“3D Lane Detection System Based on Stereo Vision”

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Review by :

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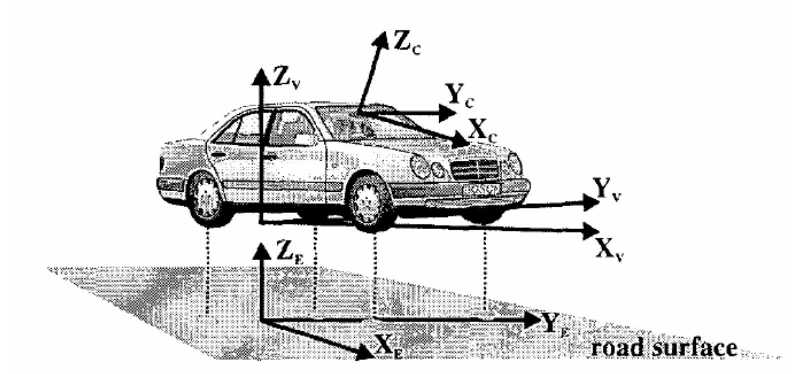
Lane Detection

- W – the width of the lane
- $c_{h,0}$ – horizontal curvature of the lane
- $c_{h,1}$ – variation of the horizontal curvature of the lane
- $c_{v,0}$ – vertical curvature of the lane
- X_{cw} – the lateral displacement of the car reference system from the lane reference system (lane center)
- α, γ, ψ the pitch, roll and yaw angles of the car (the rotation angles between the car reference system and the world reference system).

$$\mathbf{X} = (W, c_{h,0}, c_{h,1}, c_{v,0}, c_{v,1}, X_{cw}, \alpha, \gamma, \psi)^T$$

Model : Camera Calibration



Extrinsic camera calibration finds rotation matrices
to get road and vehicle axis systems

Road Model

Clothoid: a spiral curve with a curvature that is changing at a constant rate

the variation of the lateral position (X) of the center of the lane with the distance Z

$$X_c = -X_{cw} - \psi Z + c_{0,h}\frac{Z^2}{2} + c_{1,h}\frac{Z^3}{6}$$

Vertical position for any point on the road.

$$Y = Z\alpha + c_{0,v}\frac{Z^2}{2} + \gamma X$$

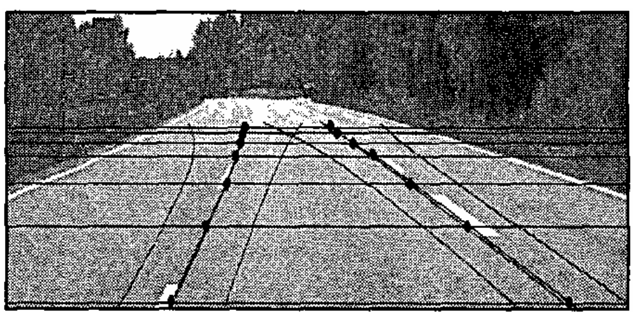
Vehicle Model

Simple dynamic system: depends on wheel spin sensors

$$\underline{\Phi}_k = \begin{bmatrix} 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 1 & v_k \Delta t_{k,k+1} & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 1 & v_k \Delta t_{k,k+1} & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 \\ 0 & -\frac{(v_k \Delta t_{k,k+1})^2}{2} & -\frac{(v_k \Delta t_{k,k+1})^3}{6} & 0 & 0 & 1 & 0 & 0 & v_k \Delta t_{k,k+1} \\ 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 \\ 0 & -v_k \Delta t_{k,k+1} & -\frac{(v_k \Delta t_{k,k+1})^2}{2} & 0 & 0 & 0 & 0 & 0 & 1 \end{bmatrix} \qquad \underline{\Gamma}_k \vec{\mathbf{u}}_k = \begin{bmatrix} 0 \\ 0 \\ 0 \\ 0 \\ 0 \\ \frac{(v_k \Delta t_{k,k+1})^2}{2} \\ 0 \\ 0 \\ v_k \Delta t_{k,k+1} \end{bmatrix} c_{0,k}$$

Input vector and transition matrix are used to find the lane state prediction and its covariance matrix

State Prediction



Input vector: provides prediction of the lane in the image space
Diagonal of its covariance matrix: provides the width of the search regions.

Road Extraction – Vertical Profile

- Search regions are processed
- Pitch and vertical curvature are extracted
  - method is similar to the Hough transform
  - angle histogram is built for each possible pitch angle using near points
  - search goes up the road until histograms are aligned
  - Pitch angle is used with the same process to find vertical curvature

Road Extraction – Horizontal Profile

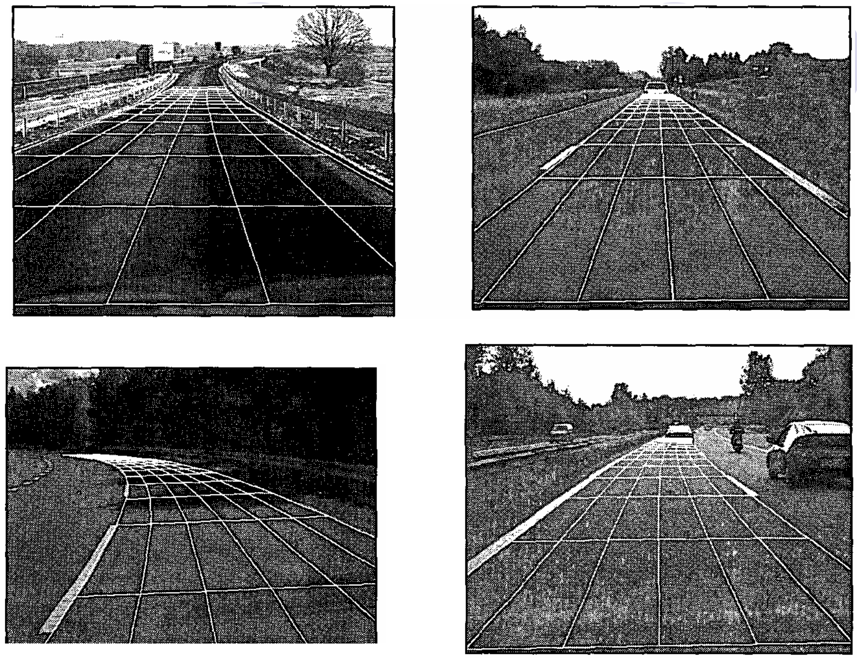
- Edges that comply with the search region and the vertical profile are used for lane model matching
- The algorithm matches straight lines within the search regions
- The lane position vector is updated through a Kalman filter
- The model fits if enough search regions have been successfully associated

Model Matching

- Parameters are extracted from the new model
- Each lane border has 10 pairs of (X,Z) coordinates
- The lane width is solved
- The roll angle is solved: this will be used for horizontal profile detection in the next frame

Vehicle Modeling and Position Tracking

- The lane state vector is updated through the Kalman filter
- Using the Kalman filter allows for more stability
- If detection fails, prediction is used for several frames to update the state vector (otherwise the track is aborted)



Disadvantages of 3D Lane Detection

- Edge segmentation is not the best for urban environments (construction, pedestrian crossings, intersections, etc.)
- This process assumes a relatively consistent width of the road/lane

Advantages of 3D Lane Detection

- modeling approach is good for long range vision
- works well even in the presence of:
  - a) strong road shadows
  - b) high vertical or horizontal curvatures
  - c) or obstacles on the current lane
- fast in real-time
  - "Increased Accuracy Stereo Approach for 3D Lane Detection" (2006) – Nedevschi modifies algorithm to be faster, more reliable, up to 60-90 meters
  - Achieves 13-18 frames/sec on a Pentium 4, 512 MB with a resolution of 644 x 512
- can easily be scaled up to another lane model
  - Color segmentation of road barriers, lines
  - Specific boundry feature extraction

Sources

McCall, J.C.; Trivedi, M.M., "Video-based lane estimation and tracking for driver assistance: survey, system, and evaluation," Intelligent Transportation Systems, IEEE Transactions on , vol.7, no.1pp. 20- 37, March 2006.

S. Nedevschi, R. Schmidt, T. Graf, R. Danescu, D. Frentiu, T. Marita, F. Oniga, and C. Pocol, "3D lane detection system based on stereovision," in *Proc. IEEE Intelligent Transportation Systems Conf.*, Washington, DC, Oct. 2004, pp. 161–166.