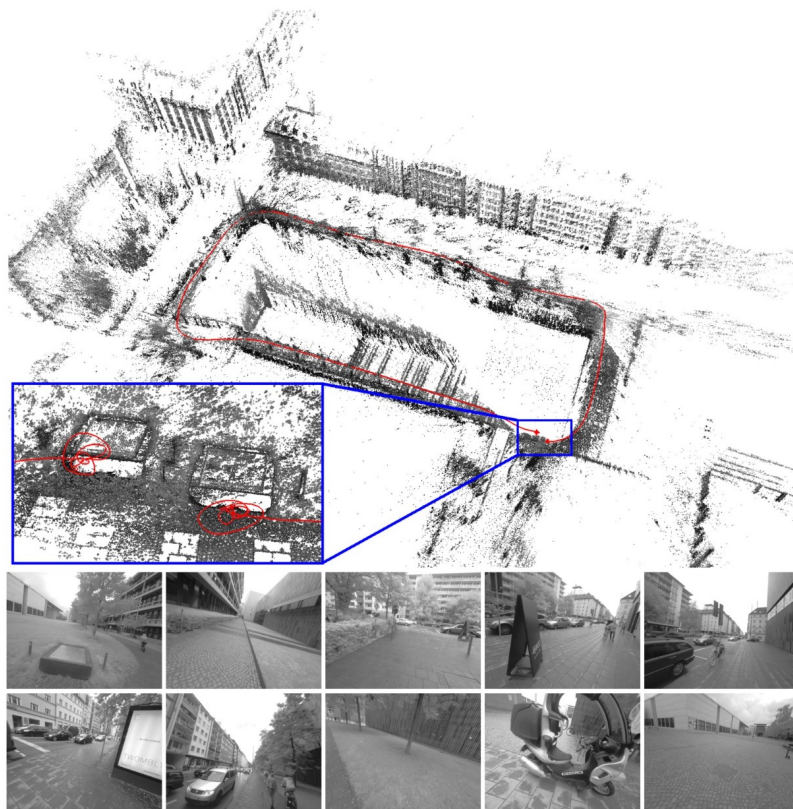


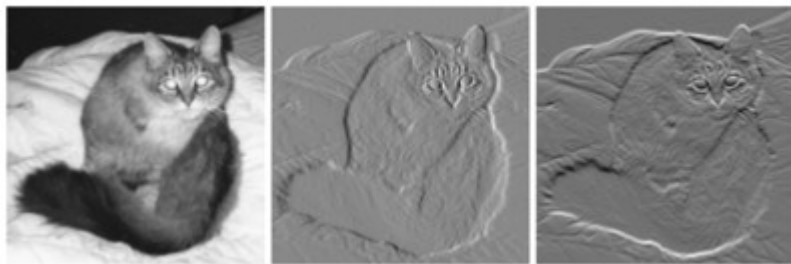
Direct Sparse Odometry

Tobias Sippl



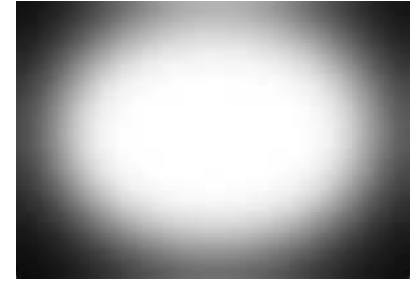
Indirect vs. Direct

- Keypoints
- Image Intensities



Photometric Error

- Vignetting
- Exposure Time – intensity
- Small (8) Pixel Neighbourhood
- Gradient Dependent weighting



Total Photometric Error

$$E_{\text{photo}} := \sum_{i \in \mathcal{F}} \sum_{\mathbf{p} \in \mathcal{P}_i} \sum_{j \in \text{obs}(\mathbf{p})} E_{\mathbf{p}j}.$$

All Frames

All points in
Frame i

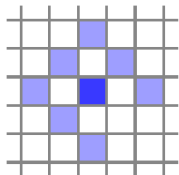
All frames where \mathbf{p}
is visible

Difference in
pixel Intensity

Photometric Error

$$E_{\mathbf{p}j} := \sum_{\mathbf{p} \in \mathcal{N}_{\mathbf{p}}} w_{\mathbf{p}} \left\| (I_j[\mathbf{p}'] - b_j) - \frac{t_j e^{a_j}}{t_i e^{a_i}} (I_i[\mathbf{p}] - b_i) \right\|_{\gamma}$$

Pixel
Neighbourhood



Gradient
Dependent
Weight

Target Frame
 \mathbf{p}' contains
transformation matrices

Exposure Time

Reference
Frame

Gauss Newton Optimization

$$\mathbf{H} = \mathbf{J}^T \mathbf{W} \mathbf{J} \quad \text{and} \quad \mathbf{b} = -\mathbf{J}^T \mathbf{W} \mathbf{r},$$

$$\mathbf{J}_k = \frac{\partial r_k((\boldsymbol{\delta} + \mathbf{x}) \boxplus \boldsymbol{\zeta}_0)}{\partial \boldsymbol{\delta}}.$$

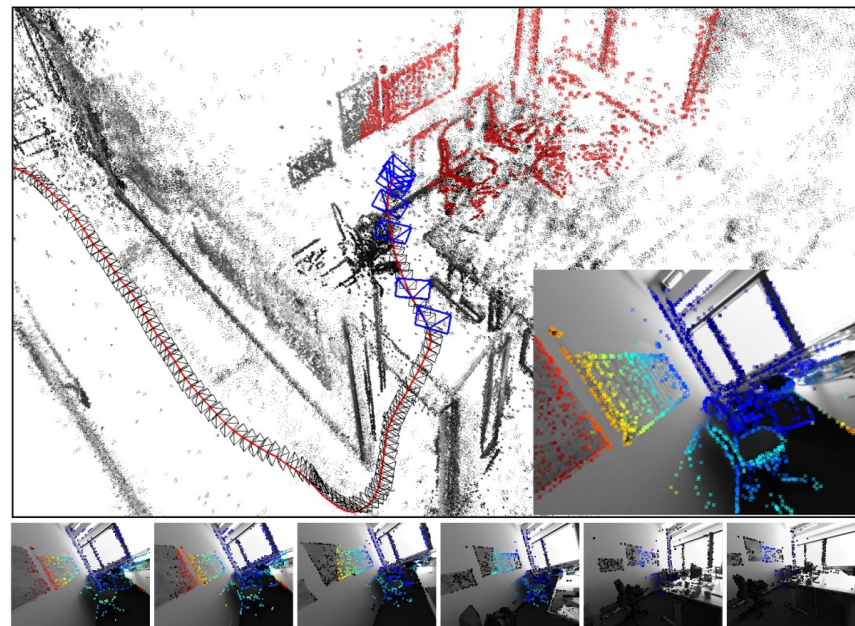
$$\mathbf{J}_k = \left[\underbrace{\frac{\partial I_j}{\partial \mathbf{p}'}}_{\mathbf{J}_I} \underbrace{\frac{\partial \mathbf{p}'((\boldsymbol{\delta} + \mathbf{x}) \boxplus \boldsymbol{\zeta}_0)}{\partial \boldsymbol{\delta}_{\text{geo}}}}_{\mathbf{J}_{\text{geo}}}, \underbrace{\frac{\partial r_k((\boldsymbol{\delta} + \mathbf{x}) \boxplus \boldsymbol{\zeta}_0)}{\partial \boldsymbol{\delta}_{\text{photo}}}}_{\mathbf{J}_{\text{photo}}} \right],$$

$$\boldsymbol{\delta} = \mathbf{H}^{-1} \mathbf{b};$$

$$\mathbf{x}^{\text{new}} \leftarrow \boldsymbol{\delta} + \mathbf{x}.$$

Keyframes

- Up to 7 Keyframes (5-10/s)
- Project active points into new Keyframes
- RMSE, if failed, 27 small rotations to recover

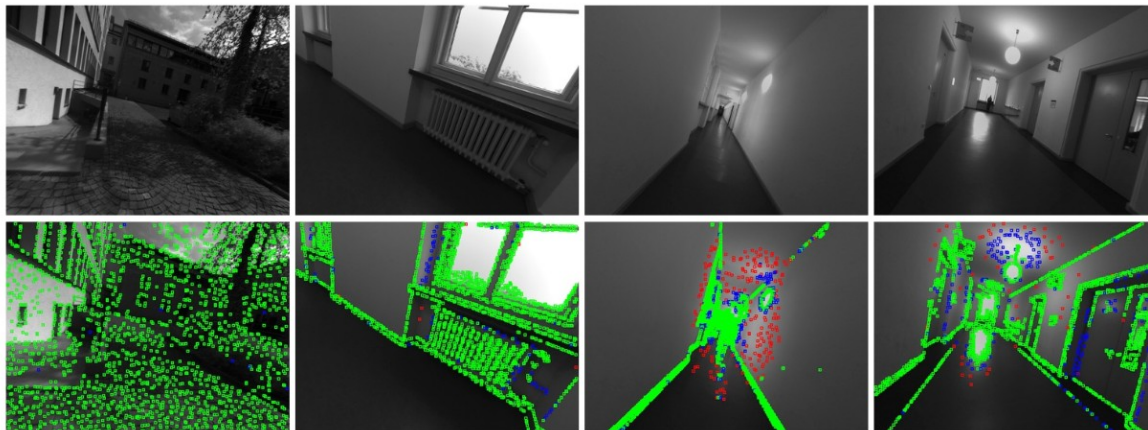


Keyframes II

- Keep latest 2 Keyframes
- Drop frames with $< 5\%$ visible Keypoints
- Maximize distribution of Keypoints

Points

- Around 2000 active Points
- New points may be added from previous (but active) Keyframes
- Depending on distribution and image gradient



Video

- Video, doesn't work in pdf, will have the slides with me.