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Tracking a single cyclist during a team changeover on a velodrome track with Python and OpenCV

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Abstract

Team pursuit races are contested by teams of 4 cyclists in a velodrome. The lead rider in each team experiences the highest aerodynamic drag. Team-mates alternate the lead to delay fatigue. The path taken during the changeover is critical to finishing time. An automated video tracking system was developed to track the riders during changeover. It will be used by coaches to refine the team's performance during changeover. The system uses a single camera in burst mode, and employs background subtraction, edge detection and predictive tracking. The system is implemented in Python and OpenCV.

Keywords: track cycling; edge detection; Python; OpenCV; tracking;

1. Introduction

Team pursuit is an Olympic cycling discipline in which two teams of four cyclists contest a 4000m race (~16 laps depending on the length of the track). The teams start on opposite sides of a banked velodrome track (Fig. 1). The team who passes their opponents, or who crosses the finishing line first, wins.

Aerodynamic drag is the greatest of the resistive forces, and the lead cyclist in each team experiences the most drag. The others draft behind the leader, experiencing lower drag in the leader's slipstream. The lead rider is changed periodically, one of the three drafting riders taking over.

The time taken for the changeover manoeuvre is critical. The front rider peels off up the banked track and uses gravity to slow them down while the other three cyclists pass underneath. The changeover rider then accelerates back down the banking and reattaches to the rear of the group. The time taken to make this manoeuvre, and the energy expended, are important factors in determining the winner.

Video analysis offers a convenient way for coaches to track and analyse the performance of athletes, and to carry out limb motion analysis, and is applied in a number of sports [1-3]. This paper describes a video tracking system designed to determine the path of the rider moving from the lead to the rear, to aid teams and coaches in improving changeover manoeuvres. The positional accuracy of the tracking system, requested by the coaches, was 0.1m. Ease of use of the system was emphasized with minimal input required from the operators. The project was conducted by a team of four final year BE Mechanical Engineering students.

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2. Methods

2.1. Hardware

The Casio Ex-F1 camera was selected on three criteria: spatial resolution (high pixel count, non-interlaced), frame rate and format compatibility with Python. It can capture a burst of 60 frames at up to 60 fps. This task required only 10-15 fps. Each frame is a 6MP (2816x2112 pixels). This is sufficient to capture a complete changeover, which lasts between 3 and 4 seconds. It was fitted with a 36-432mm zoom lens of maximum aperture f/2.7 (W) to f/4.6 (T).

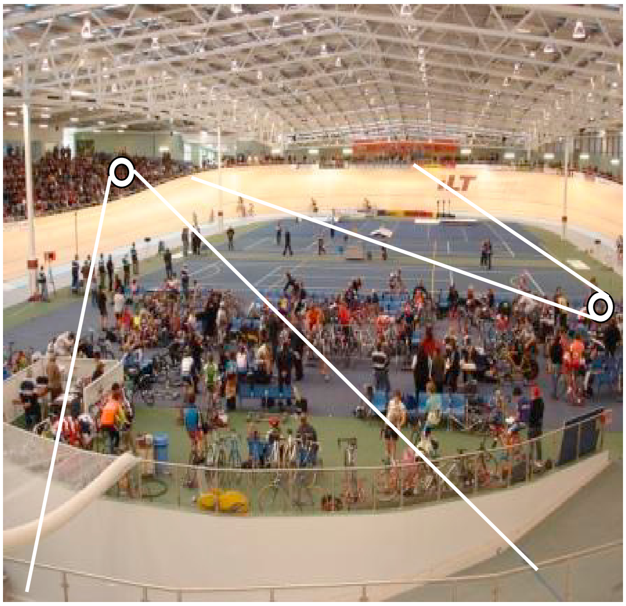

Fig. 1. Invercargill ILT Velodrome with the camera position (white circle) and field of view (white lines)

The camera is set up in the spectator seating or in the infield as shown in Figure 1, viewing the opposite side of the track, where the changeover takes place. The camera set to the ‘Auto’ mode. This makes it simple for the coach to set up and ensures that the quality of the photos taken is of a reasonable contrast in ordinary lighting. Image acquisition is manually triggered by the coach using a remote shutter release.

The data is written to a high speed SD card at 30 megabytes per second: the 60 frame burst is written in about 7 seconds which is sufficient to ensure the camera is ready for the next changeover. Once all the data is collected it is transferred to a laptop for post processing.

2.2. Software

The code was written in Python [4] and implements the OpenCV library [5]. Python was chosen as it is freeware. OpenCV was chosen for its large library and extensive user base, making sample code readily available.

In each image, the centre of the wheel is located in order to track the cyclist. The wheel is reasonably large in each image and an ellipse can easily be fitted to it so is an ideal candidate as a marker to track. Tracking is achieved with the following steps:

1. A region of interest around the expected position of the cyclist is selected, in order to reduce the amount of data to be processed. To determine where this regions should be the position of the cyclist is predicted with an estimator as described below.
2. A background image of the empty track is subtracted.

3. The image is thresholded leaving a silhouette of the cyclist.
4. Edge detection is performed with the cvCanny function (with default parameters) leaving the outline of the cyclist.
5. Points on the wheel are found using the estimate of the position of the wheel and a tracer. An initial point is found on the wheel using the estimate, and then the tracer finds the remaining points on the wheel. The tracer finds these points by finding adjoining points then identifying whether the point is part of the wheel. If the point is following the same curve, the point is on the wheel, or if it is a sudden change in direction, it is not on the wheel.
6. The points are then fed into a least squares ellipse fitter [6]. This fits an ellipse to the points, from which the centre, the point being tracked, can be found.
7. An estimate of the position in the next image is made after two centre coordinates are found. This is done using a simple linear extrapolation (Eq. 1)
8.

$$(X_{i+1},Y_{i+1}) = (X_i,Y_i) + ((X_i,Y_i) - (X_{i-1},Y_{i-1})) \tag{1}$$

More complex estimators such as condensation and Kalman filters were trialled but were not required as the linear estimation makes a sufficient estimate even at 10fps.

3. Results

Testing was performed at the Invercargill ILT indoor velodrome. Three riders performed a standard changeover at near full racing velocity. The code was designed to track cyclists using a front disk wheel, however during this testing a deep rim wheel was used and the code was able to track this accurately.

The camera was set up as shown in Fig. 1 at 10 frames per second approximately 60m away from the track. The field of view was approximately 40m which is sufficient to capture the entire changeover. A sample trajectory output is shown in Fig. 2.

Fig. 2. The changeover trajectory of the leading cyclist: the trajectory determined by the program is shown in red

The mean error in the location of the front hub was determined by inspecting several frames. An example is shown in Fig. 3. In this particular frame the centre of the wheel, as estimated by the ellipse fitting algorithm, lay within three pixels of the actual centre. On average over several frames the code tracked the hub to within ± 0.06 m, which exceeds the accuracy requirement specified by the coaches of ± 0.10m. Assuming negligible error in the frame rate the maximum uncertainty in the measured speed is ±7% at 50kph or ±3.5kph.

Fig. 3. Close up image of the lead cyclist which indicates the predicted centre of the front wheel in green and actual centre in blue.

4. Future work

4.1. Camera Calibration

Currently the variation in magnification over the field of view is not taken into account. This will be corrected with a calibration function determined from known landmarks, such as the blue and red lines, and the 10m distance markers visible in Fig. 4 and indicated by arrows. A smoothing filter can be applied to the velocity profile to further reduce random noise.

Fig. 4. An image of the track with the position of the distance markers indicated.

4.2. Automation

Full automation of the burst photography can be achieved by triggering the camera from a light beam sensor near the track close to the beginning of the changeover.

4.3. Additional Features

The system can easily be extended to incorporate extra features.

- The lean angle of the rider can be calculated using the ellipse that approximates the front wheel.
- The position of the riders head can be calculated using colour recognition of the helmet
- Apex lap timing. Lap timing is calculated at the start/finish line but coaches have indicated it would be more beneficial to have a lap time from the apex of the turn. This gives the time for a lap lead solely by one rider as opposed to one including the changeover.
- The system can be extended to synchronise with existing SRM systems. This will allow the power exerted, cadence and other data to be studied/monitored over the changeover.

5. Conclusions

A video tracking system to determine the trajectory of a velodrome cyclist was implemented in Python and OpenCV. The front wheel is identified, edge detected and an ellipse fitted, which gives the hub position to within ±6cm from a working distance of 60m. The system performed correctly during testing at the Invercargill ILT velodrome. The system will prove very helpful to NZ coaches and cyclists as a tool to improve their changeovers.

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