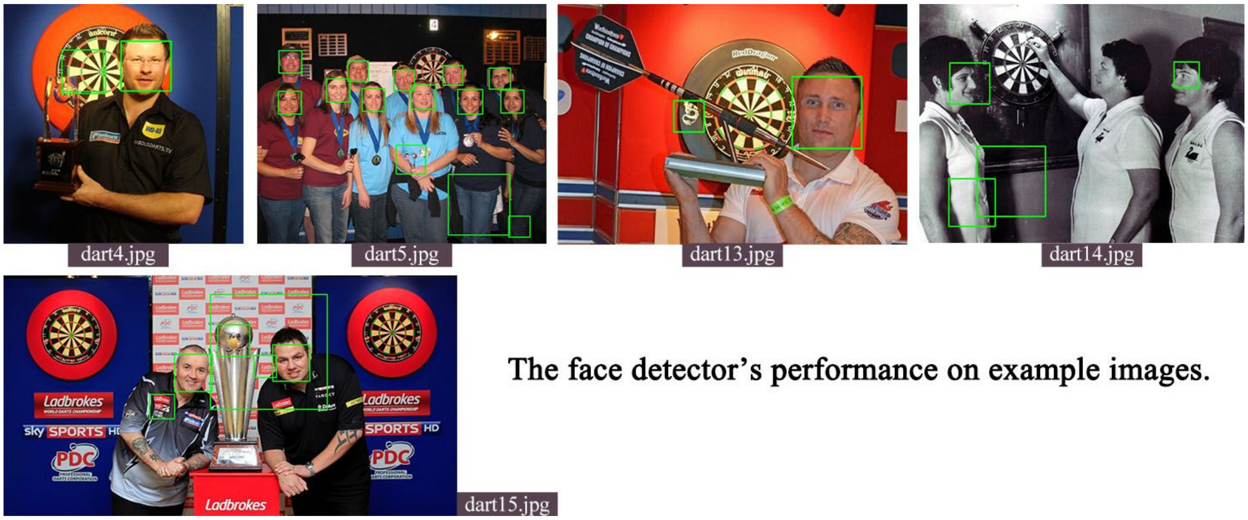
Image Processing Report

Subtask 1:



The face detector's performance on example images.

The true positive rate (TPR) of image "dart5" is 100% because it detects 11/11 of the valid faces in the image. The TPR of image "dart 15" is 33.3%. It detects 2/3 of the valid faces in the image but the bounding box over one of these faces does not adequately cover all the features that are required to recognize a face so only 1/3 of the faces were successfully detected.

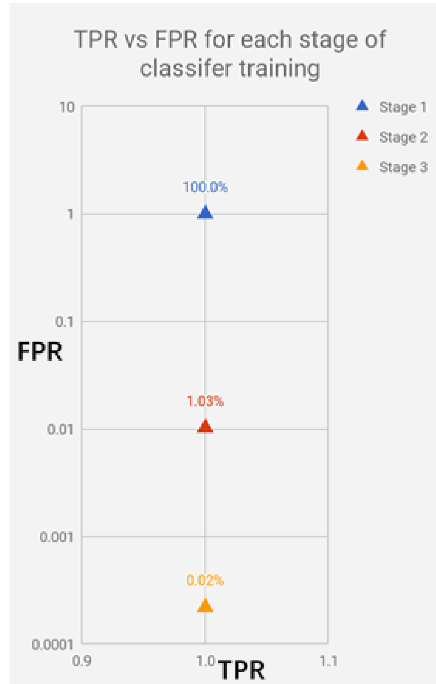
This highlights one of the difficulties in assessing the TPR of images since it can be difficult to tell whether a face was recognized correctly or if image features in and around certain parts of the face actually caused the algorithm to incorrectly detect a face.
It is clear in "dart 15" that the bounding box around the woman's eye must be incorrect but if the box was larger, it would be harder to differentiate between this and a legitimate detection of the woman's face.

It is always possible to reach a TPR of 100% on any detection task because all that is required to do so is to use an algorithm which supposedly "detects" an object at every possible location, scale and rotation within the image. When this is done, there is no possibility that an object in the image isn't detected, regardless of its attributes so the TPR of the algorithm will be 100%.

We will use the IoU (intersection over union) metric in order to produce a value for how well each bounding box from the algorithm matches each ground truth bounding box produced by us. The IoU value will have to be more than 0.5 for a detected box to qualify as detecting the face given by a ground truth box. In cases where multiple bounding boxes could potentially be matched to multiple different ground truth boxes, the configuration which produces the maximum number of pairs of boxes is used. From here, the number of pairs of detected boxes matched to ground truth boxes is given by F, the number of detected boxes is D and the number of ground truth boxes is A and the F1 score of effectiveness is given by: (2 * F) / (D + A) with best value given by 1 and worst value given by 0.

Subtask 2:

The scatter graph shows that in each stage of the classifier training, the true positive rate does not reduce from 100%. Instead, the false positive rate significantly decreases. Going from from 100% in the first stage, down to 1.03% and then 0.02% in the final stage.

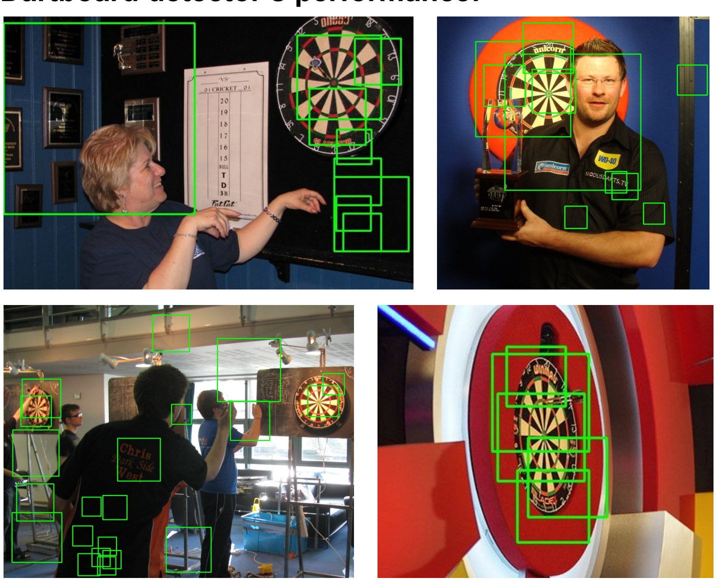


This can be interpreted as the classifier "learning" what dartboards are *not* using samples from the negative images so that the frequency of its *incorrect* detections reduces without also reducing the frequency of its correct detections.

Over all 16 test images, the classifier had a 0% TPR on 7 of them, 50% TPR on 4 of them and 100% TPR on the remaining 5 images. This gives an average TPR of 43.75% for the entire set of test images, a lot worse than the perfect 100% TPR as displayed by the scatter graph.

Based on the results, it is clear that the scatter graph isn't useful for predicting the performance of the classifier on testing data since it only gave a single, perfect, value of TPR for us to base our expectations on. This value turned out to be far too optimistic as the classifier didn't even manage to correctly detect the majority (TPR>50%) of the dartboards in the testing images.

Dartboard detector's performance:



F1 Scores for each image:

- Dart0: (2*0)/(9+1) = 0
- Dart1: (2*1)/(4+1) = 2/5 = 0.4
- Dart2: (2*2)/(7+2) = 4/9 = 0.44
- Dart3: (2*1)/(9+1) = 1/5 = 0.2
- Dart4: (2*1)/(10+1) = 2/11 = 0.18
- Dart5: (2*0)/(7+1) = 0
- Dart6: (2*0)/(4+1) = 0
- Dart7: (2*0)/(17+1) = 0
- Dart8: (2*1)/(21+2) = 2/23 = 0.09
- Dart9: (2*1)/(9+2) = 2/11 = 0.18
- Dart10: (2*0)/(26+3) = 0
- Dart11: (2*1)/(4+2) = 1/3 = 0.33
- Dart12: (2*0)/(5+1) = 0
- Dart13: (2*1)/(8+1) = 2/9 = 0.22
- Dart14: (2*1)/(31+2) = 2/33 = 0.06
- Dart15: (2*0)/(8+1) = 0

Subtask 3:

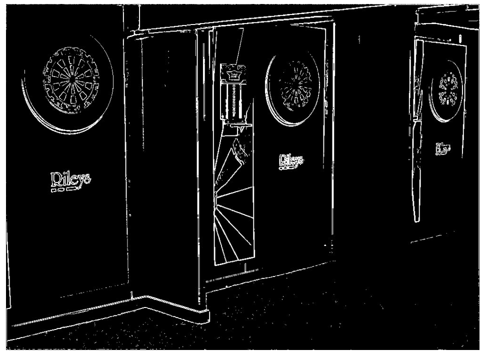
The average F-score across all test images was: 0.4979167.

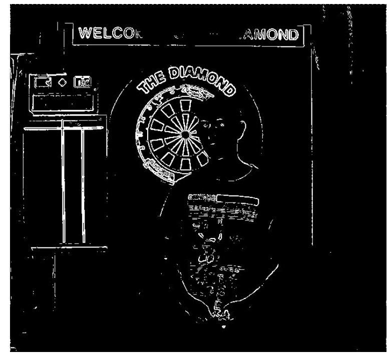
The average recall value across all images was: 0.66

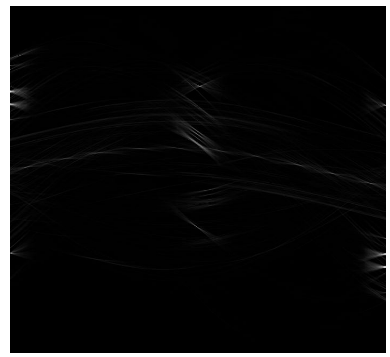
The average precision value across all images was: 0.43

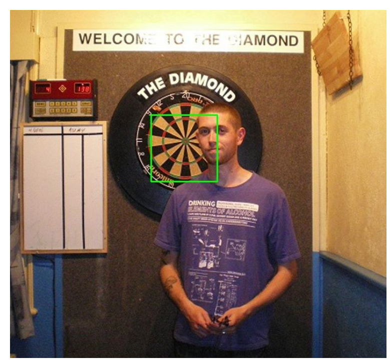
Merits:
Hough transform allows line intersections to be easily distinguished from other features.
Boxes are filtered to heavily reduce number of incorrect detections.

Drawbacks:
Code is very inefficient and takes a long time to run on large images.
Dependent on thresholded image to show dartboard lines very clearly.









Subtask 4

In this subtask, a dartboard detection algorithm is designed based on the feature points matching of SURF(Speeded-Up Robust Features) algorithm and it is could combined with the previous algorithms to get a higher detection effect. The reason for using this vision approach of SURF depends mainly on the following points:

1. Although detectors of Haar-like features can effectively recognize faces, detecting dartboards is not efficient;
2. By pre-processing the image and performing the Hough transform, lines, circles, Intersection and even concentric circles can be effectively identified. However, these huff information is still easily affected by other similar information in the environment and this algorithm is highly time-consuming when detecting complex information.
3. Combined with the above two methods, our results are not satisfactory enough. This subtask requires the use of other methods to improve the detector.
4. SURF algorithm can extract interest points on the object for feature description and based on their principle of relative position to achieve the goal of detection. These features could be detectable even under changes in scale, noise and illumination of training images. Furthermore, this algorithm has a very high computational efficiency.

This method can find the target in complex scenes(see the images below):

With this method F-score has been significantly improved: 0.68125

However, SURF is high quality at handling images with blurring, but not very well at handling viewpoint change and illumination change. Therefore, it is need to combine hough or others method to promote the detection effect based on this situation.