COMS30121 - Image Processing and Computer Vision
The Dartboard Challenge

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Introduction

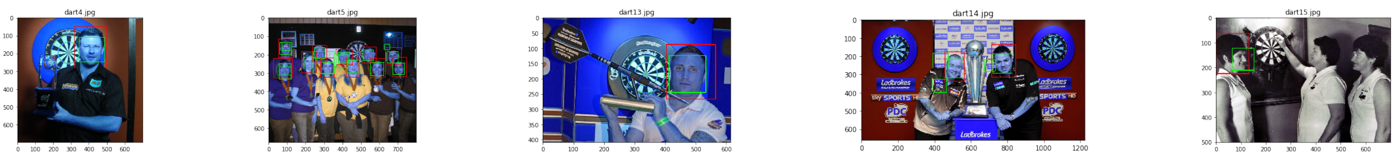
This report focuses on detection and local instances of an object class in an image. This explains the methods used such as the Viola-Jones Object Detection(VJOD) framework (an “off the shelf” face detector) and combine it with other detection techniques to improve its F1-score. The image set used is from the popular sport darts.

The Viola-Jones Object Detector

This is the first Object detection framework to provide competitive object detection rates in real time. The algorithm has been in existence for decades and is still used in video cameras, mobile phones, CCTVs etc.

Task1: Using the Detector on Human Faces

The algorithm was used with a strong classifier, trained using AdaBoost for detecting human faces from the front. This algorithm is tested on the following 5 images – dart4.jpg, dart5.jpg, dart13.jpg, dart14.jpg, dart15.jpg. The ground truth values are calculated using the VGG image annotator tool.



(a) dart4.jpg. (b) dart5.jpg (c) dart13.jpg (d) dart14.jpg (e) dart15.jpg

Figure 1: Result of the Viola-Jones Algorithm on human faces (green boxes). Red boxes represent ground truth.

Detector Performance

The TPR or True Positive Rate measures the proportion of relevant items that are correctly identified. One significant observation was found while calculating the True Positive Rate (TPR) that TPR is mostly 1 or 100%, this is because the formula for TPR does not consider False Detection or False Positives. That’s the reason the TPR is usually coupled with other metrics such as Precision and F-score to evaluate performance.The main reason as to why the false positives were being detected was because the Haar-like features, which are used in Viola Jones, were also present in other non-face objects in the image, such as shadows, creases on clothes etc. Based on these values, the F-score was calculated on the above 5 images.

- The F_1 score will be calculated by:

$$\frac{2 \times P \times R}{R + P}$$

Where

- Recall (TPR) $P = \frac{truepositives}{groundtruth}$.
- Precision $R = \frac{truepositives}{truepositives + falsepositives}$.

As calculating the F1 score is challenging due to manually counting boxes as per figure dart5.jpg , a process was implemented that makes this easier and scalable. It will compare the centres of the ground truth (which are manually added) and detection boxes. If the detected bounding box is below a certain threshold, this will be counted as a true positive. Table 1 below shows the result of this.

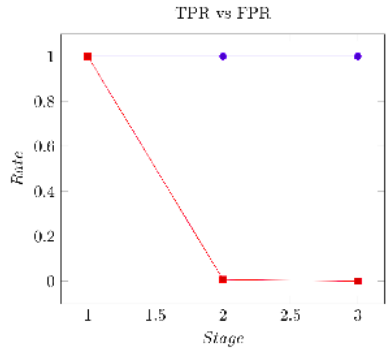
Table 1: Comparing the F_1 Score of different images

filename	Threshold(IoU)	Precision	RECALL	F_1 Score
dart15.jpg	0.1	1	0.166666666666667	0.285714285714286
dart14.jpg	0.0039	1	0.277777777777778	0.434782608695652
dart13.jpg	0.1	1	1	1
dart5.jpg	0.0092	1	0.147727272727273	0.257425742574257
dart4.jpg	0.1	1	1	1
Average	0.06262	1	0.518434343434343	0.595584527396839

Task2: Building and Testing the Detector

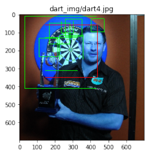
Interpreting TPR vs FPR

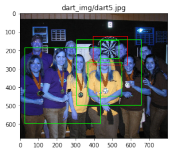
Figure 2 shows the training of the detector over 3 stages. The TPR always remained as 1, therefore, it was successful in detecting all dartboards. The decreasing FPR portrays that the detector firstly detects as much as it can, then reduces the number of objects it detects. As a consequence, it is clear that the detector is improving. The parameters of the detector were changed to be optimum. A ratio of 500:1000, positive to negative was used with a maximum false alarm rate of 0.4.

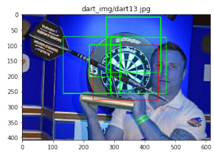


(a) TPR (blue) vs FPR (red) across the 3 stages

Testing on images


(b) dart4.jpg.


(c) dart5.jpg


(d) dart13.jpg


(e) dart14.jpg

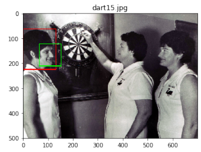

(f) dart15.jpg

Figure 2: Result of the trained dartboard detector.

The F_1 of the images are:

- dart15.jpg 0.500000
- dart14.jpg 0.280000
- dart13.jpg 0.666667
- dart12.jpg 1.000000
- dart11.jpg 0.600000
- dart10.jpg 0.354839
- dart9.jpg 0.307692
- dart8.jpg 0.111111
- dart7.jpg 0.173913
- dart6.jpg 0.800000
- dart5.jpg 0.250000
- dart4.jpg 0.615385
- dart3.jpg 0.285714
- dart2.jpg 0.461538
- dart1.jpg 0.444444
- dart0.jpg 0.555556

The overall F_1 score is consequently 0.1625. The F_1 score is relatively low meaning that the denominator is much bigger concluding that there was a high number of detections with respect to hits. This means that there were a lot of false positives. The usefulness of the plot (Figure 2) is that it can be clearly seen that the detector is currently under fitting - the TPR remains at 1 while the FPR decreases. This fact, along with the F_1 scores, shows results of a poor detector. However, it can be used as an advantage. The under fitting can be combined with other classifying detectors in order to improve results.

Task3: Integration with Shape Detectors

Image Results

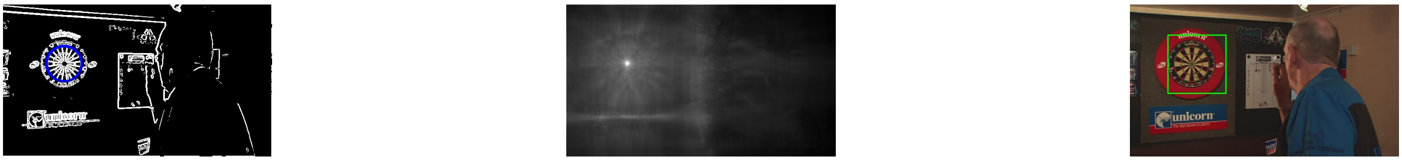
Below are some resulting images from our improved detector.

(a) Threshold Gradient Magnitude.

(b) Hough Space

(c) Result

Figure 3: dart1.jpg shows the merits of the detector.

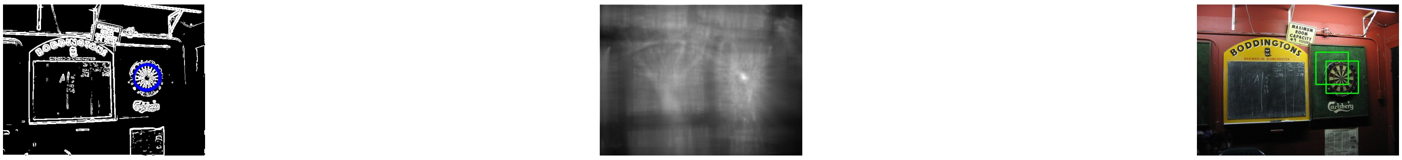


(a) Threshold Gradient Magnitude.

(b) Hough Space

(c) Result

Figure 4: dart2.jpg shows the limitations of the detector.



(a) Threshold Gradient Magnitude.

(b) Hough Space

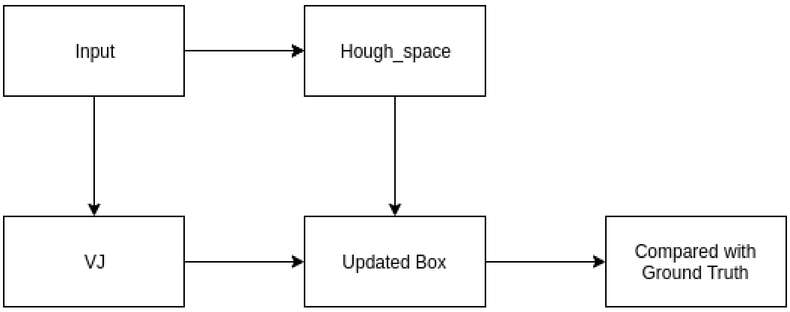
(c) Result

Figure 5: dart3.jpg shows the limitations of the detector.

The new dartboard detector did considerably better than the previous, achieving an overall F_1 score 0.75

- dart15.jpg 1
- dart14.jpg 1
- dart13.jpg 1
- dart12.jpg 0
- dart11.jpg 0
- dart10.jpg 0
- dart9.jpg 1
- dart8.jpg 1
- dart7.jpg 1
- dart6.jpg 0
- dart5.jpg 1
- dart4.jpg 1
- dart3.jpg 1
- dart2.jpg 1
- dart1.jpg 1
- dart0.jpg 1

Combination of Detectors



(a) Flowchart representing the detector.

- Our approach was to create new classifiers which would refine the large set of negative and positive hits of the Viola Jones detector down to only true positives by accepting Viola Jones hits that were also observed by the line and circle detectors.
- Line detections are achieved by accepting a hit when a large number of lines intersect at a pixel position, relative to the number of lines found in the image via the Hough transformation. This involves iterating through the set of Viola hits, comparing whether any line or circle hits are contained in the Viola bounding box, accepting if so, rejecting otherwise. Accepted hits would change its location based on the average position of itself, along with its combined detections.
- Circle detections also give the ability to estimate the size of the dartboard. Furthermore, it takes the average radii of included circles and includes this in the approximation.

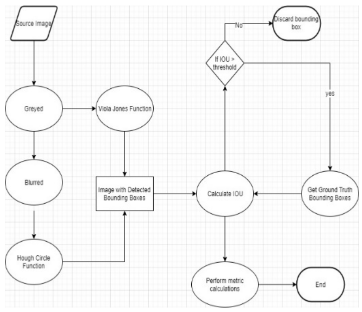
Table 2: TableName

filename	F1_Score_GT_PT_1000	F1_Score_GT_PT_500	F1_Score_PT_500_1000_H	F1_Score_GT_PT
dart15.jpg	0.5	1.0	0.5	1.0
dart14.jpg	0.28	0.33333333333333337	0.17989417989417988	0.6666666666666666
dart13.jpg	0.6666666666666666	0.6666666666666666	0.3448275862068965	1.0
dart12.jpg	1.0	1.0	0.8750000000000001	1.0
dart11.jpg	0.6	0.6666666666666666	0.5263157894736842	1.0
dart10.jpg	0.3548387096774194	0.2439024390243902	0.2183406113537118	0.5
dart9.jpg	0.30769230769230765	0.3333333333333333	0.21138211382113822	1.0
dart8.jpg	0.1111111111111111	0.2857142857142857	0.14545454545454545	0.6666666666666666
dart7.jpg	0.1739130434782609	0.8	0.14705882352941177	1.0
dart6.jpg	0.7999999999999999	1.0	0.6153846153846154	1.0
dart5.jpg	0.25	0.4	0.2635658914728682	1.0
dart4.jpg	0.6153846153846154	1.0	0.6153846153846153	1.0
dart3.jpg	0.2857142857142857	0.5	0.28571428571428575	1.0
dart2.jpg	0.4615384615384615	0.8	0.2608695652173913	1.0
dart1.jpg	0.4444444444444444	0.8571428571428571	0.35294117647058826	1.0
dart0.jpg	0.5555555555555556	0.8	0.375	1.0

Task4: Improving the Detector

- Combining the output of Viola-Jones to the output of Hough Transform (circle detection) to improve detection and all images required for this subtask can be found here. To improve the Viola-Jones dartboard detector, we decided to use Hough transform for detecting circles. This allowed us to discard the false positives like text fields and tripods.

Combination of Detectors

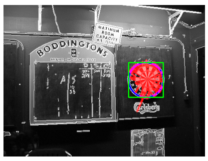


(b) Flowchart representing the detector.

Including these approaches into our detector, new F_1 score has improved to 0.17708

(c) dart10.jpg Overlay Detections

(d) dart10.jpg Result



(e) dart11.jpg Overlay Detections

(f) dart11.jpg Results

The new dartboard detector did considerably better than the previous, achieving an overall F_1 score 0.92708

Merits and Limitations

Limitations of the implementation:

- We believe the performance can be improved by using ellipse detections since the angle of the images makes the dartboards look like ellipses in some samples.
- We've used canny edge detector, which does not give the direction value as we get in Sobel. The execution time of the program is longer since we are looping from theta values 0 to 360.

- Circle detections also give the ability to estimate the size of the We've used canny edge detector, which does not give the direction value as we get in Sobel. The execution time of the program is longer since we are looping from theta values 0 to 360.
- We have successfully removed the false positives from the images, improving the F-score and precision. In addition to that, where Viola Jones failed to detect any dartboards, i.e. image dart6 and dart11, our Hough implementation could detect them.
- The Viola Jones detector detected 3 dartboards in the dart9.jpg. With our improvised solution, we managed to detect the correct one.

References

1. http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.420.3300&rep=rep1&type=pdf
2. https://en.wikipedia.org/wiki/Otsu%27s_method
3. http://opencv-python-tutroals.readthedocs.io/en/latest/py_tutorials/py_feature2d/py_surf_intro/py_surf_intro.html