DETERMINATION OF AXLE COUNT FOR VEHICLE RECOGNITION AND CLASSIFICATION[1]

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We have solved the axle count determination problem for video-based automatic vehicle classifier in the case of quasi-uniform vehicle speed. The procedure is simple, robust to wheel detector errors, and computationally efficient due to the use of the fast Hough transform. It provides a self-test for applicability for detection of cases where it is not applicable, thus allowing adaptive method switching for cases of non-uniform speed.

Introduction

Toll roads play important role in modern transportation systems. Fee on such roads usually depends on several characteristics of a vehicle. To maximize the throughput of a toll gate it is essential to measure these characteristics automatically. Systems that do this are known as automated vehicle classifiers (AVC).

One rather common parameter to be determined is the wheel axle count. In commercially available AVCs axles are usually counted by optic pairs which are occluded by wheels of the passing vehicle. This system has significant disadvantages: it cannot discriminate between wheels and other objects and doesn't register raised wheel pairs which are quite common in some trucks. It quickly becomes dysfunctional in conditions of snow or dirt as optic pairs are located very close to the road surface, and thus has very large maintenance costs. Compared to such systems, computer vision-based systems for counting vehicle axles seem beneficial.

One obvious way to count vehicle axles is to set up a video camera looking at the side of a passing vehicle and use some object tracking method to trace the path of each wheel (Fig. 1). The problem of counting axles thus becomes the problem of counting wheels. A wheel can be defined as a characteristic static shape on a frame, and wheel detector can be constructed using pattern recognition methods, such as Viola-Jones method [1] or any other. To determine the total wheel count we could plot the wheel centers in *x*–*t* coordinates, *x* for the position along the motion direction (horizontal) and *t* for timestamp of the frame and then count the continuous tracks (connected components) corresponding to each wheel.

In practice, since “wheel” is highly varied and thus ill-defined pattern, any wheel detector would have finite accuracy and generate errors in the form of false positives, false negatives or multiple activations per wheel (Fig. 1). Determination of total wheel count from connected components is not very effective in these conditions since there may be false tracks and large gaps.

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Fig. 1. Vehicle passing near the automatic vehicle classifier camera. Squares show wheel detector results.

We present a robust and accurate method of determination of vehicle axle count based on inputs from one or many noisy wheel detectors for the case of quasi-uniform motion of the vehicle. The essence is that in the case of uniform motion the track of each wheel is a straight noisy line (Fig. 2*a*) and we can robustly count these lines using fast Hough transform (FHT) [2] with pre-smoothing. The algorithm works with any wheel detector which gives the coordinates of proposed wheel centers on a frame. Specifics of wheel detection on a static image are beyond the scope of this paper.

Throughout the text the algorithm or software component that computes the integral wheel count from outputs of wheel detectors on frames of video sequence will be referred to as wheel integrator.

Method

Input to the wheel integrator consists of wheels $\{w\}$ detected at each frame by one or more wheel detectors. Each wheel w is characterized by the horizontal coordinate x of the center, frame timestamp t and confidence score s given by the detector premultiplied by the weight of the specific detector relative to all detectors. Wheels are plotted on an image $W(x, t)$ (Fig. 2*a*):

$$W(x,t) = \sum_{w:\, x(w)=x,\, t(w)=t} s(w).$$

Since our wheel detectors have either significant x-coordinate error or discretization step bigger than 1 pixel, we perform smoothing of the image using a box filter along the x axis. After the box filter wheel tracks are represented by almost continuous straight lines (Fig. 2*b*). These lines are to be counted to give the final answer.

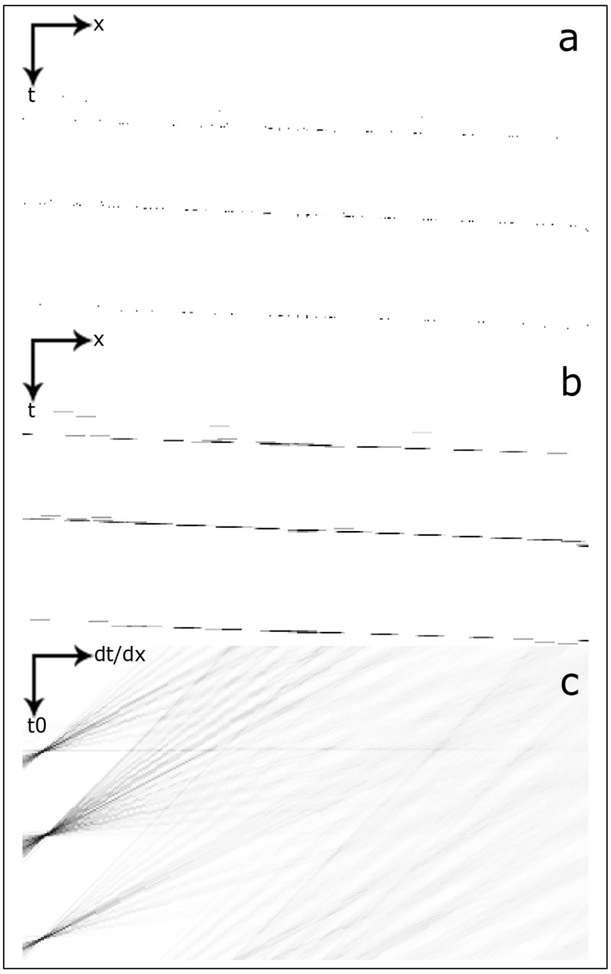

Fig. 2. Steps of the wheel integrator algorithm for a vehicle with 3 axles: x–t image of wheel detector results (a); result of application of box filter to (a) along the x axis (b); Hough transform of the (b) image (c).

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A good means of line detection is the fast Hough transform (FHT) [2], which is both computationally efficient and robust to noise. Lines are represented by sharp maxima in the Hough-image (Fig. 2*c*). To find all straight lines in the image we employ the back projection method. First, we compute the initial Hough image:

$$H(t_0, dt/dx) = \mathrm{FHT}(W(x, t))$$

and find the global maximum:

$$M = \max H(t_0, dt/dx) .$$

If $M < T_M$ (T_M is an adjustable parameter) then there have been no wheels in the video sequence and we return 0. Else we compute the secondary threshold $T_m = M\ T_r$ (T_r is an adjustable parameter) and record one line. Then we determine the parameters of the line, erase it on W and recompute $H = \mathrm{FHT}(W)$. We find the maximum again and if its value exceeds T_m, record the line repeat the process until either

$$\max H(t_0, dt/dx) < T_m$$

or line count exceeds maximum possible axle count.

As a side effect, the procedure allows us to determine speed of the vehicle in pixels per frame:

$$dx/dt = \left(\arg\max H(t_0, dt/dx)\right)^{-1} .$$

The described method only gives good results when the speed of each wheel is close to uniform. However, we can automatically detect whether the algorithm succeeded in its task. First, in the case of uniform motion wheel tracks cannot intersect each other within the bounds of $W(x, t)$. Second, when the line count limit is exceeded, there is a good chance that the motion was non-uniform. Using these criteria, we can automatically fall back to methods that are generally less accurate but correct with respect to non-uniform motion.

Conclusion

We have solved the axle count determination problem for video-based automatic vehicle classifier in the case of quasi-uniform vehicle speed. Multiple wheel detectors are supported. The procedure is robust to errors of wheel detectors. Execution time of the entire procedure is less than 25 ms on modern personal computer due to use of the fast Hough transform.

References

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