Camera Parameter Estimation For Highway Images

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1 THE PROBLEM

Knowing only the height of the camera, can we use regulated lane widths to estimate the focal-length and tilt-angle of the camera from a single image?

Why is this useful?

Highway traffic monitoring cameras (Fig. 1, 2) provide urban planners & local transit authorities important information such as vehicle counts and incident detection.

Figure 1 - A highway monitoring camera [2].

Many automated analysis techniques require knowledge of the camera's intrinsic and extrinsic parameters, such as focal-length and tilt-angle for calibration purposes.

Previous methods have shown that focal length and tilt angle can be estimated in scenes with curved roadways by maximizing the parallelism of the rectified reprojections of curved lane boundaries. Unfortunately, this fails for scenes containing only linear roads[1].

Figure 2 - Image captured by MTO's highway monitoring cameras.

Thus, there exists a need to accurately estimate camera focal-length and tilt-angle from linear highway scenes in order to perform traffic analysis.

2 METHODOLOGY

We propose a method to estimate focal-length and tilt-angle by back-projecting detected lane boundaries to the ground plane and matching the known lane width (3.5m).

If focal length, tilt angle and the height of the camera are known, image points *[x, y]* can be back-projected to ground plane points *[X, Y]* (Fig. 3).

$$\begin{bmatrix} X \\ Y \\ 1 \end{bmatrix} = \lambda \begin{bmatrix} f^{-1} & 0 & 0 \\ 0 & (f\ cos\phi)^{-1} & 0 \\ 0 & -(fD)^{-1}tan\phi & D^{-1} \end{bmatrix} \begin{bmatrix} x \\ y \\ 1 \end{bmatrix}$$

$$Where \quad f = Focal\ Length, \quad \phi = Tilt\ Angle, \quad D = \frac{height}{cos\phi}$$

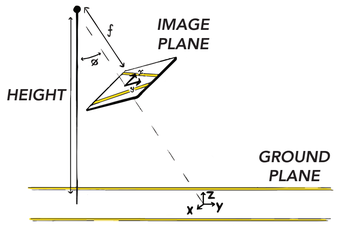

Figure 3 - Geometric modelling of the scene.

Once a pair of lane boundaries has been manually identified, the algorithm iteratively estimates the projection matrix, each time minimizing the deviation of the distance across the projected boundaries from the known lane-width (3.5m in Ontario). There are 4 steps in each iteration:

1. **Project lane boundaries to ground plane.**
2. **Sample points evenly along the lane.**
3. **Calculate normal distances across lane.**
4. **Re-estimate projection by minimizing deviation from expected distance.**

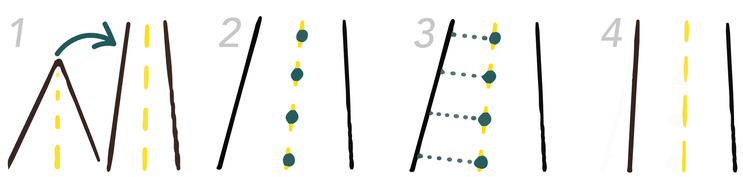

Figure 4 - Visualization of the 4 iterative steps in the algorithm

3 RESULTS

The algorithm was tested on multiple images from a hallway scene (Fig. 6), where the camera height and hall width was well known. Estimations were compared against ground-truth (Fig. 5), and were able to rectify images with a high degree of parallelism (Fig. 7, 8).

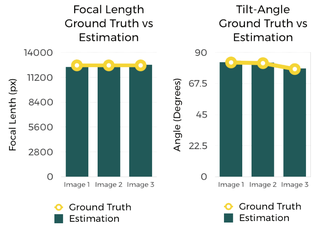

Figure 5 - Visualization of how close estimates were to ground truth values

Estimation Errors

Image	Focal Length	Tilt Angle
1	1.4%	<0.01%
2	0.7%	0.01%
3	1.1%	0.01%

Figure 6 - Hallway Image 1; lines delineate "lane boundaries".

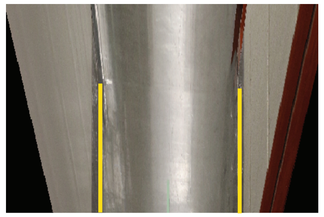

Figure 7 - Hallway Image 1 after rectification.

In testing environments, our method produced estimates within 1.4% of the true value.

Conclusion & Future Work

This algorithm was effective in hallway scenarios; however, it is sensitive to the accuracy of known height and precision of labelled lane markings.

This work could be improved by automating lane boundary detection, as well as by including multiple lanes in the optimization.

Figure 8 - MTO image after rectification with estimates.

[1] E. Corral-Soto, J. Elder. "*Automatic Single-View Calibration and Rectification from Parallel Planar Curves*". In ECCV. Centre for Vision Research, York University, 2014.

[2] "*Goa City Security Surveillance*" Intelligent Integrated Video, i2v System Pvt. Ltd., 2015, www.i2vsys.com.

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