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Computer Vision - Project 3

Automatic darts scoring system

Objective

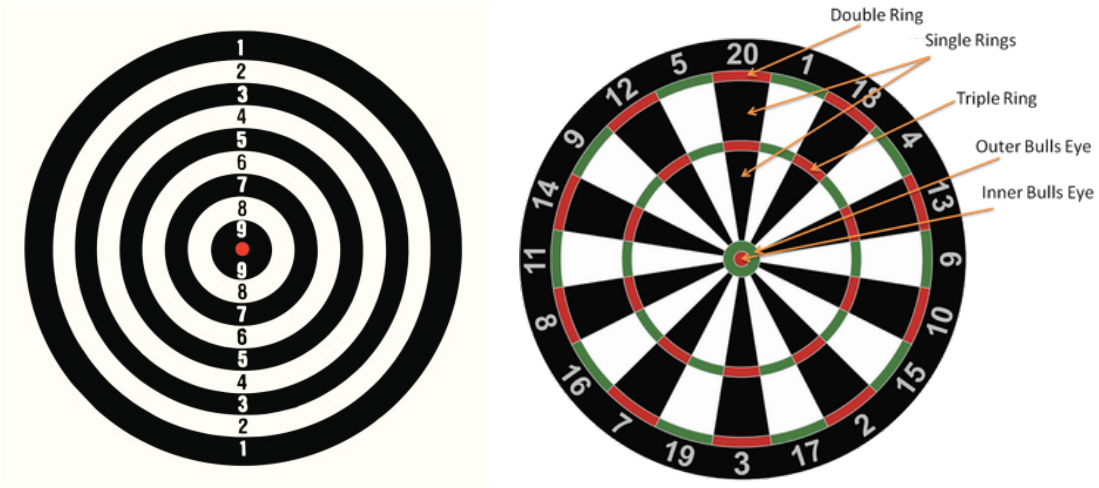
The goal of this project is to develop an automatic system for image and video analysis for the game of darts. The system should be able to infer from an input image/video the following information: (i) count the number of darts (arrows) on the dartboard; (ii) get the exact position of the darts on the dartboard.

Darts

Darts is a throwing game in which small arrows (also called darts) are thrown at a target, which is called a dartboard. Aside from being a competitive sport, darts is also a pub game that is popular across the United Kingdom and Europe.

Board types and regions of the boards

Though there are many types of dartboards, in this project we will focus on two types of dartboards (Figure 1):



(a) (b)

Figure 1: *Types of boards used in this project: (a) Target dartboard; (b) Classic dartboard.*

- *Target dartboard* - this board (Figure 1a) has 9 black and white concentric circles scored from the edge to the center with numbers from 1 to 9 and the 10^{th} circle in the middle named bullseye (red region in Figure 1a);
- *Classic dartboard* - this board (Figure 1b) is divided into twenty numbered segments that resemble pieces of pie and are of equal size. Each pie-like segment features a double ring on the outside perimeter of the scoring area plus a triple ring on the interior area. When a player hits a dartboard segment in a double ring that counts as a double of the number displayed on the segment. If a player hits the same number in the triple ring, the player scores triple of that number. In the center of the board stands the bullseye, every player's favorite. Similar to the pie-like segments, the bullseye has an outer bull (the green region) and an inner bull area (red region). If a player hits the outer bull which is also referred to as the single bull, the player will score 25. Hitting a double bullseye (inner bull area), will double the score to 50.

Data description and grading scheme

The released data directory (available at `https://tinyurl.com/CV-2023-Project3`) contains four directories: *auxiliary_images*, *train*, *test* and *evaluation*. The directory *auxiliary_images* contains images with the darts used and templates for Task1 and Task2. The directories *train* and *test* have similar structure, although the *test* data will be made available after the deadline. The *train* directory contains data in the form of images and videos with darts placed on the two types of dartboards. The data is organized in three subdirectories corresponding to the three tasks that you need to solve. The subdirectories are:

- *Task1* - this directory contains 25 training images with darts placed on the target dart-

Figure 2: *Examples of training images for Task1. Left image: there are two darts, one in the 6^{th} circle and one in the 8^{th} circle. Right image: there are three darts, two of them in the 4^{th} circle and the other one in the 6^{th} circle.*

board. For training images we include also the corresponding annotations. The images (Figure 2) are collected using Bogdan's mobile phone placed in a fixed position on a tripod. Each training image contains a number from one to three darts placed on the target dartboard. The goal of this task is to count the number of darts and also localize the positions of these darts on the dartboard. The format that you need to follow is the one used in the annotation files, with the first line specifying the total number of darts and starting with the second line enumerating the positions of each dart. For Task1 we encode the position of a dart with the corresponding number (from 1 to 10) of the concentric circle containing the dart.

Grading scheme for Task1. In the test scenario we will release 25 testing images with similar distribution to the training images containing in total 50 darts. By correctly solving the Task1 on all test images you will get 2 points. You get 0.04 points for predicting the correct number of darts in an image (in total 1 point $= 25 \times 0.04$) and 0.02 points for each correctly localized dart in an image (in total 1 point = 50×0.02). Notice that using this grading scheme, by correctly solving the Task1 for images with different numbers of darts you will get different points: (i) for an image with one dart you will get 0.06 points ($0.04 + 0.02$); (ii) for an image with two darts you will get 0.08 points ($0.04 + 2 \times 0.02$); (iii) for an image with three darts you will get 0.10 points ($0.04 + 3 \times 0.02$). Partial points will be awarded, for example if for an image with three darts you correctly count the number of darts and correctly localize just one dart you will get $0.04 + 0.02 = 0.06$ points out of the maximum 0.10 points.

- *Task2* - this directory contains 25 training images with darts placed on the classic dartboard. For training images we include also the corresponding annotations.The images (Figure 3) are collected again using Bogdan's mobile phone placed in a fixed position on a tripod. Each training image contains a number from one to three darts

Figure 3: *Examples of training images for Task2. Left image: there are two darts, one positioned at t6 and the other one at s20. Right image: there is one dart positioned at s16.*

placed on the classic dartboard. The goal of this task is to count the number of darts and also localize the positions of these darts placed on the dartboard. The format that you need to follow is the one used in the annotation files, with the first line specifying the total number of darts and starting with the second line enumerating the position of each dart. We encode the position of a dart by first specifying the single/-double/triple/bull flag and then the value of the subregion (the pie-like segment of the dartboard). We use 's', 'd' and 't' for single, double and triple rings and use 'b' for bull. Possible values are numbers between 1 and 20 but also 25 and 50 (corresponding to the green and red circles for bull area). Possible annotations include:

  - s20 - a dart placed in the single region for the segment with 20 points;
  - d20 - a dart placed in the double ring for the segment with 20 points;
  - t20 - a dart placed in the triple ring for the segment with 20 points;
  - b25 - the green circle = bull with 25 points;
  - b50 - the red circle = bull with 50 points.

  Grading scheme for Task2. In the test scenario we will release 25 testing images with similar distribution to the training images containing in total 50 darts. By correctly solving the Task2 on all test images you will get 1.5 points. You get 0.03 points for predicting the correct number of darts in an image (in total 0.75 points $= 25 \times 0.03$) and 0.015 points for each correctly localized dart in an image (in total 0.75 points $= 50 \times 0.015$). We divide the 0.015 score in two parts: correctly specifying the flag worths 0.005 points and correctly specifying the value of the subregion worths 0.01 points. Notice that using this grading scheme, by correctly solving the Task2 for images with different numbers of darts you will get different points: (i) for an image with one dart you will get 0.045 points ($0.03 + 0.015$); (ii) for an image with two darts you will get 0.06 points ($0.03 + 2 \times 0.015$); (iii) for an image with three darts you will get 0.075 points ($0.03 + 3 \times 0.015$). Partial points will be awarded, for example if for an image with three darts you correctly count the number of darts and correctly specify just the subregion value but miss the flag for one dart you will get $0.03 + 0.01 = 0.04$ points out of the maximum 0.075 points.

- *Task3* - this directory contains 25 training videos showing just one dart thrown on the classic dartboard. For training videos we include also the corresponding annotations. The goal here is to predict only the position of the thrown dart. The videos are taken from three different perspectives (Figure 4). Notice that at the beginning of the video there could be other darts placed on the board. The task is only to predict the position of the new thrown dart. We use a format similar with the one used in Task2, using the character + value to denote the single/double/triple/bull flag and the value of the dart on the board.

  Grading scheme for Task3. In the test scenario we will release 25 testing videos with similar distribution to the training videos. By correctly solving Task3 on all videos you will get 1.5 points. You get 0.06 points/video if your algorithm finds exactly its position. Partial points will be awarded, for example if for an image you correctly specify just the subregion value but miss the flag for one dart you will get 0.03 points out of the maximum 0.06 points.

Figure 4: *Examples of frames from videos for Task3. Top left image: fist type of perspective. Top right image: second type of perspective. Bottom left image: third type of perspective. Bottom right image: image showing the thrown dart, the position of the dart is s20.*

- 0.5 points - ex officio. Please note that we will award the 0.5 points only to those students who submit their results in the REQUIRED format.

Evaluation

The directory *evaluation* shows how the evaluation will take place on the test data after the deadline. It contains the following subdirectories:

- *fake_test* - this directory exemplifies how the test data will be released in the *test* directory (similar with Project 1 and 2), keeping the structure of the previously described *train* directory;
- *submission_files* - this directory exemplifies the format of the results data that we expect from you to submit in the second stage. You will have to send your results in this format, uploading a zip archive of a folder similar with the one called *Alexe_Bogdan_407*. Please note that if you don't submit your results in this format you will not get the 0.5 points from ex officio;
- *code_evaluation* - this directory contains code that we will use to evaluate your results using the ground-truth data. Make sure that this code will run on your submitted files. The ground-truth data will be released after you send us your results.

Deadlines: Submit a zip archive containing ONLY your code and a pdf file describing your approach until Monday, 24^{th} of July using the following link `https://tinyurl.`

com/CV-2023-PROJECT3-SUBMISSIONS. Please do not include in your archive training images or videos. Notice that this is a hard deadline, no projects will be accepted after the deadline. Your code should include a README file (see the example in the materials for this project) containing the following information: (i) the libraries required to run the project including the full version of each library; (ii) indications of how to run the solution for each task and where to look for the output file. Students are allowed to submit their solution in the format of Jupyter Notebook files with the code being commented. This can replace the pdf file describing their approach. Students who do not describe their approach (using comments throughout the code or a pdf file) will incur a penalty of 0.5 points.

On Tuesday 25^{th} of July we will make available the test data. You will have to run your system on the test data provided by us and upload your results in the same day as a zip archive using the following link https://tinyurl.com/CV-2023-PROJECT3-RESULTS.