Image Processing and Computer Vision

The Dartboard Challenge - Report

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Introduction

Our task for this coursework was to apply the techniques gathered throughout this unit's practical sessions and implement an image object detection algorithm.

Task 1

Ground truth and visualisation

For the first subtask, we made use of OpenCV's *Viola Jones* detector. We applied it on our images in order to detect human faces, which we marked using *green* bounding rectangles.

Simultaneously, we marked the ground truth by hand, by annotating the images with red boxes.

Fig. 1: The annotated images. From left to right/up to down: dart5, dart13, dart4, dart15, dart14

IOU, TPR, F1-SCORE

In many detection tasks, a 100% TPR can be very easily achievable. This is a consequence of the fact that, in order to ensure that most of the sought objects are detected, the classifier marks as many potential regions of the image as possible. However, the downside is that a much larger rate of false positives is produced.

Image	TPR	F1 Score
dart0.jpg	0	0
dart1.jpg	n/a	1
dart2.jpg	n/a	1
dart3.jpg	n/a	1
dart4.jpg	1	1
dart5.jpg	0.90	0.83
dart6.jpg	0	0
dart7.jpg	1	1
dart8.jpg	n/a	0
dart9.jpg	1	0.4
dart10.jpg	n/a	0
dart11.jpg	1	1
dart12.jpg	n/a	0
dart13.jpg	1	0.5
dart14.jpg	1	0.44
dart15.jpg	0.33	0.5

Table 1: The TPR and F1 score for all 16 images

In our task, this is visible, for example, in the bottom image of *Fig. 1*, where various sections of the cup are detected as faces. A more accurate detector would be one which produces a significant decrease of the FPR.

To show this lack of correctness, we have written an algorithm to calculate the F1 score for each of the images, and we've displayed the values in *Table 1*, along with the respective TPRs.

Task 2

Training performance

Figure 2 illustrates how the detector was trained over the course of 3 stages. The detector was successful in identifying all the boards, because the TPR remained at the value of 1 over the course of all stages. The decreasing value of the FPR illustrates how, at the beginning, the algorithm detects a high number of objects and, then, that number is lowered. This makes it clear that the detector is improving. We used a ratio of 500:500, positive to negative and a maximum false alarm rate of 0.5.

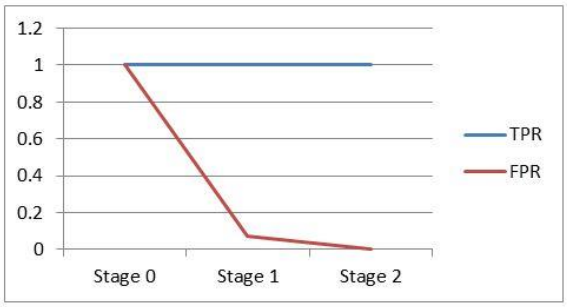


Fig. 2: Flowchart denoting the TPR vs FPR values throughout the three stages.

Fig.3: Images with annotated detections: dart0, dart1, dart15

Testing performance

The current F1 score is 0.19, which shows a low performance of the detector. This means that there was a high number of false positive detections in comparison with the number of true positive detections. As presented in *Figure 2,* the FPR is decreasing, while the TPR stays at 1. This denotes the fact that the detector is currently underfitting the data. In combination with the low F1 score, this proves that our current detector's performance is poor.

Image	TPR	F1 Score
dart0.jpg	1	0.2
dart1.jpg	1	0.66
dart2.jpg	1	0.22
dart3.jpg	1	0.28
dart4.jpg	0	0
dart5.jpg	1	0.2
dart6.jpg	1	0.14
dart7.jpg	1	0.05
dart8.jpg	1	0.12
dart9.jpg	1	0.2
dart10.jpg	0.33	0.05
dart11.jpg	1	0.33
dart12.jpg	0	0
dart13.jpg	0	0
dart14.jpg	0.5	0.04
dart15.jpg	1	0.66
AVERAGE	0.73	0.19

Table 2: The TPR and F1 score for all 16 images and their average

Task 3

Hough details

For this subtask, we decided to make use of the *Hough Circle* transform implementation as an enhancement to our detector's performance.

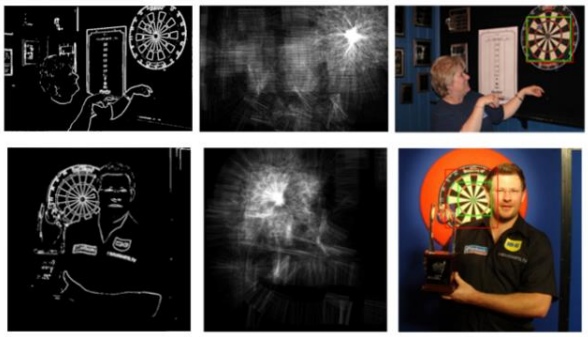


Fig. 4: from left to right: the thresholded gradient magnitude images, the Hough spaces and the resulted annotated images. "dart0" (top-most) shows the merit and "dart4" (bottom-most) shows the limitations of our implementation.

Evaluation

Image	TPR task 2	TPR task 3	F1 score task 2	F1 score task 3
dart0.jpg	1	1	0.2	1
dart1.jpg	1	1	0.66	1
dart2.jpg	1	1	0.22	1
dart3.jpg	1	0	0.28	0
dart4.jpg	0	0	0	0
dart5.jpg	1	1	0.2	1
dart6.jpg	1	1	0.14	1
dart7.jpg	1	0	0.05	0
dart8.jpg	1	0.5	0.12	0.8
dart9.jpg	1	1	0.2	1
dart10.jpg	0.33	0	0.05	0
dart11.jpg	1	1	0.33	1
dart12.jpg	0	0	0	0
dart13.jpg	0	0	0	0
dart14.jpg	0.5	0.5	0.04	0.66
dart15.jpg	1	1	0.66	1
AVERAGE	0.73	0.56	0.19	0.59

Table 3: The TPR and F1 score for all 16 images and their average, comparing the differences between Viola Jones and our implementation.

Advantages of using this implementation:

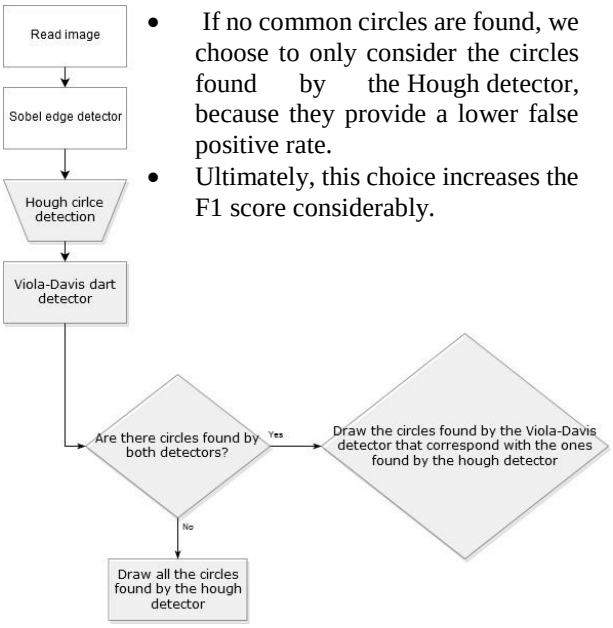
- false positive rate is reduced
- most of the noise in the image is reduced (as a result of Gaussian blurring)
- detections are more accurate (the algorithm is specifically seeking circles)

Disadvantages and limitations:

- Inability to detect dartboards from certain angles (i.e. in *Fig.4* an ellipse would be a much more suitable geometrical choice)
- Because the magnitude threshold is consistent for all images, some dartboards may not be detected if they're lighter or darker than the average. Hence, the resulting outline of the object can end up incomplete.

Detection pipeline

- The Viola-Davis detector does a great job at detecting the dartboards accurately, but has a significant rate of false positive detections, which lowers the F1 score
- The Hough detector can accurately identify circles, with a low false positive rate. The downside is that it may only detect the inner circle of the board.
- If a circle is detected by both our detectors, the true positive rate increases considerably.
- The Hough identifier helps exclude the false positives made by the Viola-Davis detector.
- If no common circles are found, we choose to only consider the circles found by the Hough detector, because they provide a lower false positive rate.
- Ultimately, this choice increases the F1 score considerably.



- If no common circles are found, we choose to only consider the circles found by the Hough detector, because they provide a lower false positive rate.
- Ultimately, this choice increases the F1 score considerably.

Figure 5: Flow diagram describing the logic behind the combination of the detectors

Sign off:

Andrei Alexandru = 1

Erich-Robert Reinholtz = 1