COMS30121 - Image Processing and Computer Vision

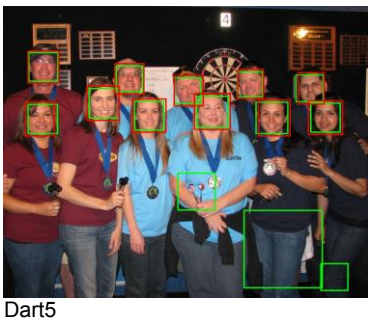
The Dartboard Challenge

Davis Offei - do17096
Chanthru Uthaya-Shankar - cu17780

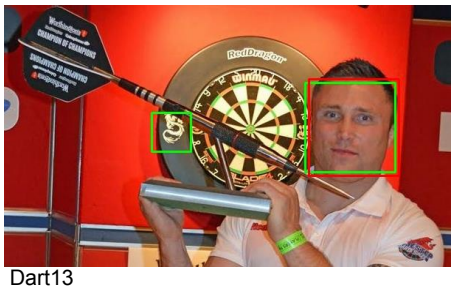
The Viola-Jones Object Detector

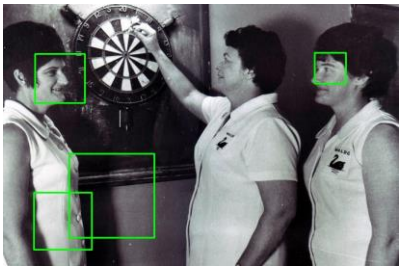
a) Ground Truth and visualisation

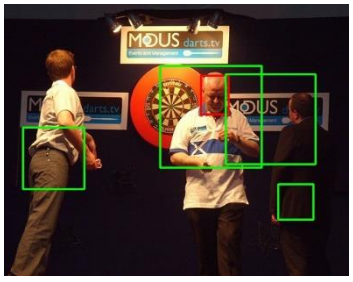

Dart4


Dart5

Dart14


Dart13


Dart15



Dart6 – below IOU threshold

b)

Difficulties in assessing TPR meaningfully

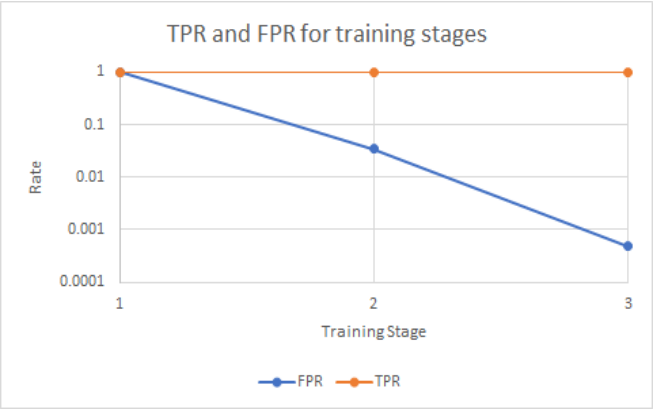
In order to be able to define whether a face has been detected or not, it is essential to have accurate ground truth boxes. There is a lot of variation in human faces, and a decision needs to be made to determine what defines a frontal face. In our implementation, we define a face as a frontal face, if it is possible to see both cheeks and eyes of the face, and neither are hidden by the nose. This distinction makes it clear what a frontal face is. The threshold between bounding boxes needs to be considered carefully, because if the output is grossly overproportioned, the algorithm failed to detect the face, such as in dart 6. Many of the images did not have any ground truth faces in them, making TPR and F1 score calculations redundant.

Image	F1 Score	True Positive Rate
Dart0	N/A	N/A
Dart1	N/A	N/A
Dart2	N/A	N/A
Dart3	N/A	N/A
Dart4	1	1
Dart5	0.88	1
Dart6	N/A	0
Dart7	1	1
Dart8	N/A	N/A
Dart9	0.4	1
Dart10	N/A	N/A
Dart11	1	1
Dart12	N/A	N/A
Dart13	0.67	1
Dart14	0.5	1
Dart15	N/A	N/A

Why it is possible to achieve TPR of 100% on any detection task

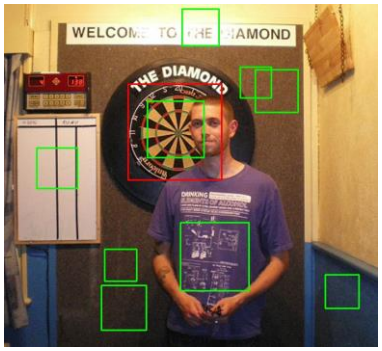
The true positive rate merely evaluates if the actual faces have been detected. It does not take into account if the classifier detected more than the ground truths- the false positives. Therefore, if the classifier simply detects everything as positive, then the ground truths will definitely be detected. However, this also produces a large number of false positives. A more meaningful way to evaluate a classifier's performance is by using the F1 score, which takes false positives and false negatives into account.

Task 2: Training Performance



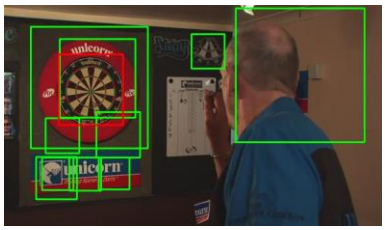
The graph shows that through the cascade stages, the TPR does not change. The TPR after the initial stage is 1 and through all the consecutive stages the TPR stays at 1. This shows that the classifier correctly classifies all images with label true as true. One aspect that can be drawn from the graph is that after each training stage the FPR drops, with the biggest drop being after the first stage, this decrease in the FPR would mean that the precision would drop resulting in an increase in the F1 score as the FPR drops between each stage this shows that the accuracy of the classifier increases with each stage. The graph shows the performance on only the training data, and achieves a miniscule FPR. This shows that the classifier is overfitting on the training data, making it able to perform very well on the training set, but not on unseen test sets, as features are included that are specific to the test set, but that do not generalise a dartboard.

Testing Performance



Dart7

Dart5



Dart2

The classifier is able to detect the vast majority of the dartboards, missing a total of only 2 dartboards and achieves a good TPR. However, the classifier also has a lot of false positives, detecting dartboards when there aren't actually any there. The detectors bounding boxes also do not match the actual dartboard accurately. One of the reasons for this is that the dartboard used to create the training images does not accurately match the entire dartboard, so it was not trained for perfectly complete dartboards. Furthermore, we created our positive training images from just one dartboard.

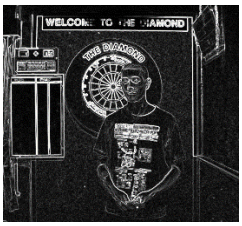
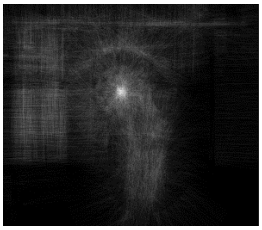
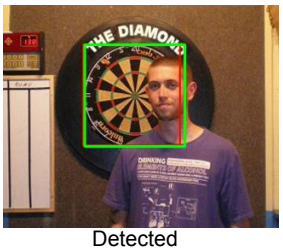
The detector also detects the same dartboards multiple times, which even though the intersection over union for both bounding boxes are within the threshold of the ground truth, one of them is a false positive. (dart 10)

The image that we used to train, did not contain a full dartboard picture, contributing to that the output bounding boxes of the Viola jones detector do not accurately detect the complete dartboard.

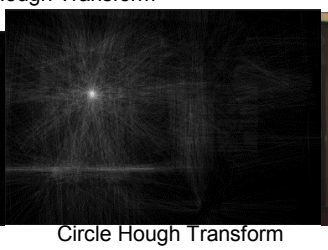
The TPR is lower than for the training set, because the classifier has not seen the images before, and wasn't able to adapt to them. Additionally, we are only evaluating our classifier on 16 images. In order to get a more accurate performance evaluation, we would have to run our classifier on a larger data set, as we did in a).

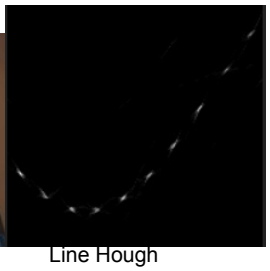
Image	TPR	F1 score
Dart0	1	0.5
Dart1	1	1
Dart2	1	0.18
Dart3	1	0.4
Dart4	1	0.25
Dart5	0	0
Dart6	1	0.67
Dart7	1	0.2
Dart8	0.5	0.14
Dart9	1	0.33
Dart10	1	0.08
Dart11	1	1
Dart12	1	1
Dart13	1	0.33
Dart14	1	0.21
Dart15	1	0.67

Subtask 3: Integration with Shape detector


Dart7.jpg: Gradient Magnitude | Circle Hough Transform | Detected | Line Hough



Dart2.jpg: Gradient Magnitude | Circle Hough Transform | Detected | Line Hough Transform

Image	TPR	F1 score	Difference TPR	Difference F1
dart0	0	0	-1	-0.5
dart1	1	1	0	0
dart2	1	1	0	+0.82
dart3	1	1	0	+0.6
dart4	1	1	0	+0.75
dart5	1	1	+1	+1
dart6	0	0	-1	-0.67
dart7	1	1	0	+0.8
dart8	0.5	0.67	0	+0.53
dart9	1	1	0	+0.67
dart10	0.33	0.29	-0.67	+0.21
dart11	0	0	-1	-1
dart12	0	0	-1	-1
dart13	1	0.66	0	+0.33
dart14	1	1	0	+0.79
dart15	1	1	0	+0.33

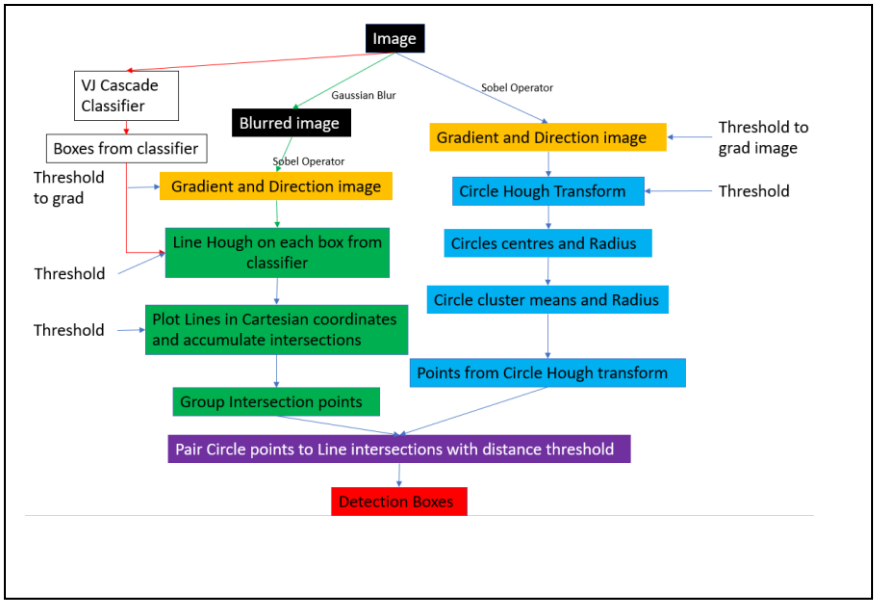


Figure 1

Average TPR: 0.67, Average F1 score: 0.66

Although the TPR has decreased, our detection system has an overall greater accuracy as shown by an increase in the average F1 score from 0.44 to 0.66. This is mainly due to a decrease in the False Positive rate. When a circle centre point is detected accurately, the exact dimensions of the dartboard are detected, even if they are larger than the VJ detected box. Furthermore, by running line detection within the detected Viola-Jones boxes we are able to detect more true dartboard lines compared to running it on the whole image. Our implementation fails when no accurate dartboard centre is found. For example, in dartboard 0. The calculated centre is too far away from the line intersections, so the dartboard isn't detected.

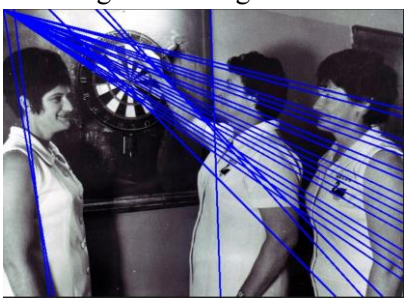
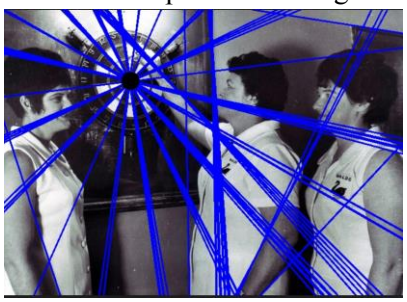
c) Figure 1 is the workflow diagram for our detection system

- Run line detection on cascade detected boxes
  - Reduces Line detector returning lines that are not board lines
  - Boxes highlighted by Viola Jones are likely to have features of a dartboard, so we remove features of the image we are not interested in
- Running circle detection on whole image
  - Viola Jones Boxes aren't big enough to detect circles
- Combine all detected points to generate classified boxes
  - Finds smallest distance between circle points and intersection points
    - Classifies as a dartboard if this distance is smaller than a threshold

Subtask 4: Improving the detector

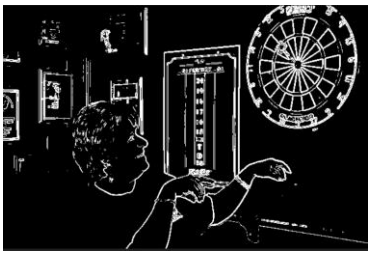
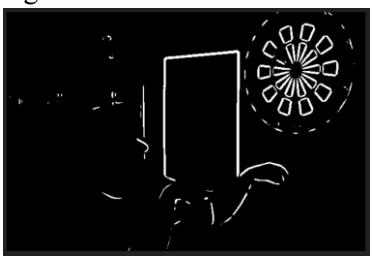
One of the features we incorporated into our line detection system was the use of the direction image when voting for lines in the Hough transform. The direction images give the change in direction at a specific point in the image. For lines this change in direction will likely be perpendicular to the lines that we are trying to detect.

We used these values in the direction image with a leeway of + and – a small angle to narrow down the range of theta angles a point could vote for in the Hough space. This decreased the time to compute the detection algorithm, and also increased the concentration of votes to lines that are actually lines. This improved the amount of lines we were detecting in the image. Shown below is an example of not using the direction image and using the direction image.

We also applied transformation to the image that we would input to the Sobel operator. The transformation that had the greatest impact was the applying a gaussian blur to the image. This gaussian blur smooths the image and makes gradient changes more prominent. This meant that when we applied a threshold to the gradient magnitude image, it produced an image with much less noise and a higher proportion of the white pixels at the dartboard lines. This drastically improved the line detection performance.

No blur on left, blur applied on right.

This shows the threshold image before and after a gaussian blur has been applied.

Contributions:

Chanthru Uthaya-Shankar – 1

Signed:

Davis Offei – 1

Signed: