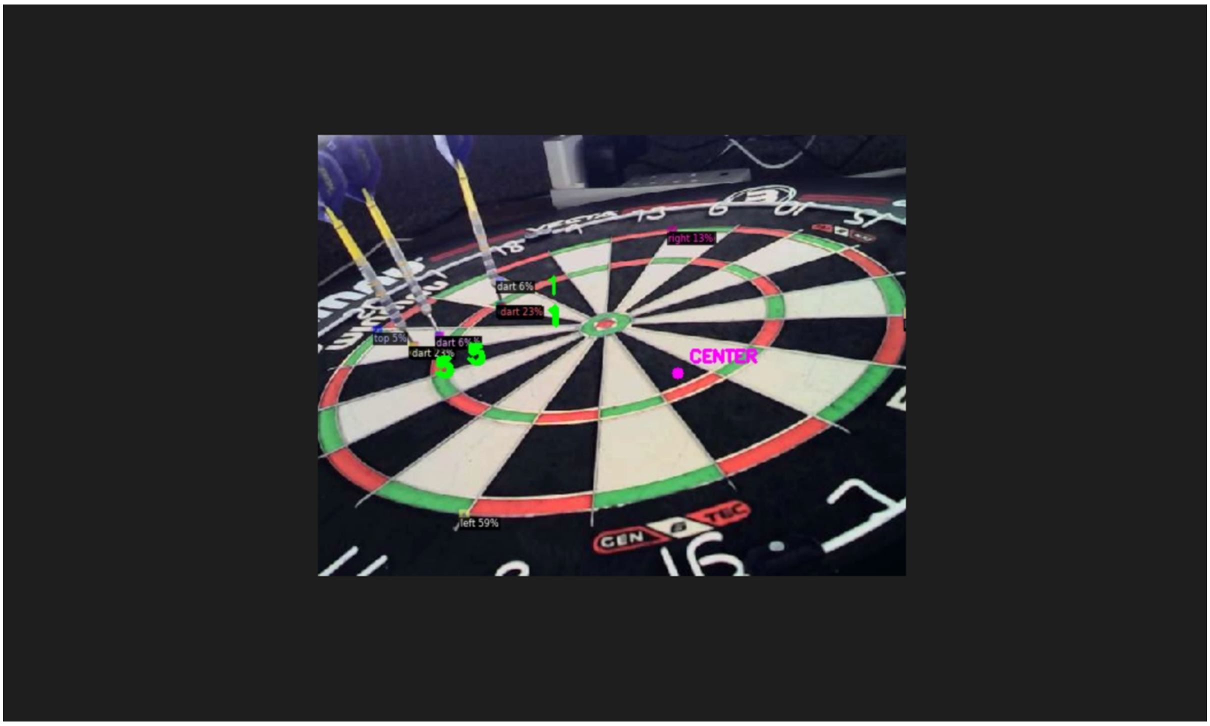

Scoring darts automatically based on key points from a single camera

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Small project done in my own time for fun, took about a year and a half. Sharing my findings in this paper.

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Abstract

The following study developed a single-camera dart tracking and scoring system inspired by the commercial multi camera solution called Dartsee. The research compared traditional computer vision approaches to more modern artificial intelligence approaches for calculating positions and scores of darts on a standard sized regulation dartboard. Using detectron2, the system achieved about 90% accuracy in dart detection and scoring. With TF-DETR, the system achieved about [TODO] accuracy. The AI based approach demonstrated similar results to multi-camera computer vision approaches but was easier to implement. Where the AI approach surpasses the computer vision approach is in varying lighting, dart angle and dartboard and camera positions. The AI system can match the performance of a multi-camera setup with only one camera while also reducing hardware cost and complexity of any setup. This paper contributes to making dart tracking and scoring systems cheaper and more accessible for personal and commercial development.

Introduction

A dart tracking system relates to program or device which can take in data from sensors and use that data to calculate where a dart landed on a dartboard and score the dart based on its position. These systems are useful because of the time they save due to player not having to manually count their scores in their head or with a device like an iPhone.

Current dartboard scoring systems are expensive and complex to recreate yourself at home. This is due to needing multiple cameras and the knowledge in math and computer vision to be able to viably create a similar system.

The solution in this paper is to use a one camera setup and use a custom trained artificial intelligence computer vision model. The key points are taken from the model output and used to automatically calibrate and score darts as they land on the board.

AI compares well to traditional approaches and can have a similar or superior success rate compared to multi-camera solutions. When AI is paired with multiple cameras it can be made to be more accurate.

Related Work

In my research there is only one similar work called deep darts. This solution uses the same kind of system but primarily uses one camera in their research. Whereas this solution can be used with only one camera, but this paper investigates using multiple cameras with an AI setup and models trained on more data.

Dartsee is another solution which uses an array of 3 to 4 cameras to triangulate the darts position on the dartboard. But this solution is geared towards businesses and they currently as of the 9th of June 2025 offer a solution for the mass market.

Scoila is a wide market dart scoring system which uses an array of 3 cameras and computer vision to find where a dart landed on a dartboard.

AI is used all over the sports industry. Wearables can be used to track motion, heart rate and GPS location. This data can then be collected and used to train AI models to detect patterns and optimize all those persons training schedules. These sensors can also be used to analyze an athlete’s form and their technique and give back feedback to prevent personal injury and give some areas of improvement. AI can also be used along with data from these sensors to collect performance data which can be used by coaches to predict how a player will perform in certain circumstances or conditions against their opponents.

Current research is missing using these new AI systems to create a high-grade commercial dart scoring system. Research is also missing using multiple cameras along with different types of AI models to make a system with very high accuracy.

Methodology

My approach in this project was to train a custom AI model. At first the plan was to create a commercial solution so using widely used models like yolo v11 was not going to work for this application.

The first AI model I trained was detection 2 and that was done with about 5000 images in coco format. Images where trained on the following classes at first

V1: {Objects, Calibration Points, Dart point}

The outputs of detection were good. But the problem with this approach is as follows. If it is not known where a camera will be placed how can I find which calibration point corresponds to what deg on the dartboard. It also had another flaw which was scoring. How can the system figure out what the score is without knowing where 20 is.

Due to these limitations I had to rethink my approach I used the same data set along with detection 2 trained on a new set of classes.

V2 {Objects, Top (351°), Bottom (45°), Left (189°), Right (171°), Dart Tip, Center}

This second approach worked well and allowed the system to find where the top of the board was regardless of the dartboards orientation or camera angle. Top was the intersection between 5 and 20 at the top of the dartboard with 5 being 342° and 20 being at 0 °. Bottom was the intersection between 17 and 3 at the bottom of the dartboard with 3 being at 36 ° and 17 at 54 °. Left was between 8 and 11 on the dartboard with 11 being 198 ° and 8 being at 180 °. Right is the intersection between 13 and 6 on the dartboard with 13 being at 162 ° and 6 being at 180 °.

This worked well but the center class was unneeded because the diameter of the board was already calculated using.

$$D = MAX(L - R, R - L)$$

So, I just used the diameter to find the center of the board D / 2. This was more accurate since a standard regulated dartboard was being used so the final classes in this project where the following.

V3 {Objects, Top (351°), Bottom (45°), Left (189°), Right (171°), Dart Tip}

Every second the program checks for differences between the start frame and the current frame looking for dart sized differences.

$$dst(I) = saturate(|src1(I) - src2(I)|)$$

Once the difference is found if it’s the size of a dart the current frame gets sent to detection for processing where the key points are found referenced in V3 above.

Once key points are found the first thing which needs to be done is calibration. Calibration only needs to be done once, and the main data collected by calibration is the homography matrix and the radius of the dartboard.

Radius is calculated using the equation above where the center is calculated. But calculating the homography matrix is more complex. Since the camera is not perfectly positioned directly at the dartboard there is perspective distortion in the image. Using the points in V3 excluding objects and dart tip we can calculate the homography matrix.

Using the outer radius top, left, bottom and right points of an average dartboard and the image points calculated by the detectron2 model the homography can be calculated and be used to transform the image.

$$s\begin{bmatrix} x' \\ y' \\ 1 \end{bmatrix} = \mathbf{H}\begin{bmatrix} x \\ y \\ 1 \end{bmatrix} = \begin{bmatrix} h_{11} & h_{12} & h_{13} \\ h_{21} & h_{22} & h_{23} \\ h_{31} & h_{32} & h_{33} \end{bmatrix}\begin{bmatrix} x \\ y \\ 1 \end{bmatrix}$$

X1 and Y1 (dartboard points) are used to calculate the scale factor and are where the image points should appear in the corrected view, and the image points X and Y are used to make the 3x3 homography matrix. The output of the operation can be used to transform the image so it’s like the camera is directly pointed at the dartboard.

The darts x, y position is then transformed using the homography matrix. The score can then be calculated using the transformed point. First the distance from the dart to the center is found which determines whether it is double bull, outer bull, single, triple of double. Then the top point is found from the calibration and the circle is cut into 18 ° segments. The deg of the dart in the dartboard is found and is used to calculate the section the dart landed on.

$$d = \sqrt{(x^2 + y^2)}$$

$$\theta = \text{atan2}(-y, x) \text{ segment} = \text{floor}(\theta/18°) \bmod 20$$

$$\text{segment index} \in \{0, 1, 2, ..., 19\} \text{ dart number} \in \{1, 2, 3, ..., 20\}$$

Method used to find the score

System Setup

The cameras in this project were positioned around the dartboard on the light ring. The cameras are 1920px by 1080px and can see the hole dartboard including the numbers. One is positioned at the bottom left and one at the bottom right with plans to add a third at the middle top.

Cameras connect to a laptop which runs the software. The plan is to move this onto a raspberry pi connected to a monitor but there are some technical considerations. The limited power in the raspberry pi requires that the processing is handled by a chip on a hat or by a remote server. This gets rid of the Realtime capabilities. So, for now I have decided to use a MacBook to run the model.

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