Occlusion-Aware Rolling Shutter Rectification of 3D Scenes

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Goal

- Recover the latent image of a 3D scene from a set of rolling shutter (RS) distorted images captured by a fast moving camera

Challenges:

- Row-wise varying camera motion
- Depth-dependent RS distortion
- Inter and intra-frame occlusion effects

Our approach

Input RS images → Occlusion robust RS aware depth recovery → Recovered depth map of inputs

Recovering occluded regions

Recovered background layer → Depth and occlusion aware RS rectification → Rectified image

Camera motion model

Image rows — Key rows — Blank rows — Camera motion

Image 1 N_r n_b Image 2 Image 3

$\mathbf{p}^1$ $\mathbf{p}^2$

time

Layered image formation model

- GS image
$$\mathbf{g} = \sum_{l=0}^{L-1} \left(\prod_{m=l+1}^{L-1} (1 - \mathbf{W}_{\vartheta,m}\boldsymbol{\alpha}_m) \right) \odot \mathbf{W}_{\vartheta,l}(\boldsymbol{\alpha}_l \odot \mathbf{f}_l)$$

- RS image
$$\mathbf{r} = \sum_{l=0}^{L-1} \left(\prod_{m=l+1}^{L-1} (1 - \mathbf{W}_{r,m}\boldsymbol{\alpha}_m) \right) \odot \mathbf{W}_{r,l}(\boldsymbol{\alpha}_l \odot \mathbf{f}_l)$$

$\mathbf{f}_0$ $\mathbf{f}_1$ $\mathbf{f}_2$ — Latent layer intensity images | $\boldsymbol{\alpha}_1$ $\boldsymbol{\alpha}_2$ — Latent layer masks

$\mathbf{W}_{\vartheta,0}\mathbf{f}_0$ $\mathbf{W}_{\vartheta,1}\mathbf{f}_1$ $\mathbf{W}_{\vartheta,2}\mathbf{f}_2$ — GS warped layer intensity images | $\mathbf{W}_{\vartheta,1}\boldsymbol{\alpha}_1$ $\mathbf{W}_{\vartheta,2}\boldsymbol{\alpha}_2$ — GS warped layer masks

$\boldsymbol{\alpha}_{\vartheta,0}$ $\boldsymbol{\alpha}_{\vartheta,1}$ $\boldsymbol{\alpha}_{\vartheta,2}$ — GS occluded layer masks | $\mathbf{g}$ — GS image — Layered 3D scene: GS image formation

$\boldsymbol{\alpha}_{r,0}$ $\boldsymbol{\alpha}_{r,1}$ $\boldsymbol{\alpha}_{r,2}$ — RS occluded layer masks | $\mathbf{r}$ — RS image — Layered 3D scene: RS image formation

$\mathbf{W}_{r,0}\mathbf{f}_0$ $\mathbf{W}_{r,1}\mathbf{f}_1$ $\mathbf{W}_{r,2}\mathbf{f}_2$ — RS warped layer intensity images | $\mathbf{W}_{r,1}\boldsymbol{\alpha}_1$ $\mathbf{W}_{r,2}\boldsymbol{\alpha}_2$ — RS warped layer masks

Algorthmic details

- Estimation of camera motion and plane parameters using optical flow correspondeces
- Graph-cut based optimization for occlusion-robust recovery of binary layer masks
- Fractional layer mask recovery using alpha matting
- Occlusion-aware rectification and latent image recovery using least-square optimization and multiple input frames

Results

Input reference frame — **Ringaby 2012** — **Ours**

Input reference frame — **Vijay 2016** — **Ours**

Input reference frame — **Vijay 2017** — **Ours**

Input reference frame — **Zhuang 2017** — **Ours**