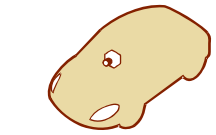
Robust lane lines detection and quantitative assessment

A. López, J. Serrat, C. Cañero, F.Lumbreras

Computer Vision Center and Computer Science Dept.
Universitat Autònoma de Barcelona

IbPRIA'07, Girona



ADAS group

Centre de Visió per Computador

UAB
Universitat Autònoma de Barcelona

Outline

1. Context : ADAS and lane markings
2. Goals
3. Method : what’s new
4. Results
5. Conclusions

What’s ADAS

ADAS=“Advanced driver assistance systems”.

Onboard systems which combine sensors and algorithms to *understand the vehicle environment* so that the driver can receive assistance or be warned of potential hazards.

Vision is the most important sense employed for driving $\rightarrow$ computer vision is a natural (but not unique) choice.

What's ADAS

Lane Departure Warning
Automatic Cruise Control
Stop & Go
Platooning
Collision avoidance
Pedestrian Protection
Intelligent frontlights
Intelligent airbags …

need

Detection of lane markings
Vehicle recognition & tracking
Pedestrian detection
Road segmentation
Driver, occupants monitoring
…
in highly varying conditions (lighting, road, traffic…)

Lane markings

may seem easy…

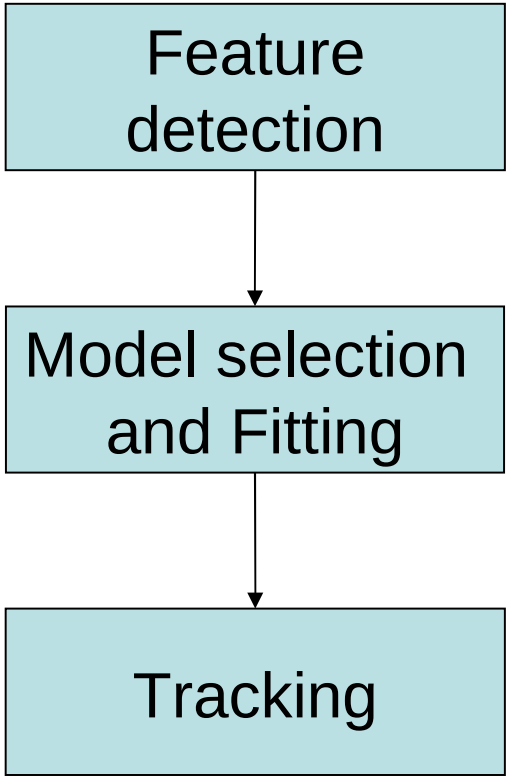
Lane markings

but occlusions, shadows, low contrast … make it difficult

Goals

- Extraction lane lines on video sequences
- Real time (>25 *fps* or <40 *ms*/frame)
- Robustness : deal with lighting changes, occlusions, etc.
- Computation of meaningful geometric parameters : road curvature, lane width, vehicle lateral offset and heading orientation w.r.t lane axis
- Validation: what ground truth ?

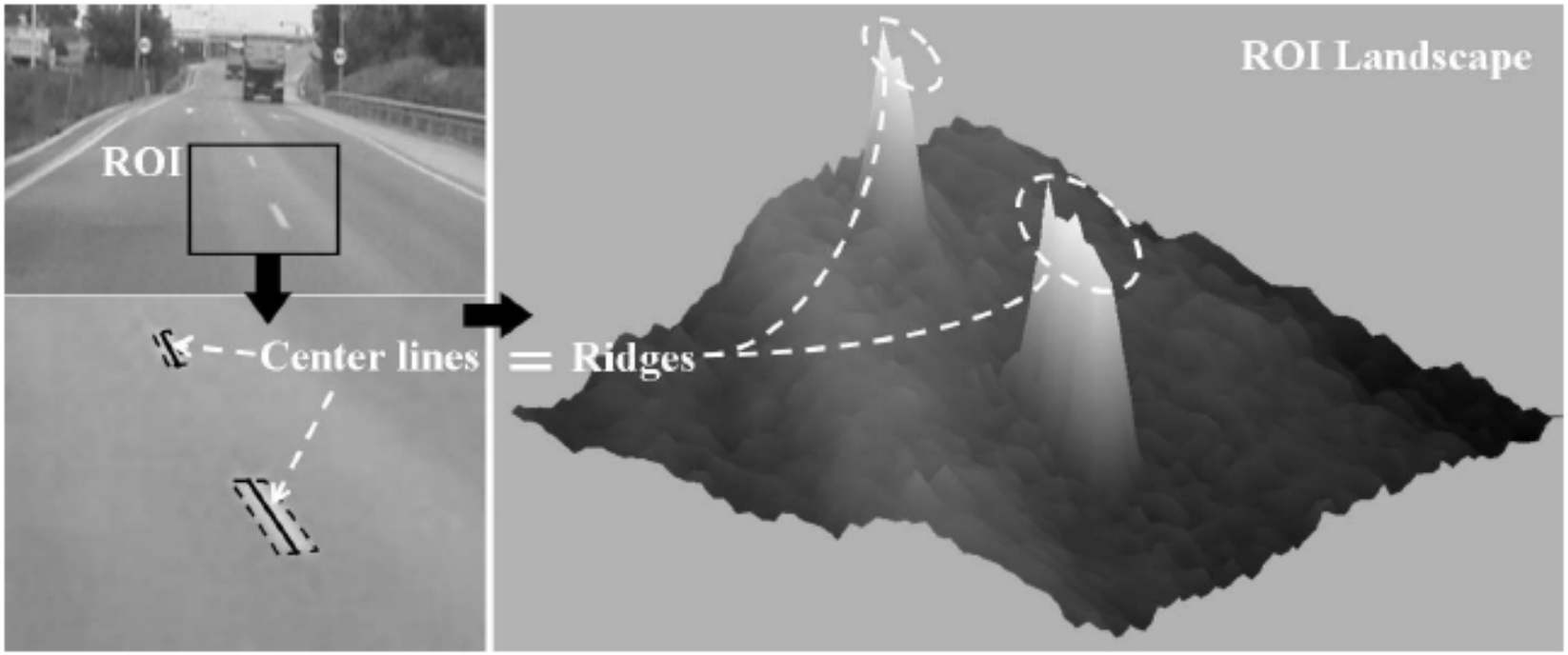
Method : what's new



- Ridges
- Two paralel hyperbola + RANSAC robust fitting
- No tracking : frame by frame processing
- Kalman filter

Method : what's new

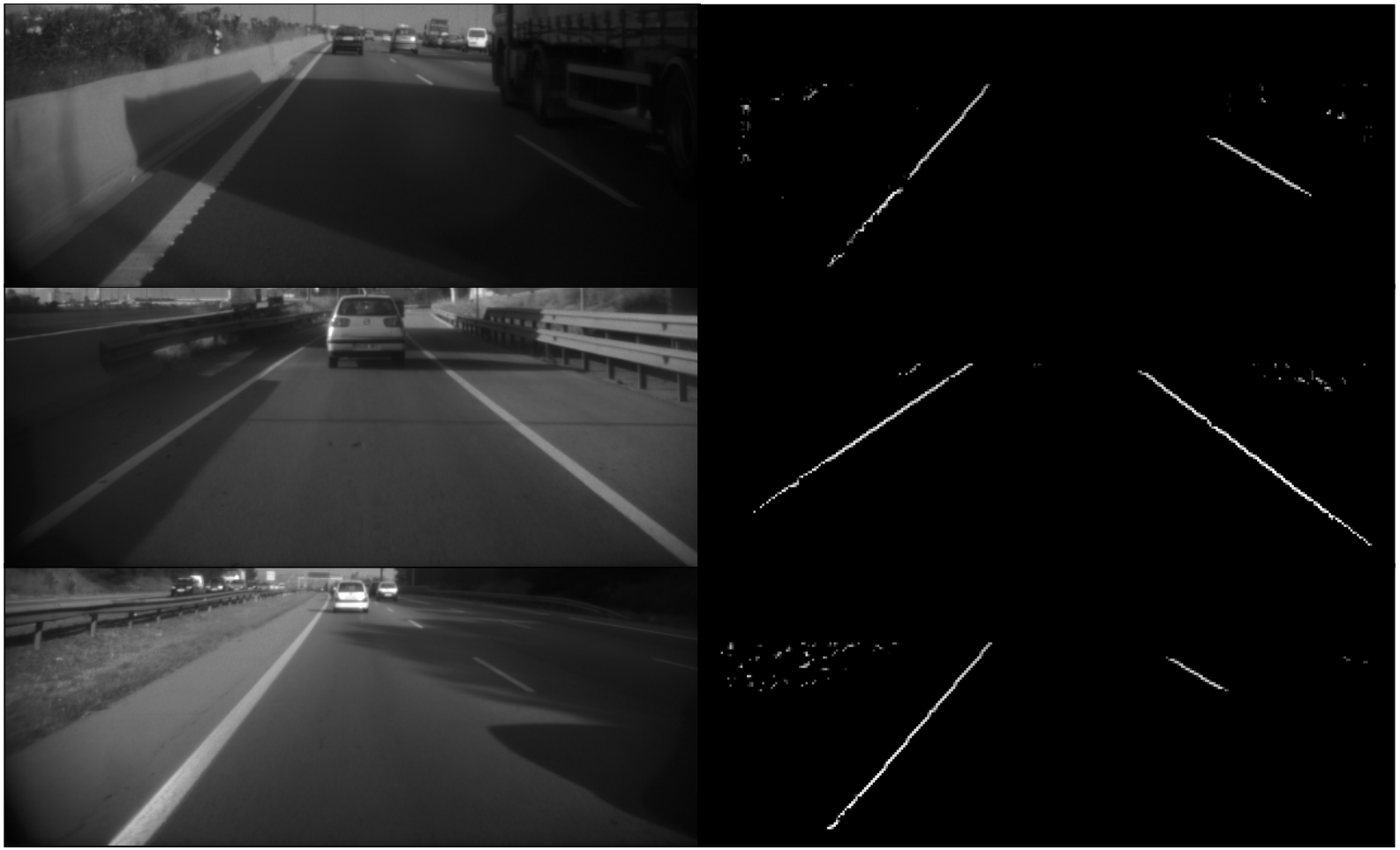
(1) Features : ridges instead of edges



$$\left.\begin{aligned} L_{\sigma_\mathrm{d}}(\mathbf{x}) &= G_{\sigma_\mathrm{d}}(\mathbf{x}) * L(\mathbf{x}) \\ \mathbf{w}_{\sigma_\mathrm{d}}(\mathbf{x}) &= (\partial_u L_{\sigma_\mathrm{d}}(\mathbf{x}), \partial_v L_{\sigma_\mathrm{d}}(\mathbf{x}))^\top \end{aligned}\right\} \quad \tilde{\kappa}_{\sigma_\mathrm{d},\sigma_\mathrm{i}}(\mathbf{x}) = -\mathrm{div}(\tilde{\mathbf{w}}_{\sigma_\mathrm{d},\sigma_\mathrm{i}}(\mathbf{x}))$$

Method : what's new

(1) Features : ridges instead of edges



Method : what's new

(2) Model selection involving 4 road and vehicle geometric *meaningful* parameters.

Under the assumptions of

- planar road
- piecewise constant curvature,

lane lines are imaged as two hyperbolae with a common horizontal asymptote.

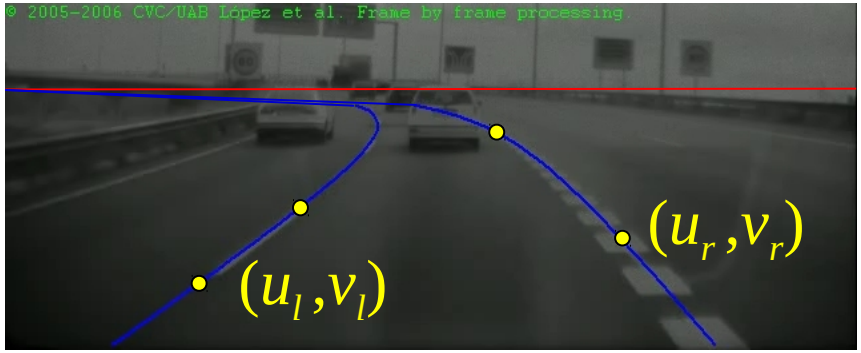
$$v = v_0$$

$$u - u_0 = a(v - v_0) + \frac{b}{(v - v_0)}$$

Method : what's new

(2) Model selection involving 4 road and vehicle geometric *meaningful* parameters

$$\begin{bmatrix} 1 & 0 & v'_l & 1/v'_l \\ 1 & -v'_r & v'_r & 1/v'_r \end{bmatrix} \begin{bmatrix} a_1 \\ a_2 \\ a_3 \\ a_4 \end{bmatrix} = \begin{bmatrix} u_l \\ u_r \end{bmatrix}$$

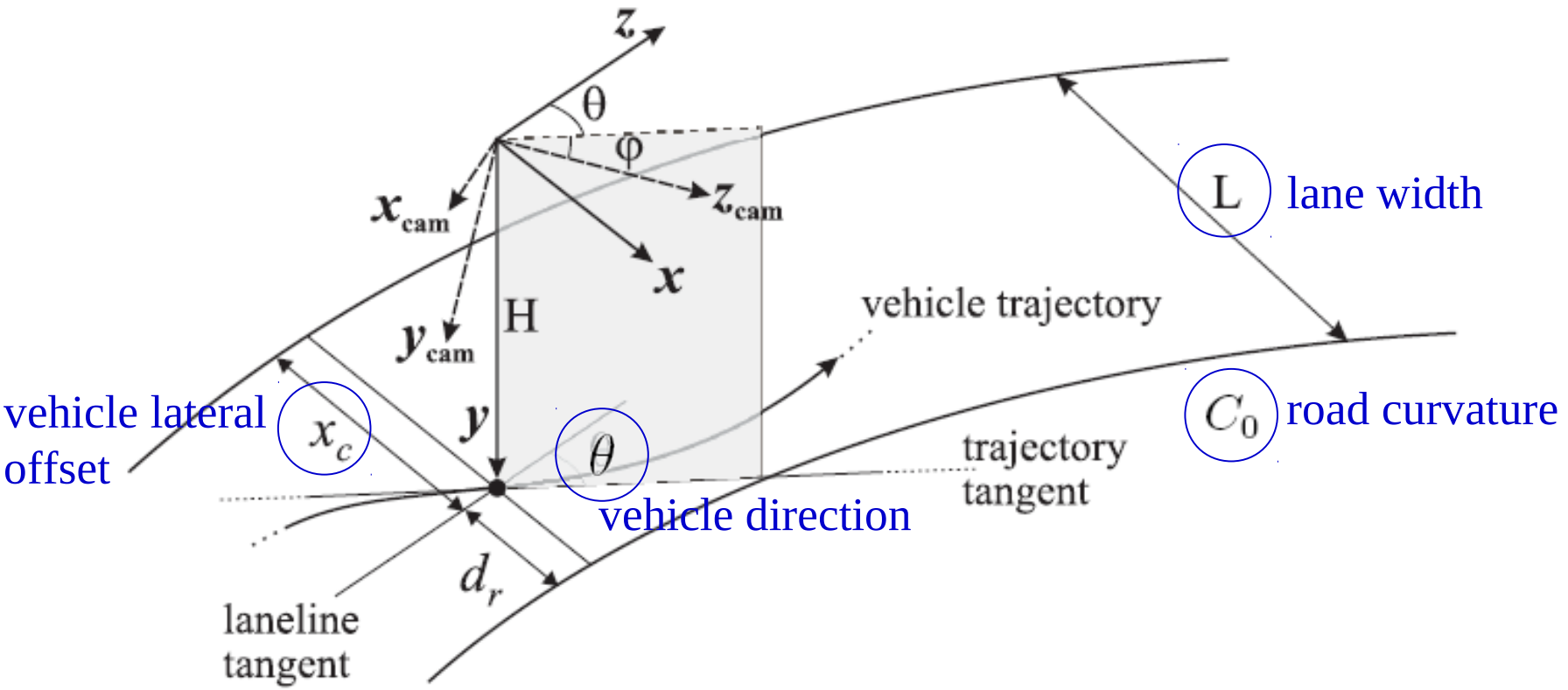


$$v'_r = v_r/E_v + \tan\varphi$$
$$v'_l = v_l/E_v + \tan\varphi$$

$$\theta = \frac{\cos\varphi}{E_u} a_1, \quad L = \frac{H}{E_u \cos\varphi} a_2, \quad x_c = \frac{H}{E_u \cos\varphi} a_3, \quad C_0 = \frac{4\cos^3\varphi}{E_u H} a_4$$

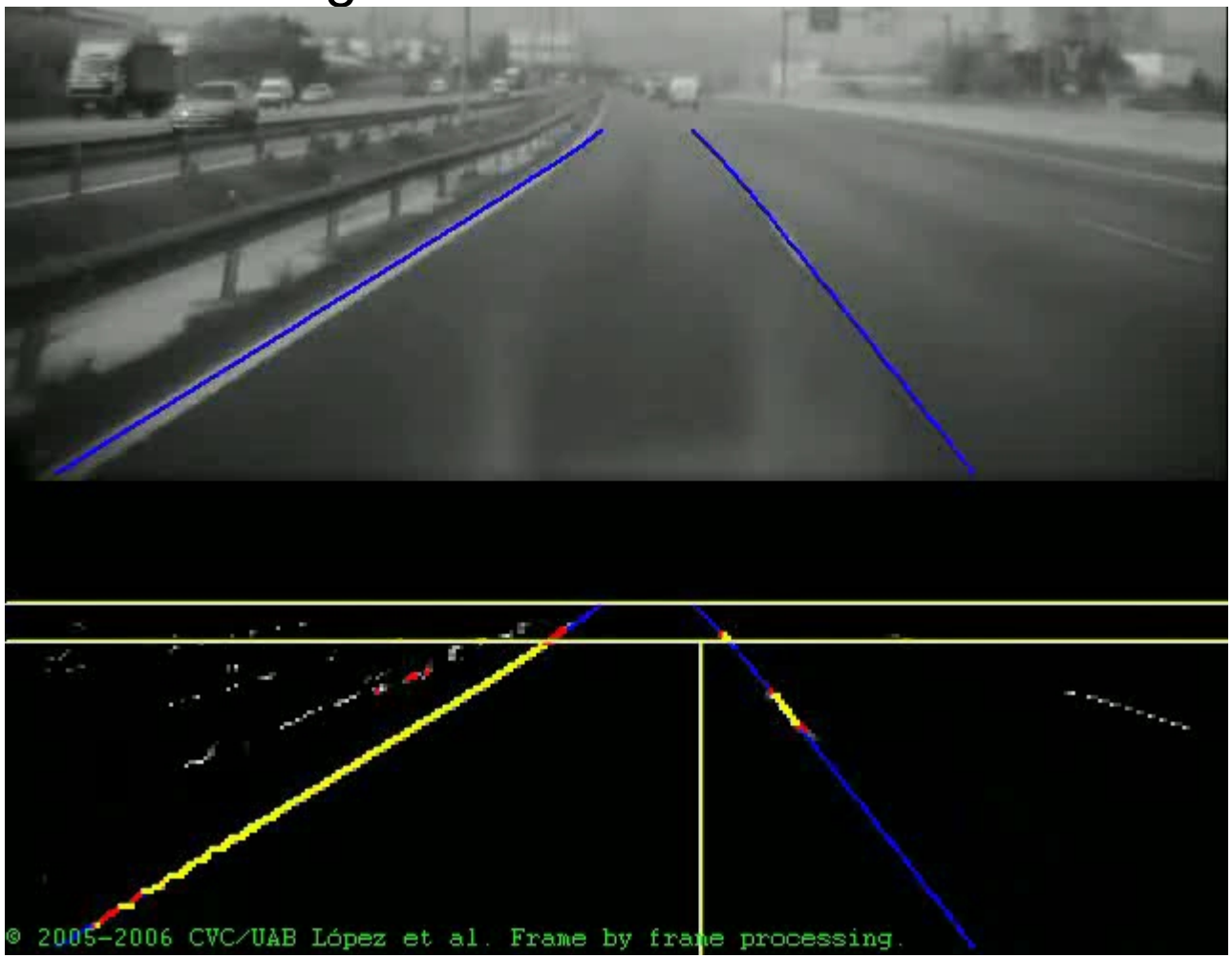
Method : what's new

(2) Model selection involving road and vehicle geometric *meaningful* parameters



Method : what's new

(3) Robust fitting with RANSAC



inlier

outlier

rejected

Results

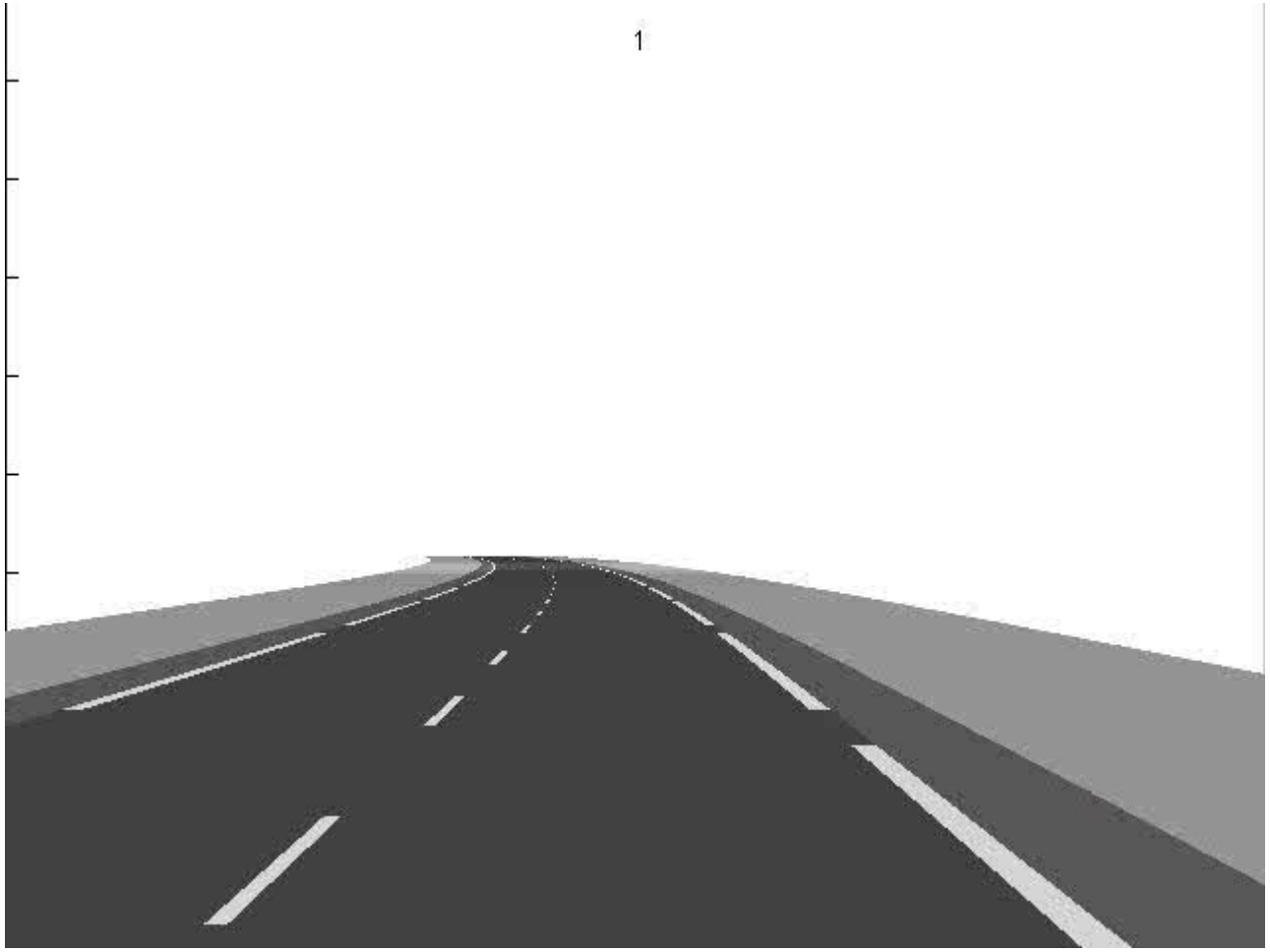
There is no ground truth available for quantitative assessment: exact (*cm*) vehicle trajectory and road curvature.

Synthetic sequences : ground truth available for the 4 estimated parameters $\rightarrow$ *quantitative assessment* is possible.

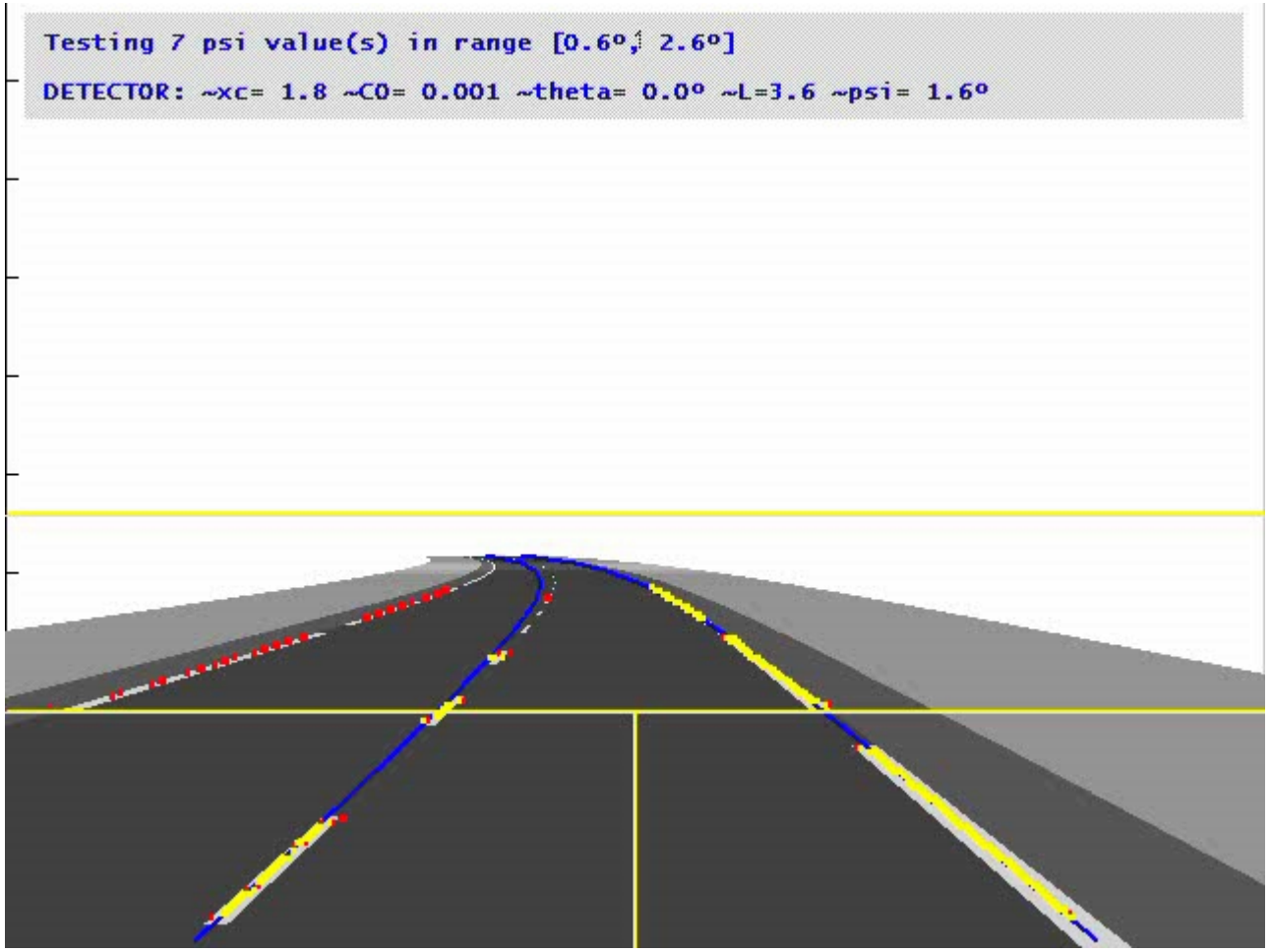
Geometrically realistic :

- smoothly varying curvature
- slope changes
- varying pitch angle (horizon line)

Results

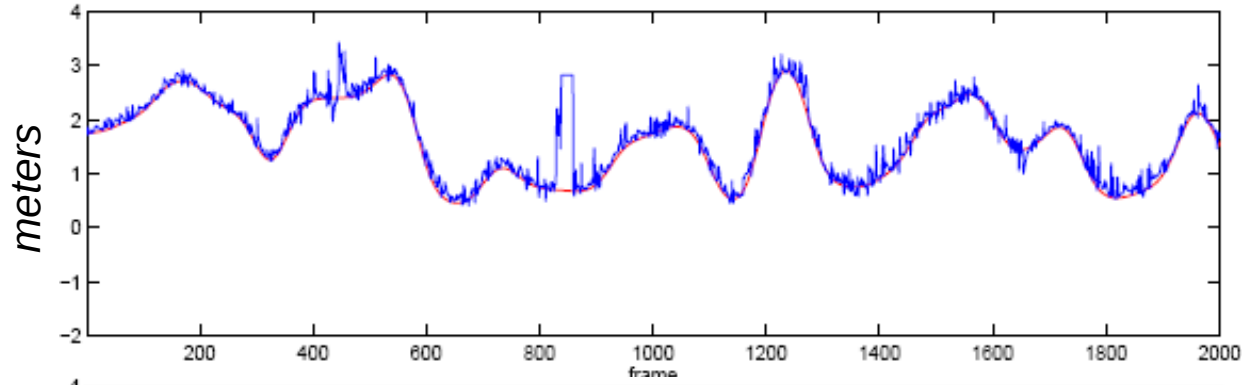


Results

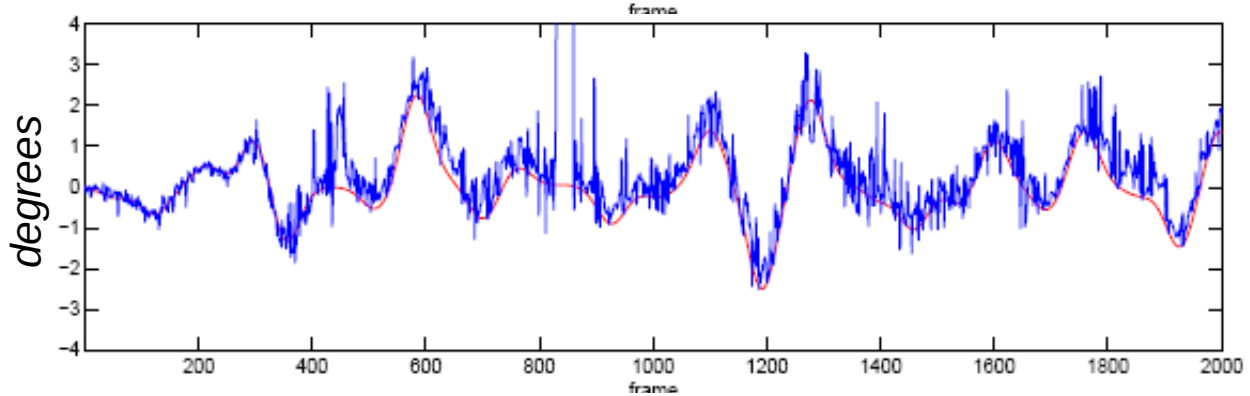

Testing 7 psi value(s) in range [0.6º, 2.6º]
DETECTOR: ~xc= 1.8 ~C0= 0.001 ~theta= 0.0º ~L=3.6 ~psi= 1.6º

computed
ground truth

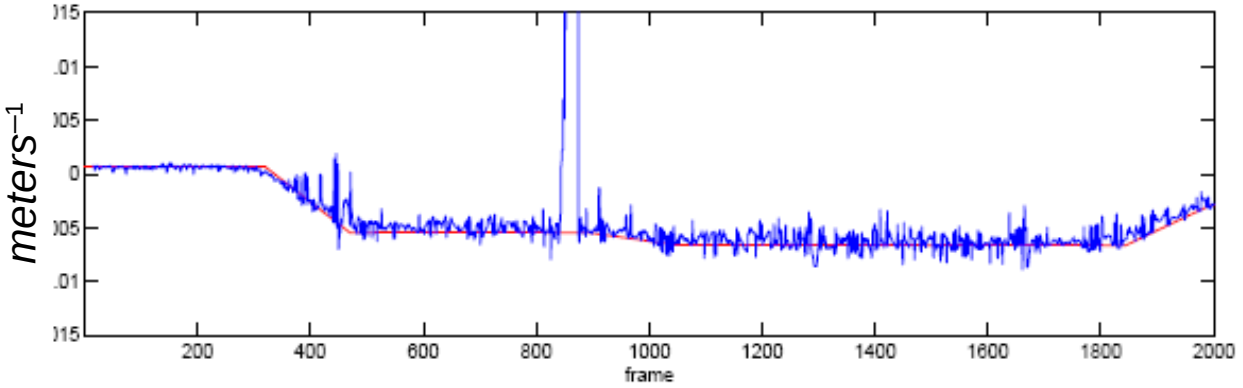
Results



x_c lateral displacement



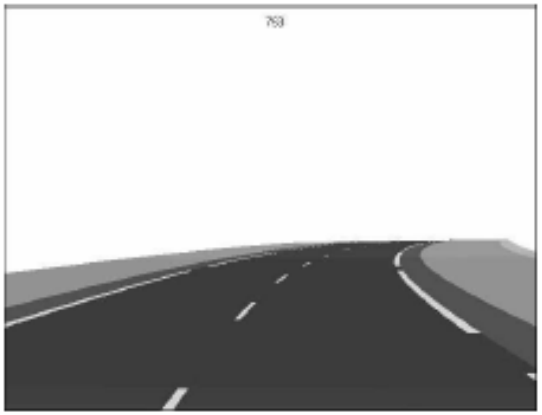
θ vehicle direction w.r.t lane axis

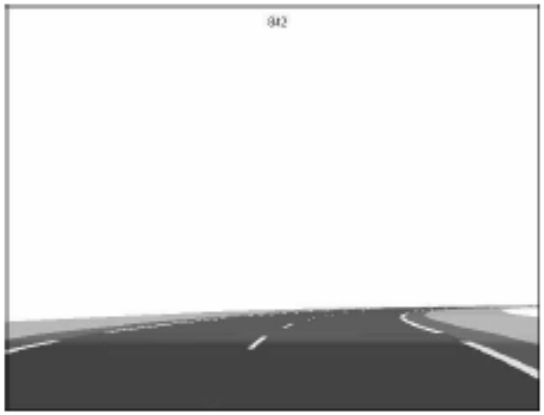


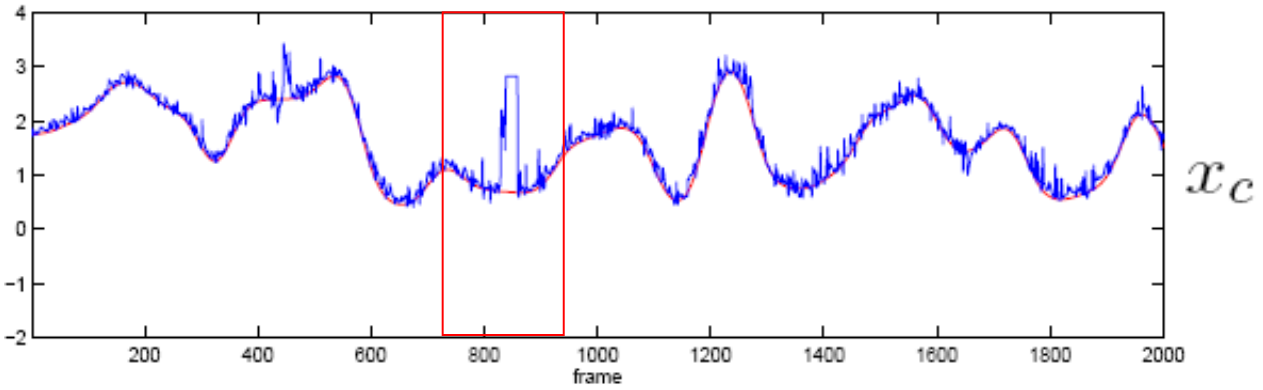
C_0 road curvature

Results

A negative slope change shrinks the road region, causing large errors

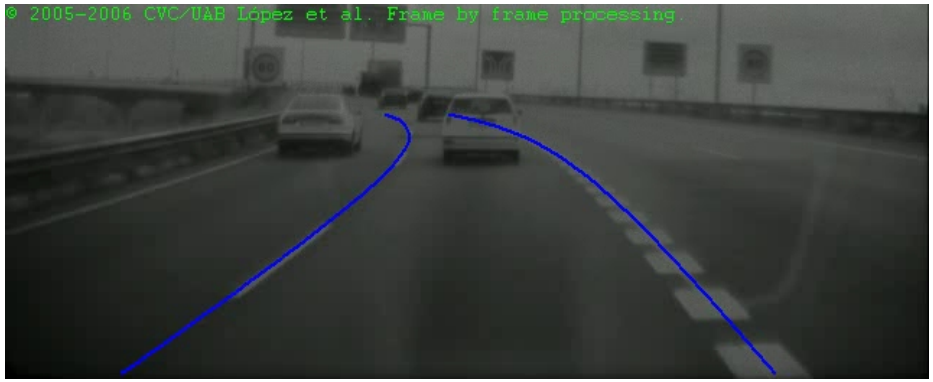


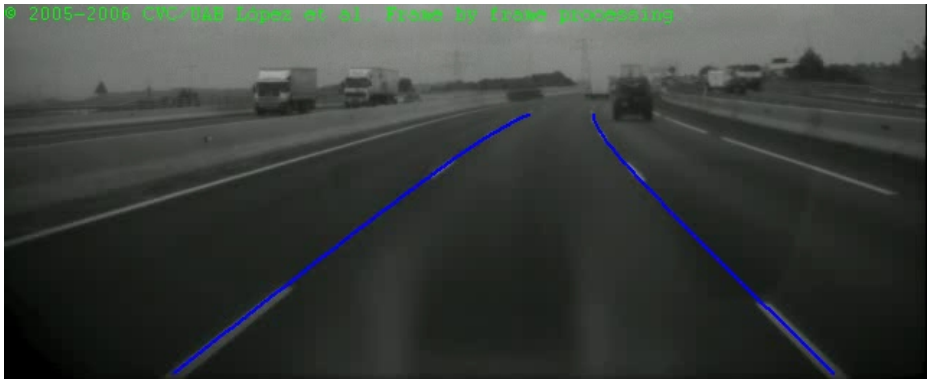


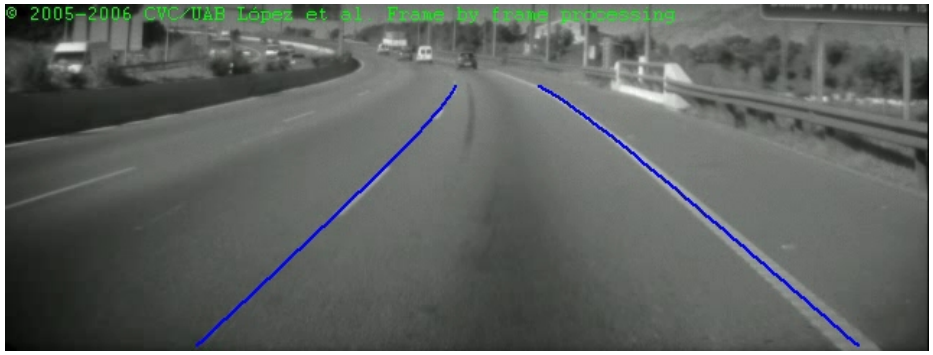


Results

Curved lane lines: 40 ms/frame, 2Ghz Pentium IV







More results at
www.cvc.uab.es/adas/projects/lanemarkings/IbPRIA07.html

Conclusions

Contribution:

- robust lane lines extraction
- estimation of 4 useful parameters for ADAS applications
- real time
- frame by frame processing
- quantitative evaluation on synthetic sequences

But there is still room for improvement:

- estimation of pitch angle φ
- enforce temporal continuity (e.g. Kalman filtering)
- relax assumptions of flat road and constant piecewise curvature

Results

Straight lane lines: 15 ms/frame