Robust Visual Odometry to Irregular Illumination Changes with RGB-D camera

Pyojin Kim*, Hyon Lim, and H. Jin Kim

Abstract

Sensitivity to illumination conditions poses a challenge when utilizing visual odometry (VO) in various applications. To make VO robust with respect to illumination conditions, they need to be considered explicitly. In this paper, we propose a direct visual odometry method which can handle illumination changes by considering an affine illumination model to compensate abrupt, local light variations during direct motion estimation process. The core of our proposed method is to estimate the relative camera pose and the parameters of the illumination changes by minimizing the sum of squared photometric error with efficient second-order minimization. We evaluate the performance of the proposed algorithm on synthetic and real RGB-D datasets with ground-truth. Our result implies that the proposed method successfully estimates 6-DoF pose under significant illumination changes whereas existing direct visual odometry methods either fail or lose accuracy.

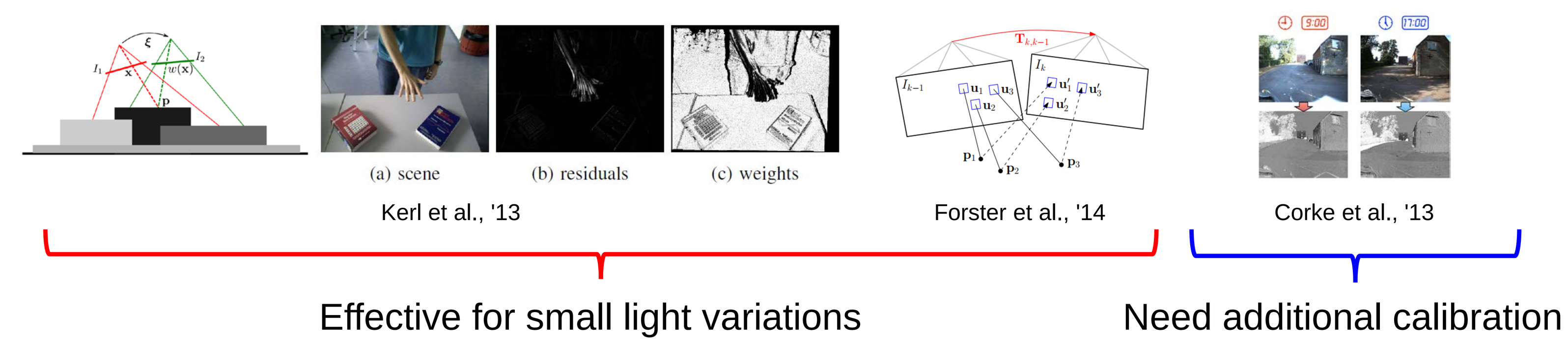
Motivation

- The most of the visual odometry methods are sensitive to light changes
- Occurrence of light variations is inevitable phenomenon in the images

- Robust VO to irregular illumination changes is necessary and essential

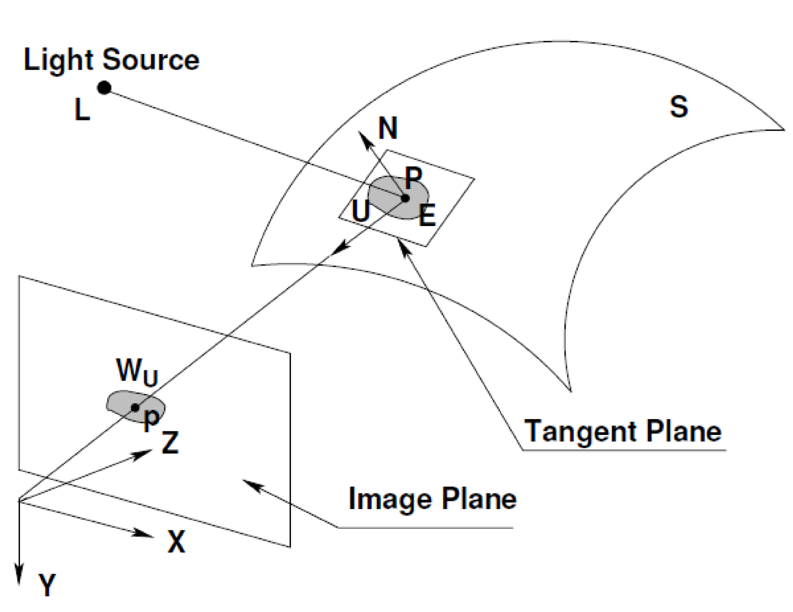
Related works

- Visual odometry methods with the direct method



Pipeline of the proposed visual odometry

❑ 1. Illumination change model



- Image intensity observation model

$$I(\mathbf{x}) = \lambda_E E(\mathbf{X}) + \delta_E$$

- Affine illumination change model

$$I^* = \lambda(t) I^k + \delta(t)$$

- Meaning of the λ, δ model parameters

Low λ High λ Low δ High δ

❑ 2. Planar patch selection

- **Step 1 :** SURF blob detector
- **Step 2 :** planarity test with RANSAC

❑ 3. Direct motion estimation

Non-linear weighted least square problem :

$$\mathbf{z}^* = \arg\min_{\mathbf{z}} \sum_{i=1}^{m} \sum_{j=1}^{n} W(r_{ij}) r_{ij}^2(\mathbf{z})$$

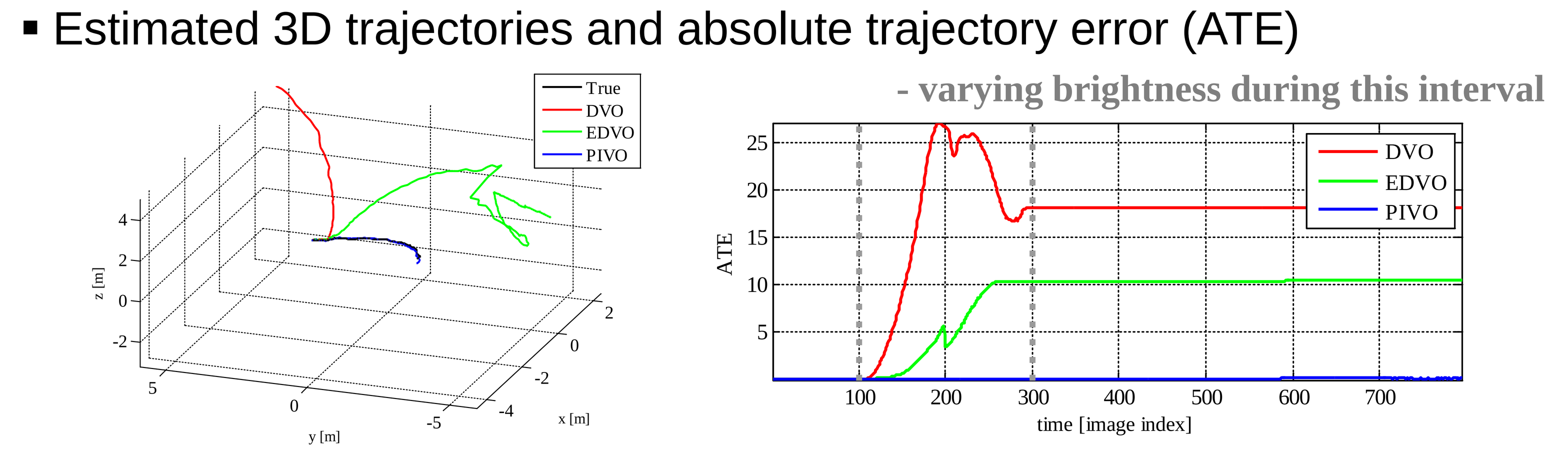
- **Weighting function :** student t-distribution by residual distribution
- **Residual :** newly defined photo-consistency assumption ($r_{ij}(\mathbf{z}) = \lambda_i I_i^k(w(\boldsymbol{\xi}, \mathbf{x}_{ij}^*)) + \delta_i - I_i^*(\mathbf{x}_{ij}^*)$)
- **Model parameter :** motion of camera (ξ), illumination change model parameters (λ ,δ)

Evaluation

❑ 1. Synthetic TUM RGB-D dataset

- Occurrence of irregular illumination changes in the video sequences

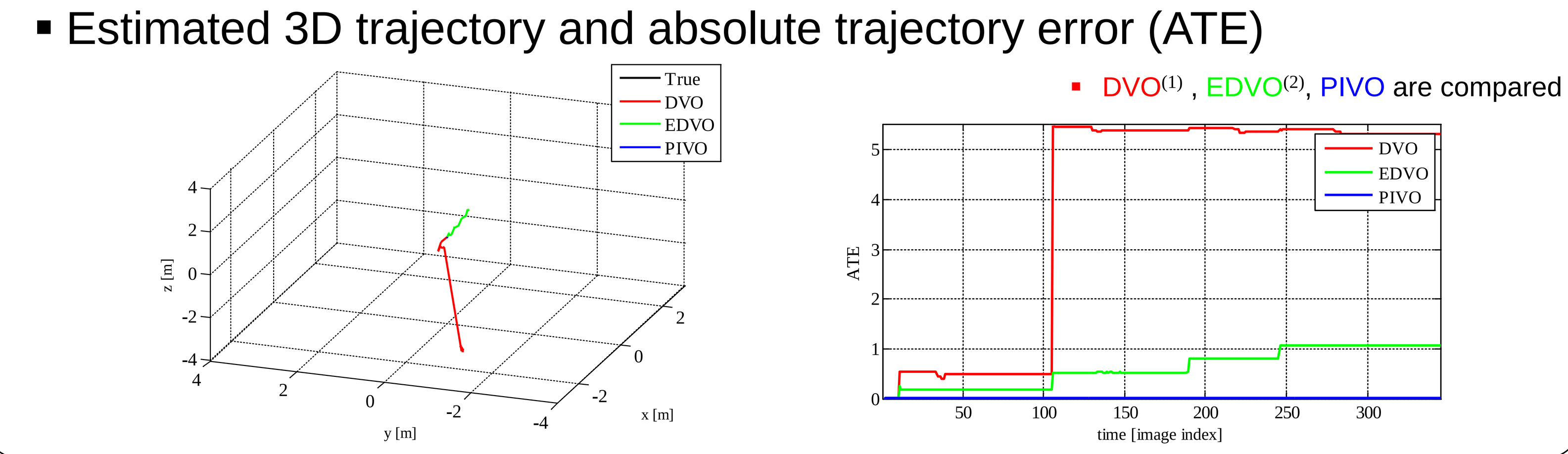
- Estimated 3D trajectories and absolute trajectory error (ATE)



❑ 2. Stationary RGB-D dataset

- Occurrence of irregular illumination changes in the video sequences

- Estimated 3D trajectory and absolute trajectory error (ATE)



(1) Kerl, Christian, Jurgen Sturm, and Daniel Cremers. "Robust odometry estimation for rgb-d cameras." Robotics and Automation (ICRA), 2013 IEEE International Conference on. IEEE, 2013.
(2) Klose, Sebastian, Philipp Heise, and Alois Knoll. "Efficient compositional approaches for real-time robust direct visual odometry from RGB-D data." Intelligent Robots and Systems (IROS), 2013 IEEE/RSJ International Conference on. IEEE, 2013.

ICSL Intelligent Control Systems Laboratory
Seoul National University, Seoul, Korea
Web. http://icsl.snu.ac.kr Tel. +82-2-880-1907