Universität Karlsruhe (TH)
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Transregional Collaborative Research Center 28
Cognitive Automobiles

Monocular Road Mosaicing in Urban Environments

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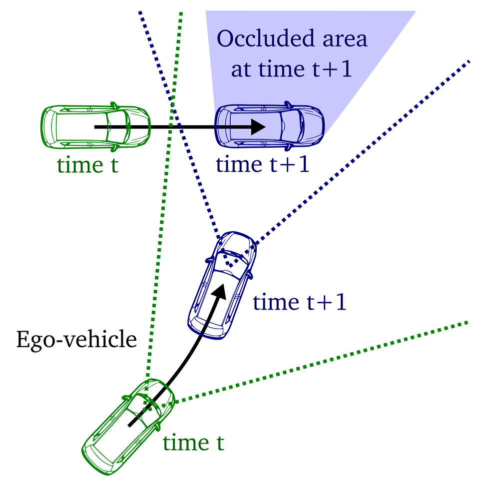
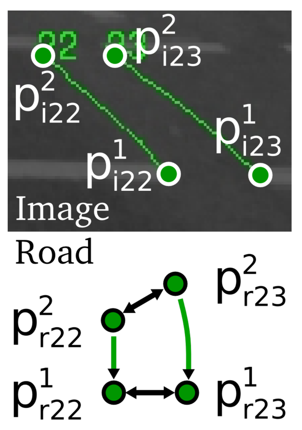
Abstract



Marking-based lane recognition requires an unobstructed view onto the road. In practice however, heavy traffic often constrains the visual field, especially in urban scenarios such as urban crossroads. In this paper we present a novel approach to road mosaicing for dynamic environments. Our method is based on a multistage registration procedure and uses blending techniques. We show that under modest assumptions accurate registration is possible using monocular image sequences only. We further demonstrate that fusing visual information from previous frames into the current view can greatly extend the camera's field of view.

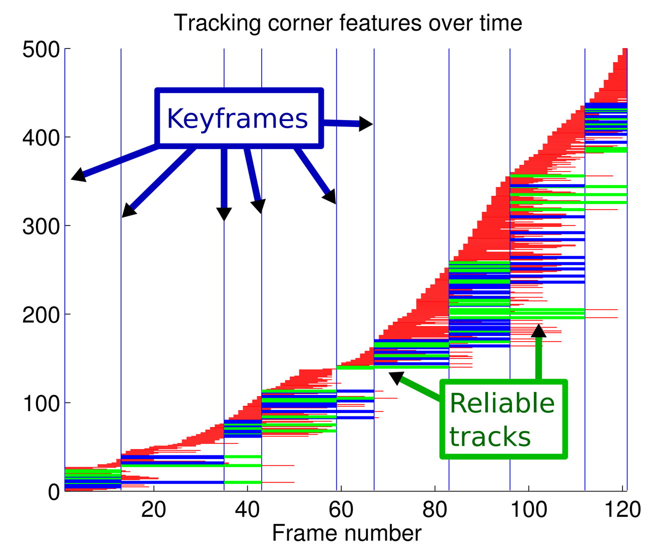
System Overview

1 Calculate and track Harris corners



- Find nearest neighbor in next frame
- Apply smoothness constraints to determine lost tracks

2 Select smallest set of "connected" keyframes



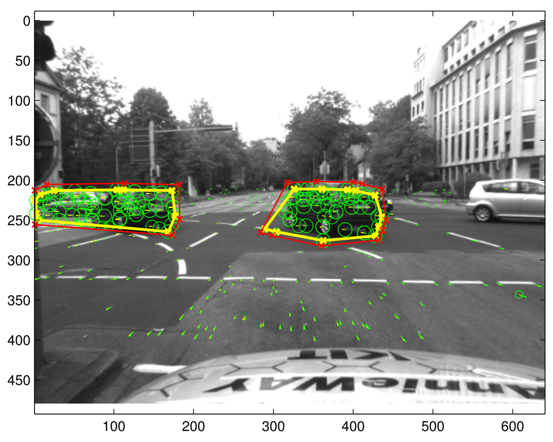
$$E_{key} = aN - b\sum_{i=1}^{N-1} t_i^{i+1}\psi(C_i^{i+1}) + c\sum_{i=1}^{N-1} |t_i^{i+1} - \frac{t_1^N}{N}|$$

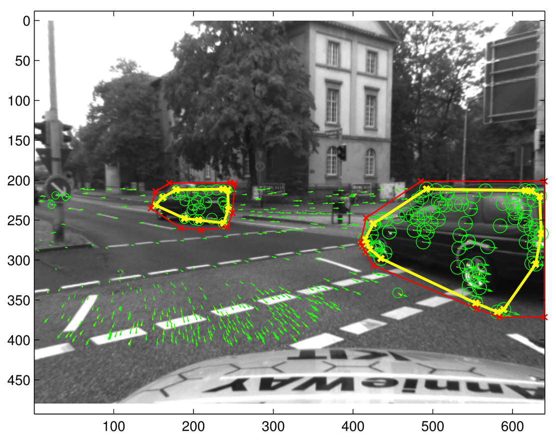
3 Initialize ego-position of the vehicle at located keyframes
Detect obstacles by comparing optical flow to virtual optical flow

a) Initialize ego-pose for all keyframes

- Initialize road-to-camera parameters (height, roll, pitch) according to prior knowledge of camera setup
- Project feature points onto the road
- Fitting the 2d point sets to each other yields an estimate for the road-to-road parameters (translation in x-direction, translation in y-direction, yaw)

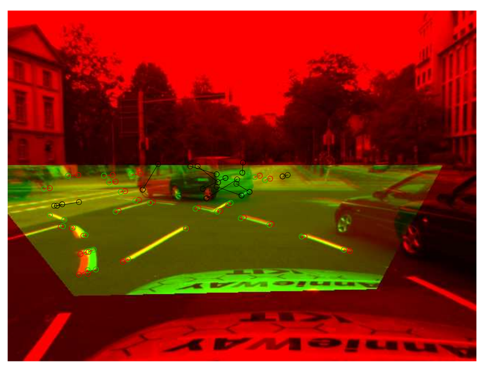
b) Segment road by optical-flow based detection of moving obstacles





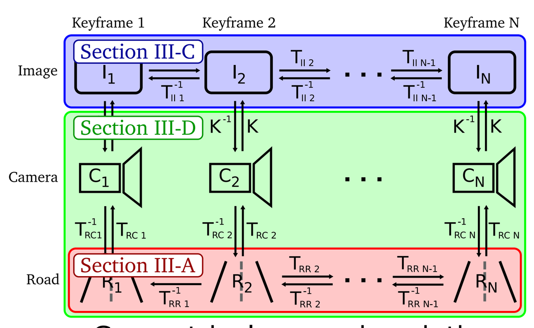
4 RANSAC-based correspondence refinement on segmented road

Iteration 1



Iteration 2

5 Global optimization with priors on extrinsic parameters



Geometrical scene description

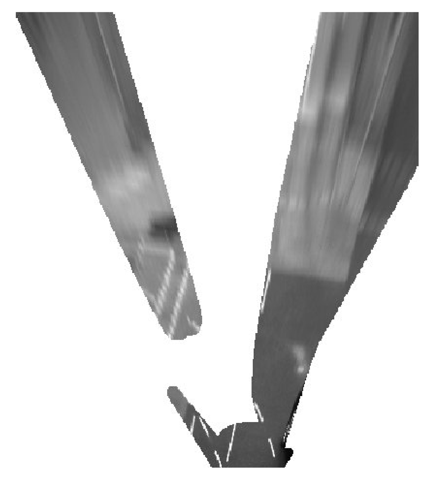
Posterior — Observation Likelihood — Prior

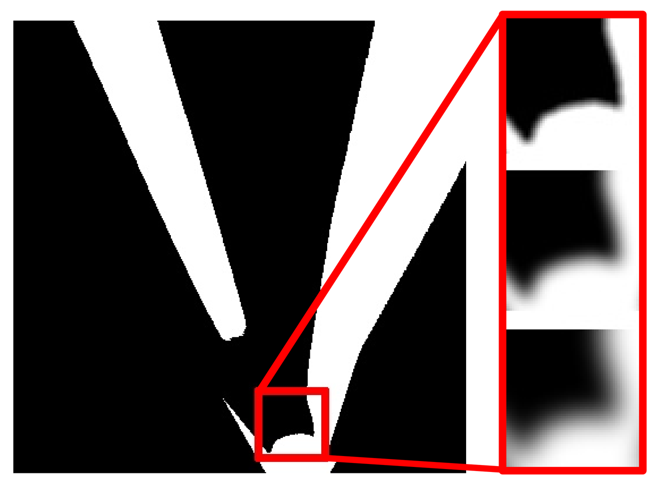
$$P(\mathbf{\Theta}|\mathbf{P}_1,...,\mathbf{P}_{N-1}) \propto P(\mathbf{P}_1,...,\mathbf{P}_{N-1}|\mathbf{\Theta})P(\mathbf{\Theta})$$

$$P(\mathbf{P}_1,...,\mathbf{P}_{N-1}|\mathbf{\Theta}) = \prod_{j=1}^{N-1} P(\mathbf{P}_j|\mathbf{\Theta}) \qquad P(\mathbf{\Theta}) = P(\mathbf{f},\mathbf{c})P(h)P(\theta)P(\phi)P(\mathbf{v})P(\omega)$$

$$P(\mathbf{P}_j|\mathbf{\Theta}) \propto \exp(-\frac{1}{2}\mathbf{d}_j^T\mathbf{\Sigma}^{-1}\mathbf{d}_j) \qquad (\mathbf{f},\mathbf{c}) \sim \mathcal{N}(\mu_c|\mathbf{\Sigma}_c) \qquad f(t) \sim \mathcal{GP}(\mu_f(t),\sigma_f(t,t')) \quad (\forall f \in \{h,\theta,\phi,v_x,v_y,\omega\})$$

6 Gain compensation and multi-band blending for compensating vignetting and registration errors





Visible road area I — Blending mask — Weight W

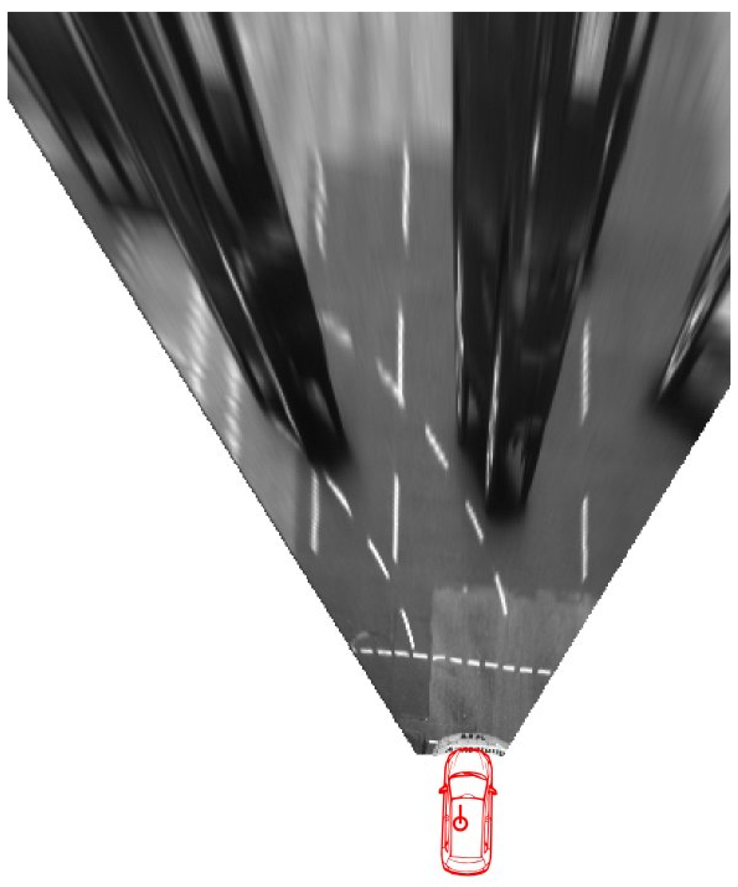
$$\mathbf{W}_i^{k\sigma} = \mathbf{W}_i^{(k-1)\sigma} \otimes g_{\tilde{\sigma}(k)} \qquad \mathbf{I}_i^{k\sigma} = \mathbf{I}_i^{(k-1)\sigma} \otimes g_{\tilde{\sigma}(k)} \qquad \mathbf{B}_i^{k\sigma} = \mathbf{I}_i^{(k-1)\sigma} - \mathbf{I}_i^{k\sigma}.$$

$$I_\Sigma^{k\sigma}(u,v) = \frac{\sum_i W_i^{k\sigma}(u,v)I_i^{k\sigma}(u,v)}{\sum_i W_i^{k\sigma}(u,v)} \qquad B_\Sigma^{k\sigma}(u,v) = \frac{\sum_i W_i^{k\sigma}(u,v)B_i^{k\sigma}(u,v)}{\sum_i W_i^{k\sigma}(u,v)} \qquad I_{mosaic} = I_\Sigma^{K\sigma} + \sum_k B_\Sigma^{k\sigma}$$

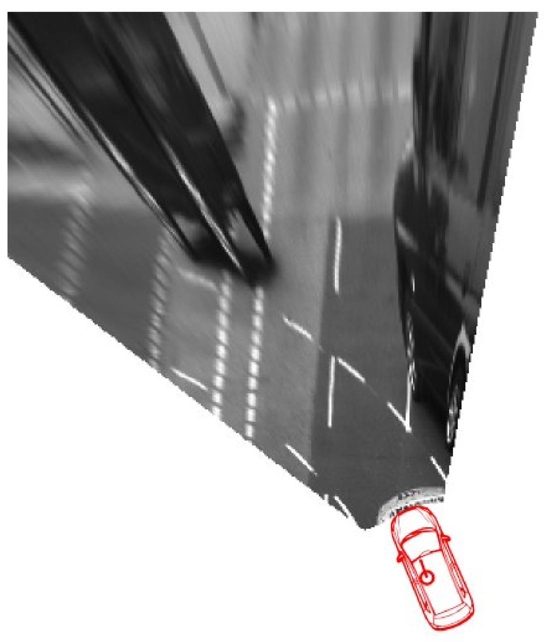
Result: Road mosaic in image or road coordinates

Experimental Results

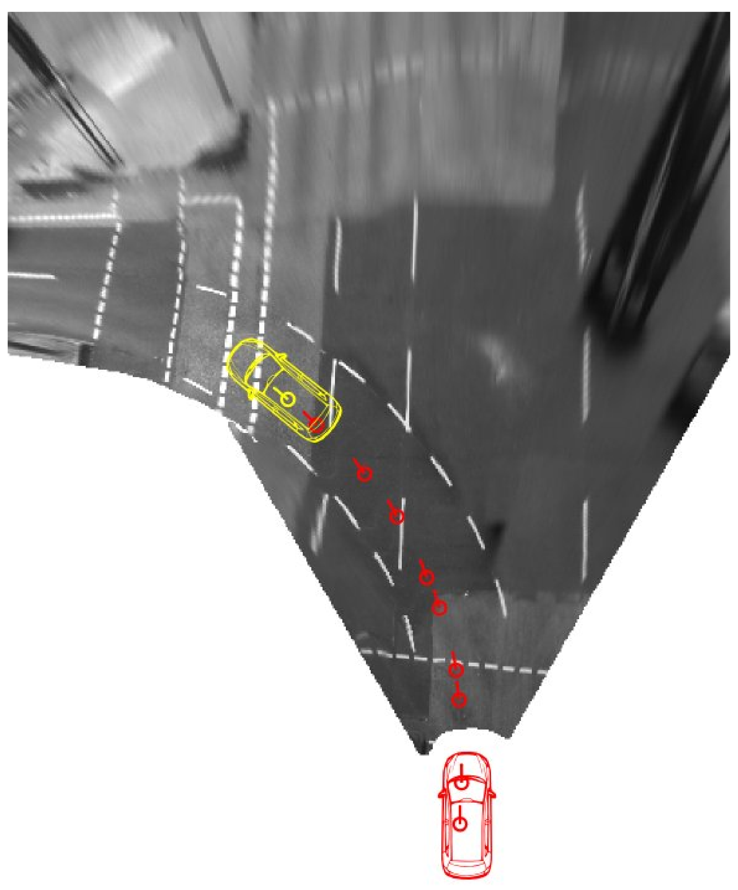
Frame 1 in road coordinates



Frame 6 in road coordinates



Mosaic in road coordinates



Mosaic in image coordinates*

* The difference to the original image taken by the camera is overlayed in red.

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