COMS30121
Image Processing and Computer Vision (2016-17)
The Object Detection Challenge

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Subtask 1: The Viola-Jones Object Detector

Part(a) Test the face detectors performance

(a) dart 4   (b) dart 5   (c) dart 13   (d) dart 14   (e) dart 15

Figure 1: Five result images with bounding box drwan around detected face

Part(b) Calculate TPR and F1-score

- True Positive (TP): Face be detected

- False Positive (FP): Something is detected but not the face

- True Negative (TN): Not face and undetected

- False Negative (FN): Face but undetected

True Positive Rate (TPR)=TP/(TP+FN)=face be detected/ total face in the image

- Dart5: TPR=11/11=1   Dart15: TPR=2/3

Discussion:

1. Difficulties in assessing the TPR accurately:
   After testing all the sample pictures, the results showed that both background conditions and face itself can be the factors to affect the accuracy of TPR. Too complicated background may confuse the detector i.e., part of background has many similar characteristics of a face or the edges between face and background are ambiguous. In addition, side faces or faces turned in a large angle are not easy to be detected by this method(Figure 1(e)).

2. Why it is always possible to achieve a TPR of 100% on any detection task?
   TPR is a measurement only focus on whether the face has been detected or not, it does not care how many false detection occurs i.e., FP is not important. Therefore, decrease the standard of the face detector in recognising system will enable the TPR always be 100% on any detection tasks

3. An example set of measures and rules for F1-score of the detection system.
   Ground truth: the square should just cover the whole face features (reasonable size).

$$F1\,score = \frac{2 * Precision * Recall}{Precision + Recall} = \frac{2 * TP}{(2 * TP + FN + FP)} \tag{1}$$

   Precision also called positive predictive value (PPV) is "how useful the search results are"and recall also called true positive rate(TPR) is "how complete the results are". For example for dart 5: F1-score=0.88 however TPR=1. The TPR showed that all faces have been detected, however, the F1-score showed the accuracy of the detector.For this example it means some non-face objects also be detected by mistake. When F1-score=1,where both FN and FP equal to zero, the image detection can be defined as succeeded.

Subtask 2: Building & Testing our own Detector

Part(a) The training tool produces a strong classifier in stages

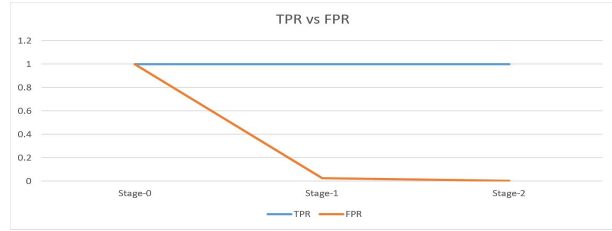|	TPR	FPR
Stage-0	1000:1000=1	1
Stage-1	1000:1000=1	0.023888
Stage-2	1000:1000=1	0.00119628

Table 1: TPR &FPR

Figure 2: TPR vs FPR

The TPR always kept as 1 but the FPR decreased when stage increased. This means after trainning this detector should be very strong. The FPR value should be nearly zero.

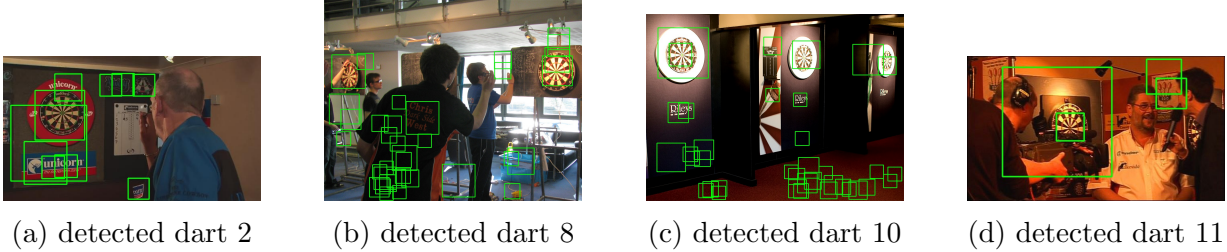## Part(b) Test the dartboard detectors performance

(a) detected dart 2   (b) detected dart 8   (c) detected dart 10   (d) detected dart 11

Figure 3: Result images with bounding box drwan around detected dartboard by Viola-Jones detector

Dart0= 0.13	Dart1= 0.4	Dart2= 0.18	Dart3= 0.18	Dart4= 0.28	Dart5= 0.1	Dart6= 0.14	Dart7=0.08
Dart8= 0.11	Dart9= 0.18	Dart10= 0.1	Dart11= 0.4	Dart12= 0	Dart13= 0.22	Dart14= 0.11	Dart15= 0.33
Overall F1-score=				0.139			

Table 2: F1-score of each dart image and the overall score

Compare results with the Figure 2 and Comment on the usefulness of the Figure 2:

- Definition of FPR: The false positive rate usually refers to the expectancy of the false positive ratio.

$$FPR = \frac{FP}{FP + TN} \tag{2}$$

- After 3 times training, the FPR rate decreased significantly from 1 to 0.001196 which is almost equal to zero. The extremely low value of FPR means FP value is low as the TN is a constant for each image. Therefore, the detector should be trained very well and enable to detect right dart only and provide a high F1-score.

- However, the F1-scores according to the ground truth of those dart images are miserable. The FPR is definitely higher than it's described.

- In my opinion, the figure 2 only showed that during the 3 stages, TPR stayed the same and FPR decreased. Nevertheless, according to this trend, after more training stages, the detector may provide more accurate results.

Subtask 3: Integration with Shape Detectors

Part(a) Merit and limitations of our implementation

(a) gradient magnitude

(b) 2D HoughLine Space

(c) Result image

(d) gradient magnitude

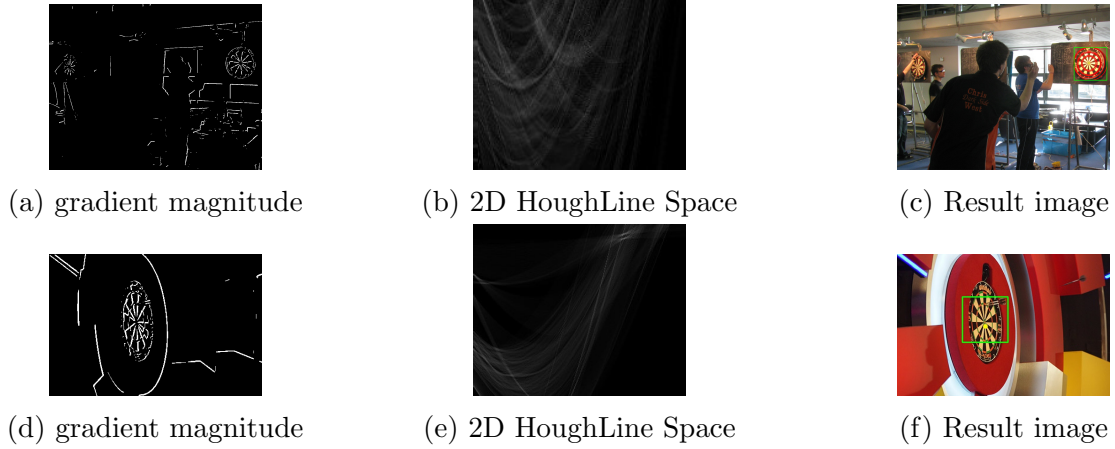

(e) 2D HoughLine Space

(f) Result image

Figure 4: Dart8 and Dart12 after applying the HoughLine and concentric circle detector

Part(b) Demonstrate our overall detection results

Dart0= 1	Dart1= 1	Dart2= 1	Dart3= 1	Dart4= 1	Dart5= 1	Dart6= 1	Dart7=0
Dart8= 0.67	Dart9= 1	Dart10= 0.5	Dart11= 0	Dart12= 1	Dart13= 1	Dart14= 0	Dart15= 1
Overall F1-score=				0.84			

Table 3: F1-score of each dart image and the overall score

- Most F1-score improved a lot by adding HoughLine and concentric circle functions on the detector. This was because the combined function decreased the false-positive rate significantly which means the precision increased.

- However, this concentric circle detector only valid for the front view of the dartboard (circular) not for the side view of the dartboard(elliptical). Houghline detectorcan find some ellipses centre but other results are discrepant and hard to improve. Those images which failed in both detection will remain the Viola-Jones results.

Part(c) Interpretation of the mdartboard detector

- Viola-Jones produced many results which include not only the right dartboard and but also many mistakes.

- Concentric circle produced the detected circle outline and the centre.

- Check F1-score for every image, if F1=1, keep the results from concentric circle, if not use houghline and Viola-Jones to improve.

- Houghline produced the point of multiple line segments intersection.

- Find which Viola-Jones boxes cantain the Houghline intersection point. Remain those boxes.

- Finally, combined the concentric circle and those selected boxes giving a chance to find the all dartboard.

3
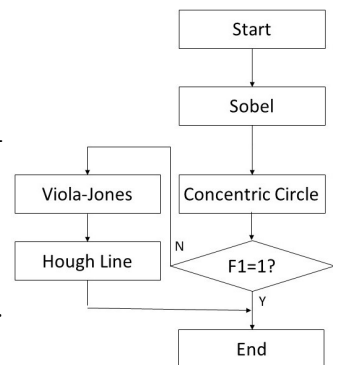
# Subtask 4: Improving the dartboard Detector

Part(a) Rationale behind the detector

- Except those images already have 1 for their F1-score, Viola-Jones the remaining images.

- For each Viola-Jone founded box, cut the image out and use concentric circle and ellipses detector to find whether there has missing dartboard or not.

- The sizes of the elliptical dartboard bounding boxes have been defined by the Houghline centre and ellipses detector.

Part(b) Best results
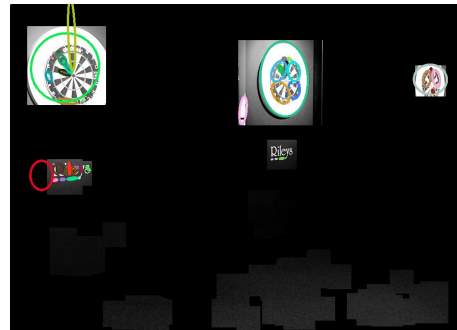
| (a) dart7 | (b) dart10 |

Figure 5: Final detection results on dart7 and dart10

Part(c) Discussion on the final detector

Dart0= 1	Dart1= 1	Dart2= 1	Dart3= 1	Dart4= 1	Dart5= 1	Dart6= 1	Dart7=0
Dart8= 1	Dart9= 1	Dart10= 0.5	Dart11= 0	Dart12= 1	Dart13= 1	Dart14= 1	Dart15= 1
Overall F1-score=				0.90			

Table 4: F1-score of each dart image and the overall score

- This program didn't sovle how to draw a bounded rectangular boxes outside the ellipses.

- New rules set to F1-score which has improved to a great value, only dart 7 has the problem on drawing right size box around the dart.

- With the combination of the functions, the detector is enabled to detect the dartboard with 90% accuracy.

- The detection of images which have both circular dartboard and elliptical dartboard is tough, but it can be solved by segmenting the image in different regions.

- In those example dart images, over half of the dartboards are encasesd with a large circular board behind it. This feature usuallly confuses the detector how large the dartboard exactlly is. Colour detection with vertex detection may have the ability to find the dartboard size accurately.