Classic Methods on Color Based Ball Tracking

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Abstract

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1. Introduction

Ball tracking is a classical problem present in a diverse range of applications. Nowadays it is used in sports events to automatically track the focus of the action and game score, it is also widely used in robotics, specially in Robocups soccer competitions.

2. Related Work

Ball Tracking has been studied for a long time, in a diverse range of applications. Some projects are interested in soccer's ball tracking [7, 11, 2], others are interested in volleyball [1] and basketball [5]. Normally, These works use a wide range of techniques to overcome the problems, in which motion estimation, Hough circle transform and Kalman filter are included.

In this project the focus is on colored balls, which was very popular in the robot-cup competition [3, 8, 4]. In order to overcome the problem some usual techniques were studied. Lucas and Kanade motion flow [10, 9] was studied in order to reduce total cost of the algorithm. It predicts the motion flow, which helps the algorithm of detection to be faster and reduce computational cost.

Another technique used in the project is the Hough circle transform, which helps the algorithm to find circles in the data.

Using a kalman particle filter modified for color based tracking Satoh et at. [6] used less particles then previous solutions and was able to track a pedestrian with partial occlusion crossing a crowned intersection.

3. Methodology

Initially the tracking was done alone by a color detector. Using the color space HSV to select a color range that would create a mask, in this mask every pixel in the range is set to white and everything else black, afterwards two erosion and dilation are applied to reduce noise. The connected components are extracted from the resulting mask, and the largest connected component is selected as a region that contains a colored ball of such range. Every other connected component region with size of at least 30% of the largest one is also selected as another object. Each of these selected regions has a center of mass, the coordinate of this point is used as a rough estimate of the ball's position and is taken as the tracking parameter, later on this information will be called 'tracking position'.

The previous steps should insure the detection of a colored blue, but it can't distinguish between a ball and a cube. The Hough Circle Transform is used in the mask obtained previously, and it tries to fit circles in the mask, using the edges detected by its internal canny filter. To ensure the best fit the parameter SUCH, WHAT SUCH DOES, is started with a value high enough to not find a single circle in the mask, from this high value it is decreased by one until it finds its first circle, the region below this circle is selected as a ball region. This process is repeated until up to K balls are fit. Using Hough Circle Transform the tracking narrows down to track only the roughly rounded shapes in the mask.

Applying the color detection every frame is redundant, add hough transform to that and it becomes expensive and redundant. Hough is applied every N frame, in each of these frames the position of the ball is corrected and from then it is estimated by the difference of its velocity and direction between two frames. These steps are faster, enabling the overall solution to perform in real time.

LK motion flow is enough to estimate the ball position, but it always depends on the last frame. Add a scenario in which the ball is occluded for more than a couple frame and LK motion will completely lose its estimative. Kalman filter is used to keep up with those scenarios.

4. Results

The experiments were designed to stress the effect of each new feature that was incrementally added. A controlled environment was set to perform these experiments, including a blank background, artificial white lighting, fixed camera and three balls of the same size and material, two yellow and a blue one.

Single color detection:

The goal was to precisely track a single ball throughout the camera's view.

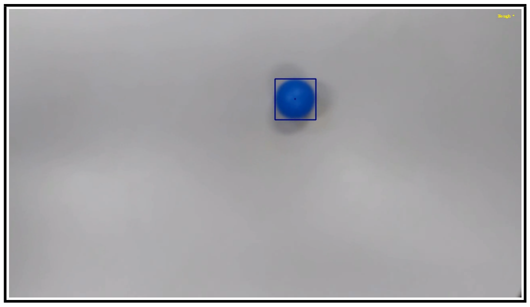

Figure 1. Detection of a colored ball.

The color detection applied to every frame was able to track the ball throughout the camera's view. This solution showed itself insufficient when some objects were introduced, with different shapes other than of a sphere but same color as the ball.

Two different color tracking:

The goal was to track each colored ball throughout the camera's view, not ever mistaking one with another.

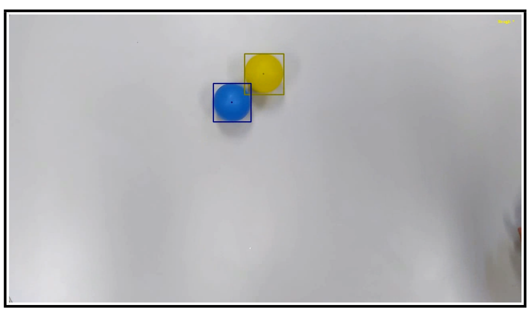

Figure 2. Detection of two balls with different colors.

The fine tuning of the colors enabled the solution to isolate one ball from the other, tracking them throughout the camera's view. This limits the solution to be tuned at every application, indoor and outdoor needs distinct calibrations.

Two same color tracking:

The goal was to track each ball throughout the camera's view, not ever mistaking one with another, now differentiating between two balls of the same color.

The size of the connected components regions found in the mask were used the discriminate between the balls, the

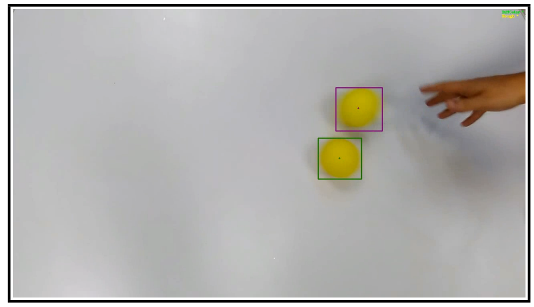

Figure 3. Detection of two balls with the same color.

ratio between the first and second was used and enabled the tracking to work, the solution is limited when the object of interest moves away from the camera and becomes too small to pass the threshold.

Ball tracking alongside with other shapes:

The goal was to track a ball in a setup with many objects with different shapes, but same color as the ball.

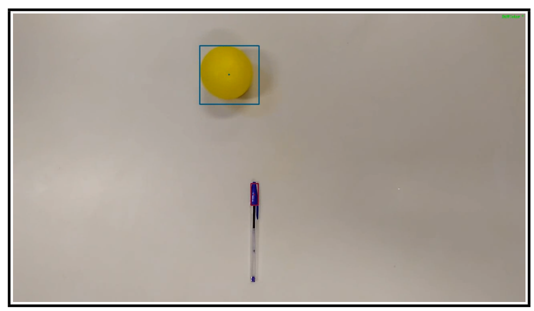

Figure 4. Detection before the Hough Circle Transform.

As seen in Figure 4 the solution wasn't able to differentiate the ball from the pen top.

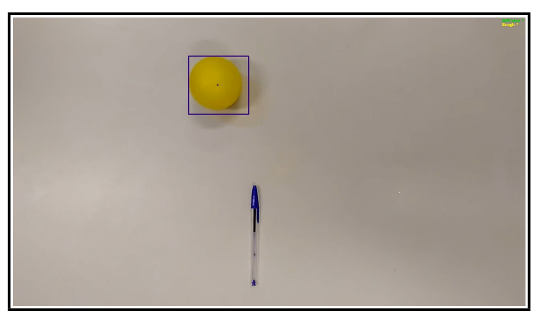

Figure 5. Detection after the Hough Circle Transform.

In Figure 5 using the Hough Circle Transform the solution was able to ignore the pen top and track only the ball shaped object. This solution is still limited by the time it took to adjust the parameters into differentiate a pen top and a ball.

Motion flow tracking compared with color tracking:

The goal was to compare both solutions, Lucas Kanade motion flow tracking and every frame color detection.

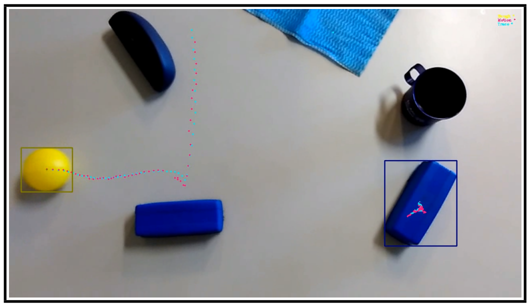

Figure 6. Lucas Kanade motion flow applied every 30 frames.

Using the Lucas Kanade motion flow the solution would only apply the color detection every N frames, this gap between detection speed up the tracking and enabled it to perform in real time (greater than 20 fps). The precision of the tracking depended on the gap size, and this experiment showed that a gap of 30 frames was too large.

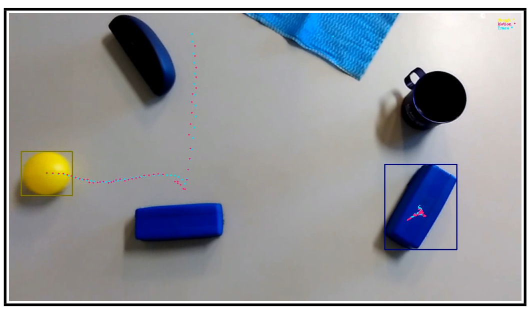

Figure 7. Lucas Kanade motion flow applied every 5 frames.

Using a 5 frames gap the precision of the tracking was close to the color tracking and the solution was still fast enough to operate in real time. Although this solution couldn't keep tracking of the ball when it was occluded.

Occlusion tracking:

The goal was to compare the LK motion flow tracking and kalman filter tracking, both applied towards a occlusion scenario.

The solution was able to overcome occlusion when the kalman filter was used in such scenarios, since it was able to estimate the ball's trajectory. The filter worked best with low speeds and couldn't estimate a position if the ball changed directions whilst occluded.

Real world tracking:

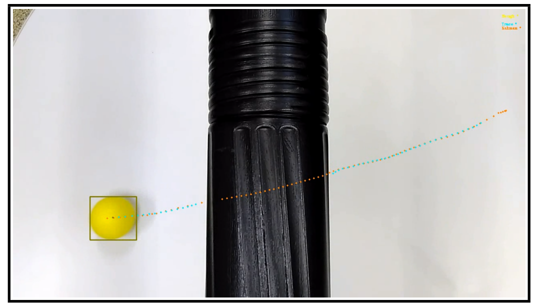

Figure 8. Kalman filter applied to overcome occlusion.

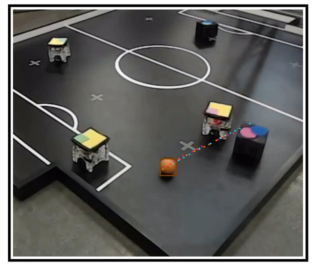

Figure 9. All features applied in a Robocup soccer match.

The goal was to hard test all the features implemented in a real world scenario to evaluate their precision.

When applied to a real world scenario the solution can keep tracking up to a point, it fails whenever the ball changes direction while occluded, or when the ball moves too fast.

5. Conclusion

As seen the classic methods were able to track and overcome some of the challenges presented in this project. It could even work good in a real example like the Robocup soccer match, however it is noticeable that the algorithm's precision is worse than in a totally controlled environment.

In harder scenarios, as a soccer, volleyball, and basketball games the algorithm had bad results, in those scenarios physics models are used to describe the parabolic trajectory of the ball, or even more complex models, which uses different clues, like the fact that a basketball player handling the ball o moves differently from the others.

In this project many of the course's topics were covered and applied, clearing our sights towards their weakness and strength in each scenario. As future work, the color based detection could be replaced with a deep neural network in order to locate the initial position of the ball. This approach could improve the overall results, and enable the algorithm to deal with harder environments.

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