6	10	0.25	0.142857
NoEntry7	18	0	0
NoEntry8	13	0.75	0.352941
NoEntry9	20	1	0.0952381
NoEntry10	14	0.67	0.235294
NoEntry11	18	0.5	0.1
NoEntry12	22	0.5	0.214286
NoEntry13	34	0	0
NoEntry14	17	0	0
NoEntry15	6	1	0.5
Average		0.62	0.144242

From the table we can evaluate the training performance by looking at the average TPR and F1 score over the 16 pictures. It turned out that the precision of my trained detector on no entry signs is not good. The average F1 score is too low because it detects too many false positives. And the average TPR is also lower by 30% than the face detector in section 1. I pick three pictures which does not reach 100% TPR below.

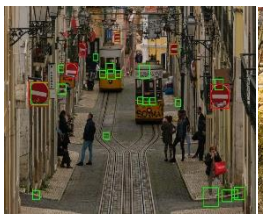


Figure 9: NoEntry12

Figure 10: NoEntry6

Figure 11: NoEntry10

It is possible to conclude the cause of low precision in section 2 compared to section 1 from these 3 pictures.

- Not working well on occlusions. Fig.9 and fig.11 both have false negatives on signs which are covered or occluded.
- *opencv_createsamples* do not generate enough samples on different angles. Fig.9 and fig.10 both have false negatives on signs which are rotated.
- *opencv_traincascade* do not train powerful Haar like features. Fig.11 have one false positive on the turn right sign which is blue and too many false positives on plate with white stride.

The main reason why TPR differ from training performance is the programme chooses a higher IOU. As section 1 argued, it is always possible to reach 100% TPR by lowering the IOU and enlarging the bounding boxes. Hence the training performance reach 1 while testing does not .

In the next section, this paper is going to introduce the method to improve the precision.

3. Integration with Shape Detector

Hough Details

The following pictures are two set of threshold magnitude, Hough space and final detections.

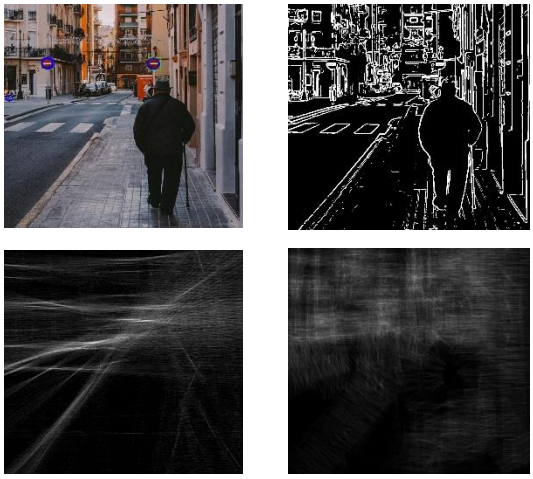


Figure 12: NoEntry0 and its Hough space

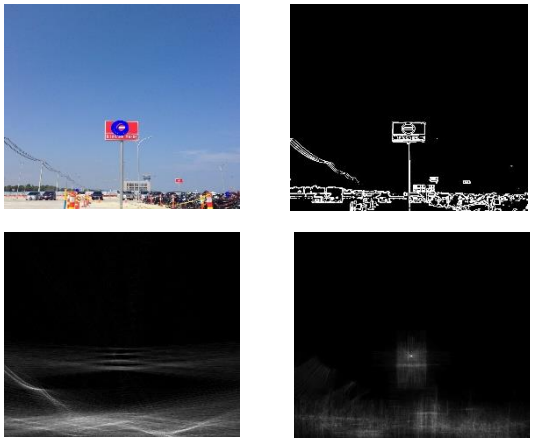


Figure 13: NoEntry9 and its Hough space

Here the programme chooses the threshold of 70 to normalized magnitude image and treat every point larger than 15 in the 3D Hough circle space as a circle. This set of limitation is suitable for all the images in 'No_entry' folder after test. The circle is drawn in blue colour, detected sign in green boxes, and ground truth in red.

Evaluation

The table on the right shows the performance after applying Hough circle filter to Viola-Jones detector.

Key merits:

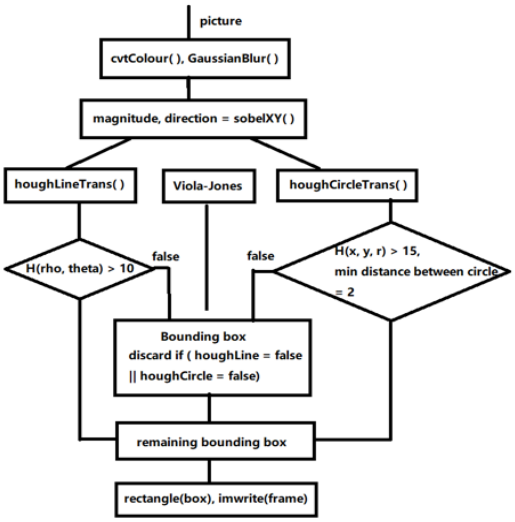
- F1 score increase by 0.4 than before.
- False positive decrease as there are not too many green boxes in the detected picture.

Shortcomings:

- Slightly decrease in TPR by 0.0575.
- Cannot affect the position of bounding boxes, only filter out.
- Cannot delete all false positives.

Picture	TPR	△TPR	F1Score	△F1
NoEntry0	1	0	1	+0.9245
NoEntry1	1	0	1	+0.92
NoEntry2	1	0	0.666667	+0.6
NoEntry3	1	0	0.571429	+0.3214
NoEntry4	1	0	1	+0.9245
NoEntry5	0	-0.25	0	-0.0976
NoEntry6	0.25	0	0.4	+0.2572
NoEntry7	0	0	0	0
NoEntry8	0.75	0	0.857143	+0.5042
NoEntry9	1	0	1	+0.9245
NoEntry10	0.67	0	0.666667	+0.4313
NoEntry11	0.5	0	0.5	+0.4
NoEntry12	0.33	-0.17	0.5	+0.2858
NoEntry13	0	0	0	0
NoEntry14	0	0	0	0
NoEntry15	0.5	-0.5	0.666667	+0.1667
Average	0.5625	-0.0575	0.551786	+0.4075

Detection Pipeline



- There are too many false positives in images, Viola-Jones detector need a filter on output.
- No entry sign has clear geometry shape such as circles and lines, bounding boxes do not contain them is not correct.
- Combine detector with Hough filter, modify the threshold to reach the best testing performance.
- I set a low distance between circle centres to avoid some correct circles be removed hence increase the error.

4. Improving my detector

Idea

I improve the performance of detector by adding HSV filter at the top of working flows of detector.

- Sometimes the detector will mis-classify blue turn right signs with no entry signs because they have similar features and geometry. This is dangerous for traffic.
- Viola-Jones and shape detector takes grey image as input, this will discard the colour information of no entry sign. We can hence improve the performance of detector by filtering out red colour then send the image to the detector.
- RGB value varies depend on the lighting condition. While the HSV value remains constant in most situation. So, the HSV filter is more appropriate for this task.

The HSV filter mask range in [0-20, 100-255, 20-255] and [160-179, 100-255, 20-255]. Every pixel without this range will be discard.

Visualise

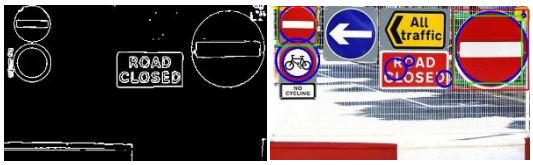


Figure 14: NoEntry3

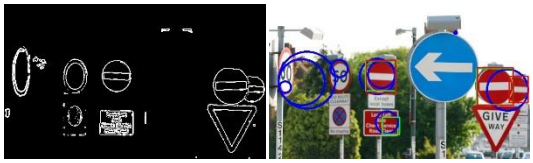


Figure 15: NoEntry10

The graph above is the threshold magnitude image after Sobel filter and HSV filter. It is easy to see that there are no blue signs anymore. As a result, it can increase f1 score by filter out false positives.

Evaluation

Picture	TPR	△TPR	F1 score	△F1
NoEntry3	1	0	1	0.43
NoEntry10	0.67	0	0.8	0.13

The table above shows the performance after applying HSV filter to Viola-Jones detector.

Key merits:

- F1 score increase, less false positive.

Shortcomings:

- TPR remains same

In general, the HSV filter utilize the colour information hence remove signs that is not in red. However, both HSV filter and Hough shape detector are filtering out the output of Viola-Jones detector. If there is no improvement on Viola-Jones detector, it will never lead to an increase in TPR.

Future improvement

This part is some further improvement can be used on the detector.

- The performance of Viola-Jones detector can be improved by training with larger data set. In this coursework it uses the data set of 500 positive examples and 500 negative examples. However, this is a small number for machine learning and deep learning.
- Sometimes train the detector again will give different result. This is because each training stage may choose different Haar like features. We can train detector for several times and use cascade file from the best testing results.
- IOU and bounding boxes size will affect the TPR. We can use lower IOU and larger bounding boxes. This can improve the performance numerically, but not in the real.