On Target: An Electronic Archery Scoring System

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Abstract

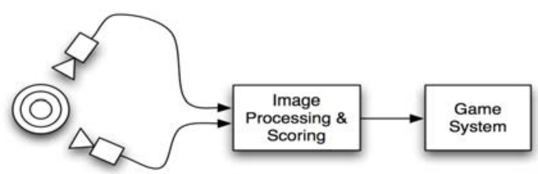
There are several challenges in creating an electronic archery scoring system using computer vision techniques. Variability of light, reconstruction of the target from several images, variability of target configuration, and filtering noise were significant challenges during the creation of this scoring system. This paper discusses the approach used to determine where an arrow hits a target, for any possible single or set of targets and provides an algorithm that balances the difficulty of robust arrow detection while retaining the required accuracy.

Introduction

Currently, the structure of archery competitions does not allow for interaction between the spectators and the competitors. Scoring is done manually and is not posted until the end of the competition, making it impossible for the spectators to know each competitor's current score. To alleviate this problem, OnTarget, an electronic scoring system, was developed. OnTarget scores each player's shots, keeping track of and displaying players' scores and rankings to the spectators, making the competition more interactive.

Approach

OnTarget is written in C++ using OpenCV, an open source image processing library developed by Intel. The images are captured by two cameras connected to a frame around the target.



Setup of the target and cameras and flow of information.

OnTarget uses numerous computer vision techniques to detect the target and the location of the arrow. First, edge detection is used to detect individual rings on the target.
Then, ellipse fitting is used to create masks of the target and of the individual rings. These can be used to filter out all extraneous noise in the image and to detect which ring an arrow should be scored under. Morphological operators are used throughout the program to remove some of the excess noise.
To find the arrow within an image, the difference between the current and previous images is found. This provides a differential mask. From this point, a structuring element is used to find the arrow. Then, OnTarget can calculate the collision area between the arrow and the target, and can properly place the arrow within the rings that are identified in the edge detection step.

Results

Out of 16 scored arrows, an overall accuracy of 87.5% was obtained (See the table below for more information). The arrows scored incorrectly were due to poor calibration on the side camera. By addressing the miscalibration of the cameras, a minimum accuracy of 93.75% would easily be achieved. At least one of the incorrectly scored arrows would be correctly scored by the side camera if poor calibration were not a problem.

	Correct	Incorrect	Total	Accuracy
Side camera	11	5	16	68.75%
Top camera	14	2	16	87.50%
Overall	14	2	16	87.50%

Results of running 16 image sets through OnTarget.

Unfortunately, there are several factors that limit the baseline of comparison between this method and a human judge. One limiting factor is the way in which a human judge scores an arrow. When a judge scores an arrow, he will walk up and look at the shot after all shots for that player have been taken. Our system, on the other hand, provides real time scoring. Also, according to Tom Green, Chair of USA Archery's Officials and Rules Committee, judges only score about 30 out of 18,000 shots in a competition. This means that the maximum possible error for a human judge would be .17%.

Conclusion

This method shows that, given certain constraints and assumptions, this type of system can be efficiently implemented in archery tournaments to increase interaction between the competitors and spectators. However, changes do need to be made to obtain accuracy closer to that of a human judge.

These changes include decreasing the sensitivity of the camera calibration, using a more accurate ellipse detection algorithm, addressing light variation, and adding a probabilistic edge completion algorithm. These changes, along with the current minimum resolution of 1280 x 960, would provide the required accuracy for competitions.

A decrease in the sensitivity of the calibration can easily be achieved by using better cameras. The cameras used in this setup did not focus well on the target. Addressing light variability would also decrease the sensitivity of the calibration. Light conditions can easily blur or brighten the images taken by the cameras. Removing these lighting problems is necessary to detect the target within the image.

A more efficient ellipse detection algorithm, such as those developed by Aguado et al. or Xie et al. should be used to create all masks. This will eliminate the high amount of ellipses that were detected which were not part of the target. Therefore, the target will be easier to detect accurately.

The canny edge detection algorithm used to find the contours of the ellipse and in several other steps produces incomplete edges with respect to some of the innermost rings. To detect all rings of the target accurately, a probabilistic edge completion algorithm should be added. This will also aid in ellipse detection.

Although this algorithm was developed for archery competitions, it can also be extended to gun competitions. A more simplistic version of this algorithm can also be used for any game that can be translated into a 2D scoring plane. One such example is in soccer to detect where a soccer ball enters the goal and measure its distance in relation to the goal keeper.

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