Image Processing & Computer Vision:

Dartboard Challenge

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**Subtask 1: The Viola-Jones Object Detector**

1. **Introduction**

The first subtask was to understand, compile and build the Viola-Jones object detector on a pre trained classifier to detect faces. This was to gain the knowledge of how the detector worked and to test its ability on face detection.

1. **Ground Truth & Visualisation**

To start we gathered all the data for the ground truth faces. This required manually inputting the coordinates of the rectangles into the C++ programme. The results from 5 of the images running the Viola-Jones detector with ground truths in red can be seen below. Our definition of a ‘frontal face’ was clear visibility of two eyes. This meant that there were a few faces that were not highlighted in red due to not meeting our criteria.

1. **IOU, TPR and F1-Score**

We then both implemented some code that would calculate the intersection over union (IOU) of the Ground Truth rectangles vs the Viola-Jones rectangles. Due to OpenCV’s datatype ‘Rect\_’ calculating the intersection is an easy operation of Rect\_ & Rect\_. Hence making the union the area of both rectangles minus the intersection.

The use of the IOU is to measure the True Positive Count (TPR). This is calculated by the returned count of true positive faces divided by the Ground Truth count of faces. By setting a threshold and measuring the IOU of every detected faces vs every Ground Truth face we were able to count the number of detected true positives.

|  |  |  |
| --- | --- | --- |
| *Image* | *TPR* | *F1-Score* |
| Dart0 | N/A | N/A |
| Dart1 | N/A | N/A |
| Dart2 | N/A | N/A |
| Dart3 | N/A | N/A |
| Dart4 | 1.0 | 1.0 |
| Dart5 | 1.0 | 0.88 |
| Dart6 | 0 | N/A |
| Dart7 | 1.0 | 1.0 |
| Dart8 | N/A | N/A |
| Dart9 | 1.0 | 0.4 |
| Dart10 | N/A | N/A |
| Dart11 | 1.0 | 1.0 |
| Dart12 | N/A | N/A |
| Dart13 | 1.0 | 0.667 |
| Dart14 | 1.0 | 0.5 |
| Dart15 | N/A | N/A |

**Table 1: True Positive Ratio and F1-Score of**

**Viola-Jones face detection**

The results from Table 1 contain multiple N/A’s. This is due to that specific image not containing any faces, and hence the data cannot be used to describe the accuracy of the face detection.

The F1-Score is a measure of accuracy. It takes into account the true positive count, false positive count and false negative count. We were able to use all the data from the IOU and TPR to calculate this. The results show that the accuracy of the detector was not too low and did not produce too many false negatives. However, more data would be required to make a verdict on its accuracy due to only having a small dataset.

The practical difficulties in assessing the TPR is that the all of the faces in the images were detected and hence all the TPR’s are 100%. This doesn’t really help to judge the quality of the detector as we cannot distinguish anything between different images. The reason the TPR can always achieve 100% due to it not taking in false positives. This means an infinite number of faces could be detected at every point in the image still leading to a TPR of 100%.

**Subtask 2: Building and Testing our own Detector**

1. **Introduction**

The second task involved building our own detector for dartboard images rather than face detection. This was achieved via training our detector via AdaBoost on 500 positive images and 1000 negative images. This was then applied to some test dartboard images.

1. **Training Performance**

The training tool split the training into three distinct stages, with additional features being added at each stage. Graph 1 shows how the TPR and FPR changed between stages for training sets of different sizes.

GRAPH

INTERPRETATION

1. **Testing Performance**

Like our work in subtask 1, the ground truth bounding boxes for dartboards in the test images were manually inputted. We considered the ground truth bounding box of a dartboard to cover approximately the same area of a dartboard that was seen in the training image of a dartboard which was used for the trained detector. These can be seen as red bounding boxes.

When applied to our test images, the detector performed moderately to poorly. The general theme in the results was that the detector could detect unobscured front facing dartboards well, with a relatively high TPR, but the FPR was very high. In addition, the detector often failed to detect boards if the board was partly obscured, at an angle, had a unique background or was scaled down / up. Image 1 shows a clear example of the detector correctly detecting a dartboard but producing many false positives. Image 2 is a good example of the detector struggling to detect partial obscured dartboards, and Image 3 shows that the detector sometimes found it difficult to correctly detect angled dartboards (left hand dartboard in Image 3).

IMAGES

Table 1 shows the TPR and FPR for our detector applied to all test images, as well as averages. INTERPRETATION

TABLE

**Subtask 3: Integration with Shape Detectors**

1. **Introduction**

The third task required the implementation of multiple shape detectors via the manipulation of Hough Transforms. Our implementations used a line detector to determine where intersecting lines in an image occur, and a circle detector to determine the centre of circles in an image. We then combined these detectors with the Viola-Jones detector previously used to create one improved detector. This worked on the basis that a dartboard was successfully detected if it was detected by the Viola-Jones detector and one of the new shape detectors.

1. **Hough Details**

The detection process involved the creation of thresholded gradient magnitude images and 2D representations of the Hough Space for each test image. These could then be manipulated to determine circle or edge detection which could then be reapplied to the test image.

Image 1 shows a good example of when this worked well. The inner circle of the dartboard was successfully detected (orange indicator circle), and the lines of the dartboard (red indicator lines) were successfully detected resulting in an intersection at the centre of the dartboard. The green bounding box was the Viola-Jones detection previously seen. These three detection systems were then combined to calculate one final bounding detection box as seen in Image 2, which successfully detects the dartboard with blue bounding boxes. Image 3 and 4 show the thresholded gradient magnitude for this image, and the 2D representations for the circle and line Hough Spaces.

IMAGES

Image 5 shows an example of our detector not working well. The left-hand dartboard in this image is not detected by line detection, circle detection or viola jones detection. Focussing on the shape detections, this is not likely not detected due to the angle of the image resulting in the circular dartboard becoming elliptical, and the low resolution of the image resulting in the lines not being detected. Image 6 and 7 show the thresholded gradient magnitude for this image, and the 2D representations for the circle and line Hough Spaces.

IMAGES

1. **Evaluation**

Our combined detector worked very well overall, with almost every dartboard image being detected by Viola-Jones and at least one of the two shape detectors. The dartboard which were not detected can be mostly explained due to reasons such as the dartboard being obscured, the scaling of the images resulting in elliptical dartboards or the resolution of the image being too low to detect the lines. Table 1 shows the TPR and FPR for each test image, as well as averages and a comparison against the solely Viola-Jones detector.

TABLE

EVALUATIVE BULLET POINTS

1. **Detection Pipeline**

EXPLANATION

FLOW CHART

RATIONALE