Illumination Robust Monocular Direct Visual Odometry for Outdoor Environment Mapping

Introduce

deal with global and local lighting changes(solar flares)

since feature-based method robust photometric and geometric, but direct method has a brightness constancy assumption. So it may not perform good in outdoor scene.

this paper proposed a illuminationinvariant costs method for monocular

such as exposure compensation strategy, median value of pixel residuals, affine brightness transfer function, use image gradients rather than pixel intensities can adverse effect of lighting changes in rgbd or stereo.

Proposed FrameWork

Joint Optimization

in tracking module, optimize pose and depth given as prior.

in reconstruction module, jointly optimize pose and depth.

Illumination Robust Cost

change pixel to intensity value by bilinear interpolation(intensity)

- Global Affine Model

  compensate for the additive and multiplicative global lighting or exposure changes

$$E_{k,GAff} := \sum_{\mathbf{p}\in S_{\mathbf{p}}} w_{\mathbf{p}} \| I_i(\pi(\mathbf{p}')) - \beta_i - \frac{e^{\alpha_i}}{e^{\alpha_r}} I_r(\pi(\mathbf{p})) - \beta_r \|_\gamma$$

- Gradient Magnitude(Local)

  use the gradient magnitudes instead of intensities

$$F_{Grad}(\cdot) := \|\nabla I(\cdot)\|_2$$

  The gradient method has proven to be robust with the local lighting changes

- Ceres Transform

  a local binary descriptor that compares a pixel intensity with its neighborhoods and results in one-bit results indicating the neighbors are lighter or darker than this given pixel

$$F_{i,CT}(\cdot) := \begin{cases} 1, & \text{if } I(\cdot) > I(N_i(\cdot)) \\ 0, & \text{otherwise} \end{cases}$$

- Proposed Method

  found that the gradient method showed maximum robustness and smaller convergence radius

  combine the energy functions of affine, and gradient approaches to obtain global minimum and large convergence basin

  - more weights put on affine at the beginning
  - more weights put on gradient at the end

$$E_k := (1 - w_k)E_{k,GAff} + \frac{1}{2\sqrt{2}} w_k E_{k,Grad}$$

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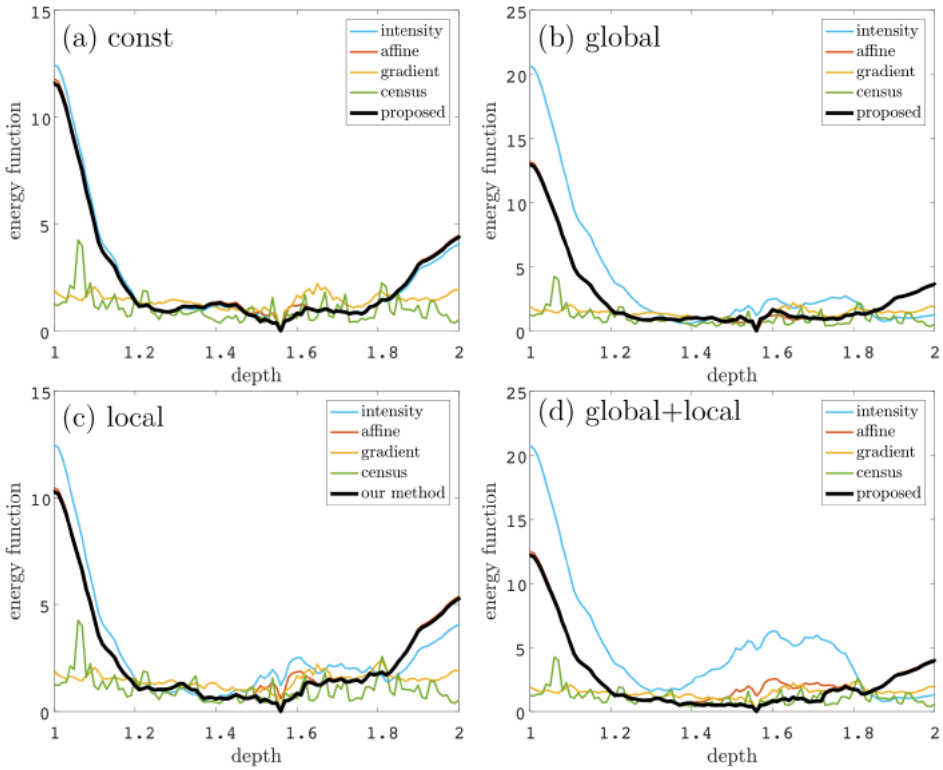

Result

image-20200219171607475

- affine : perform well in global change
- gradient&census : smaller convergence radius

WHOLE SYSTEM PERFORMANCE EVALUATION REGARDING TRACKING PRECISION, ROBUSTNESS, AND RUNTIME.

	vKITTI								Devon Island				Symphony Lake			
	const		*global*		*local*		*glo+loc*		*s00-09*		*s10-19*		*1502*	*1504*	*1507*	*1510*
	rate	err	rate	err	rate	err	rate	err	rate	err	rate	err	rate	rate	rate	rate
intensity	**0.0**	**0.37**	-	-	-	-	-	-	15.7	8.32	14.9	7.12	5.2	15.3	10.1	3.1
affine	0.3	0.38	**0.3**	0.38	4.5	0.42	-	-	5.9	5.78	6.2	5.66	4.1	13.8	8.2	**1.2**
gradient	3.5	**0.37**	3.3	**0.37**	3.4	**0.38**	3.6	0.38	10.9	5.12	11.4	5.27	13.6	12.2	13.5	10.9
census	3.4	0.43	3.3	0.43	3.3	0.44	3.2	0.43	10.3	5.13	12.7	**5.21**	12.4	13.2	13.3	13.7
proposed	0.3	**0.37**	**0.3**	**0.37**	**0.5**	**0.38**	**0.9**	**0.37**	**4.2**	**5.11**	**3.0**	5.23	**1.2**	**3.1**	**2.1**	1.4
orbslam2	0.9	0.38	2.4	0.42	1.8	0.41	5.3	0.55	12.6	6.35	13.1	6.31	7.7	16.7	12.1	5.5

Rates are failure rate per sequence, averaged over 10 trials. Err is a drift rate in $[cm/m]$. Processing time in $[ms]$ per frame.