# Zsfg Masterarbeit

Jacob Nieswand

June 8, 2018

# Light Field Parametrization

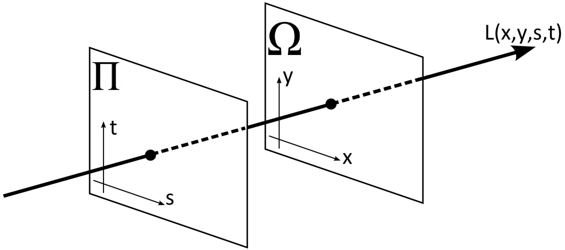



Figure: In a 4-dimensional two-plane parametrisation a light ray is characterized by the intersection with two parallel planes. we refer to the plane Π as the camera plane and the plane Ω as the image plane.

# Epipolar Plane Images

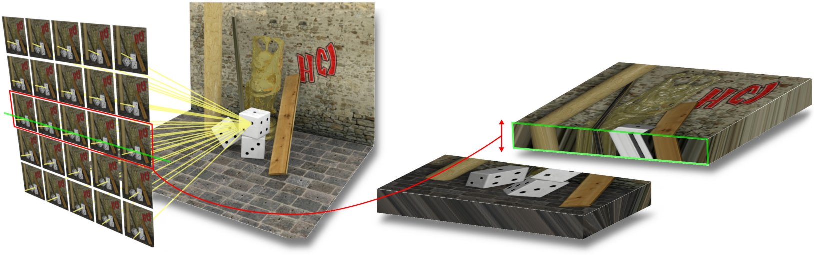



Figure: Visualization of an Epipolar Plane Image extractoin: A camera array takes images of the same scene from slightly different angles (left array). For a fixed image coordinate $y^*$ (green) and a fixed camera coordinate $t^*$ (red) the pixels are extracted and stacked up resulting in an EPI $\Sigma_{y^*,t^*}$ (green box on the right).

# EPI


Figure: An Epipolar Plane Image (EPI) that consists of 9 rows (9 equidistant views or sample points in the camera plane). Points with the same color correspond to the same scene point. Since the viewpoints are slightly shifted, the scene point is also shifted in each view by the disparity $d$. Marked in red one can identify the center position of the camera viewpoints.

# Refocussing an EPI

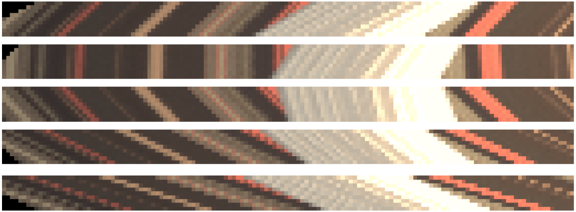
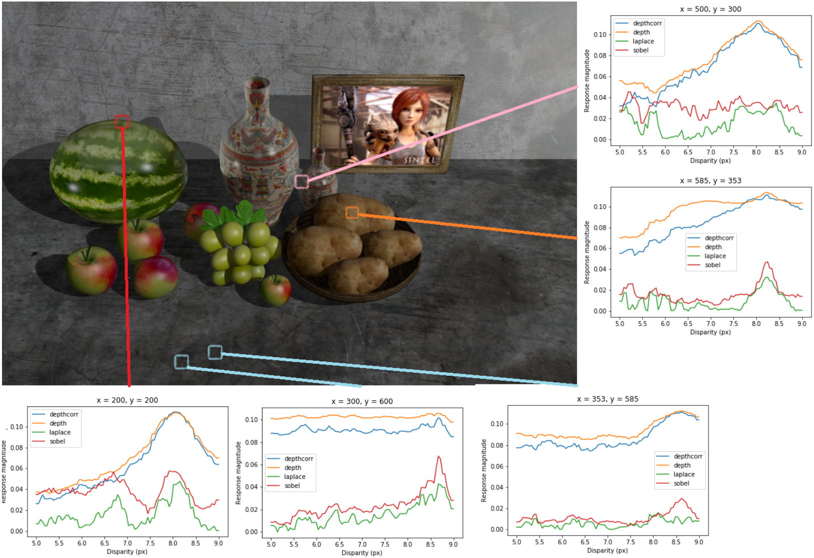
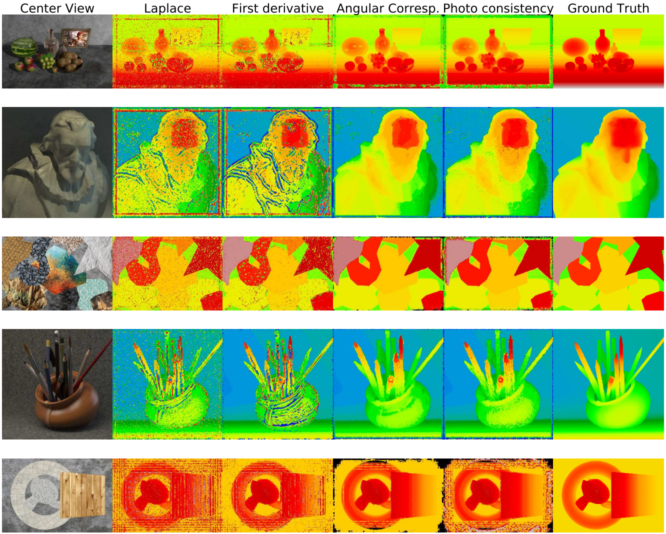


Figure: The EPI is refocussed by integer disparity steps. If the slope at a scene point is zero (vertical line) the EPI is perfectly focussed on that point. An integration of all views would still result in a sharp image at the corresponding depth.

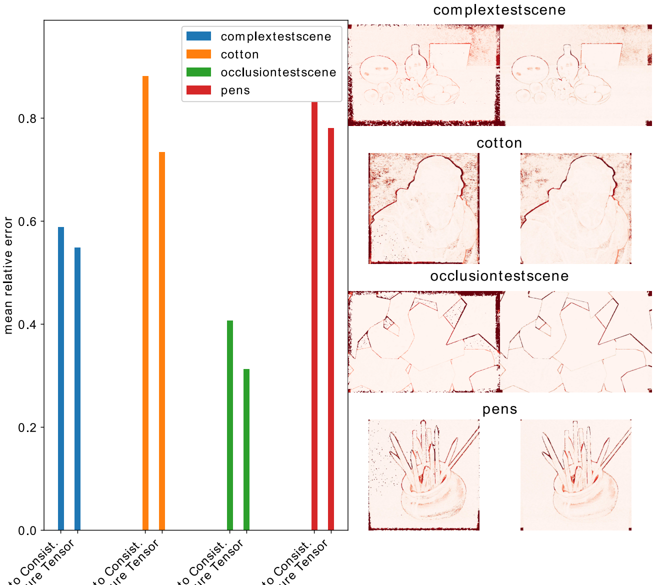
# Evaluation: Depth-from-focus



# Evaluation: Depth-from-focus



# Evaluation: Depth-from-focus



# Occlusion problem

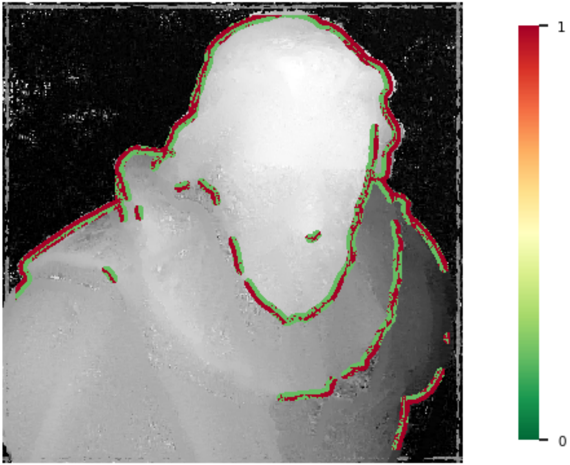



Figure: Evaluation of the deviation from Ground truth at the depth discontinuity for scene "cotton". The red border indicates that the depth map is errorneous at the outside of the edge.

# Occlusion Problem

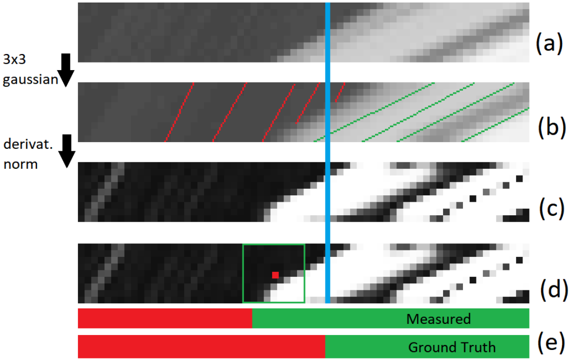



Figure: (a) The structure of an occlusion border in a gray-value EPI. (b) Before calculating the gradient, the EPI is smoothed with a $3 \times 3$ gaussian kernel. One sees the smoothed EPI with colored lines indicating the Ground Truth orientation. (c) shows the norm of the gradient calculated via the Scharr-filter. White significates a high gradient, black significates low gradient. In (d) the local environment around the red dot $(x_r, y_r)$ as an example point is marked to show which gradient values go into the structure tensor components $J(x_r, y_r)$. (e) marks the orientation

# Sandclock kernel

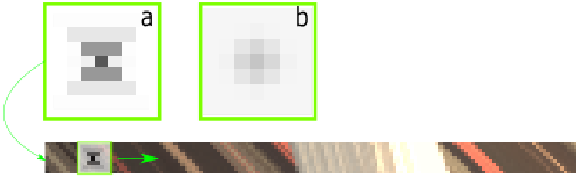



Figure: (a) shows a custom-shaped kernel in form of a sandclock. (b) shows a normal gaussian kernel.

# Evaluation:Sandclock kernel

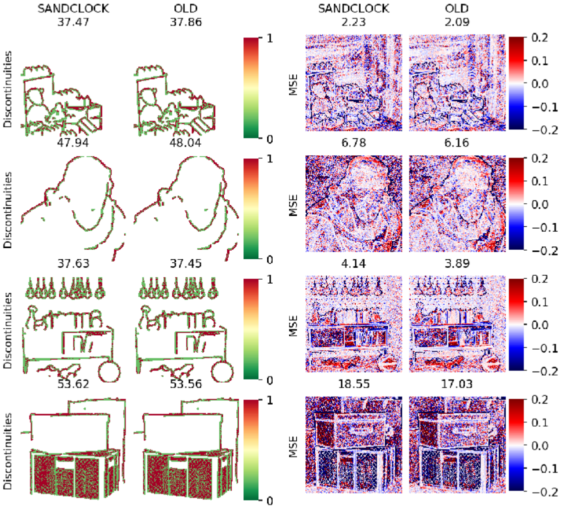



Figure: Comparison between the normal structure tensor and the sandclock- like kernel for the scenes *dino, cotton, sideboard, boxes*. The left side compares the mean squared errors in the disparity map, the right

# Bilateral filtering


$$G_P = \frac{1}{W_p} \sum_{q \in N} g_{\sigma_d}(||p - q||) g_{\sigma_c}(||I_{p,\mathrm{EPI}} - I_{q,\mathrm{EPI}}||), \tag{1}$$

# Evaluation: Bilateral filtering

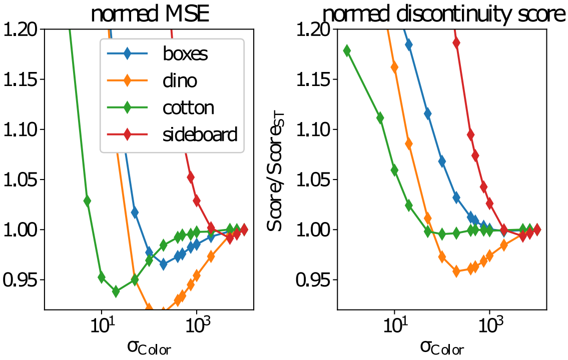
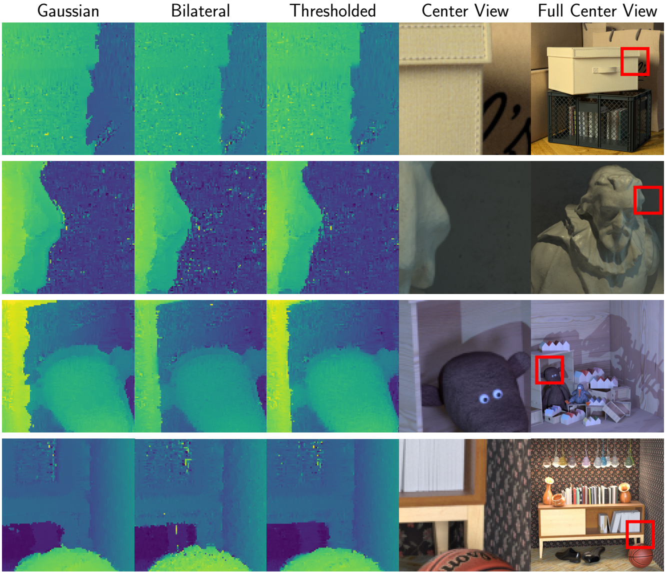



Figure: Bilateral filtering with Structure Tensor Components themselves as the guide:On the left the Mean Squared error for different scenes in function of the $\sigma_{\text{Color}}$ of the bilateral filtering is shown, devided by the MSE with using a gaussian filter. On the right the Discontinuity score based on [?] is shown, also normed to the Score using the standard gaussian filter.

# Evaluation: Bilateral filtering



# Thresholding Gradients

$$\tilde{\vec{\nabla}}(x, y) = \begin{cases} \frac{\text{threshold}}{\text{norm}} \vec{\nabla}(x, y) & \text{if} \quad \text{norm} > \text{threshold} \\ \tilde{\vec{\nabla}}(x, y) & \text{else} \end{cases} \tag{2}$$

$$\text{with} \quad \text{norm} = \sqrt{\nabla_x(x, y)^2 + \nabla_y(x, y)^2}. \tag{3}$$

$$\tag{4}$$

# Evaluation: Thresholding gradients

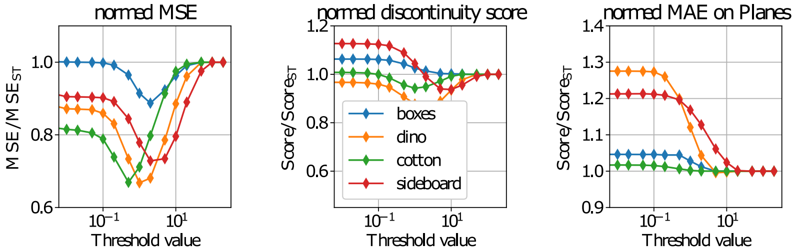



Figure: Results when thresholding the Gradients in the EPI are shown. All results are divided by the score obtained from the normal structure tensor algorithm. On the left the Mean Squared Error is shown, in the middle the discontinuity score is shown, on the right we see the Mean Average Error on planar surfaces in the scene. All metric scores follow the metrics from [**?**].

# Evaluation: Thresholding gradients

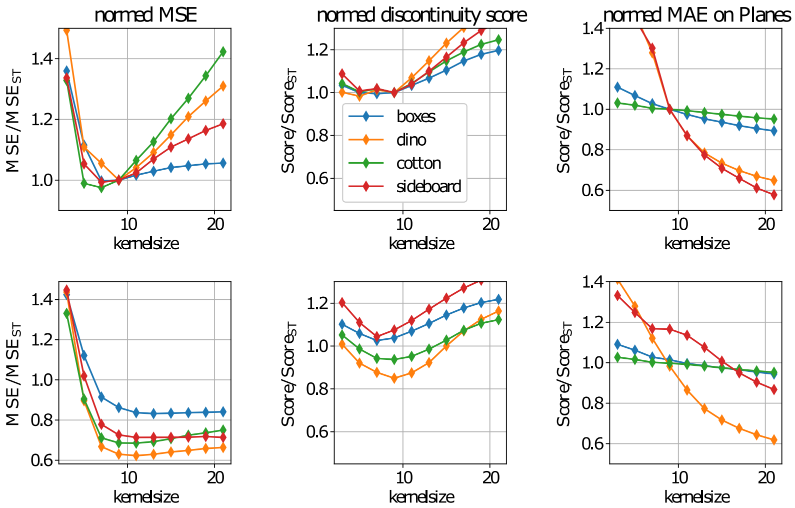



Figure: Varying the kernelsize, using the old ST pipeline (up) and with thresholded gradients (down)

# Occlusion Segmentation

1. Segmentate the transitions and the rest of the EPI with a binary mask.
2. Calculate the structure tensor components on the masked gradient of the EPI. All masked gradients are zero and do not affect the local environment structure.
3. Calculate the structure tensor components again, now on the inverted masked gradient of the EPI.

# Occlusion Segmentation

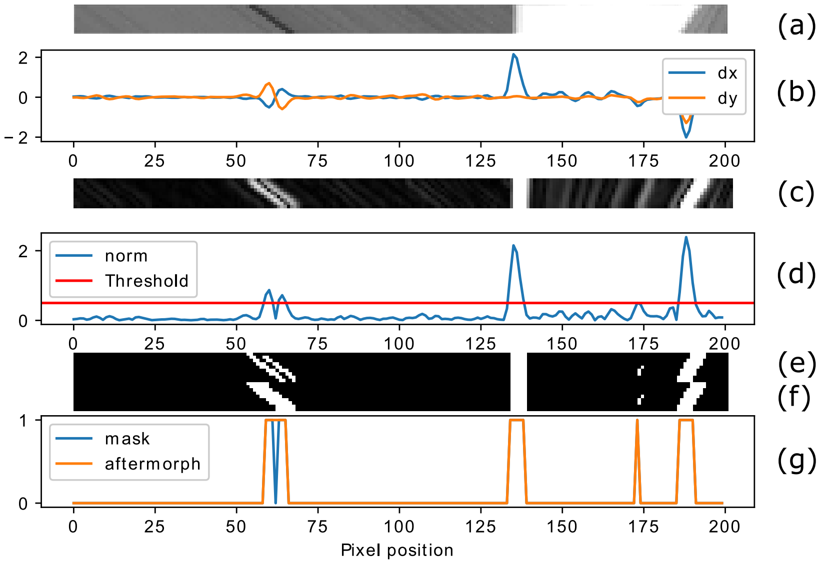



Figure: (a) Input EPI to be segmented. (b) show the local derivatives

# Morphological Closing

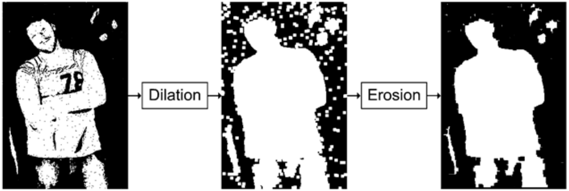



Figure: Morphological closing is a combination of Dilation and Erosion. Dilation uses a custom-sized kernel and turnes any 0 to 1, if at least one 1 isfound in the local environment. Erosion turnes any 1 to 0, if at least one 0 is found in the local environment.

# Evaluation: Segmentation

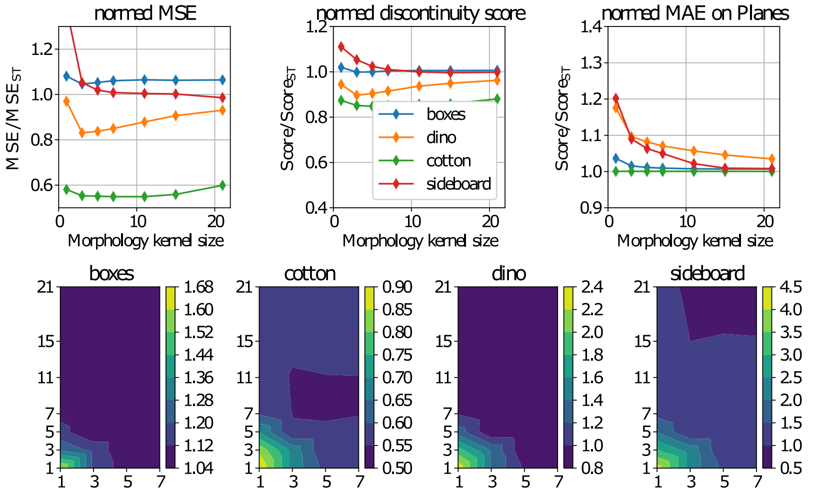



Figure: Upper row: Metric scores in dependence of the size in $y$-direction of the morphology kernel. Lower row: dependence of the MSE for the size of the kernel.

# Alternative to coherence

$$d = \tan\left(\frac{1}{2}\arctan\left(\frac{J_{22} - J_{11}}{2J_{12}}\right)\right), \tag{5}$$

$$\Delta d = \sqrt{\left(\frac{\partial d}{J_{11}}\Delta J_{11}\right)^2 + \left(\frac{\partial d}{J_{22}}\Delta J_{22}\right)^2 + \left(\frac{\partial d}{J_{12}}\Delta J_{12}\right)^2} \tag{6}$$

$$\Delta d = \sqrt{\left(\frac{0.5 \cdot (d^2 + 1)}{x^2 + 1} \cdot x\right)^2 \cdot \left(\left|\frac{\Delta J_{12}}{J_{12}}\right|^2 + \left|\frac{\Delta J_{11}}{J_{11} - J_{22}}\right|^2 + \left|\frac{\Delta J_{22}}{J_{11} - J_{22}}\right|^2\right)} \tag{7}$$

$$\Delta J_{11} = G * |2\nabla_x|\Delta\nabla_x \tag{8}$$

$$\Delta J_{22} = G * |2\nabla_y|\Delta\nabla_y \tag{9}$$

$$\Delta J_{12} = G * \sqrt{\nabla_x^2 \Delta\nabla_y^2 + \nabla_y^2 \Delta\nabla_x^2} \tag{10}$$

# Alternative to coherence

$$\Delta\nabla_{x,\text{normalized}} = \sqrt{E[\nabla^2_{x,\text{normalized}}] - E[\nabla_{x,\text{normalized}}]^2} \tag{11}$$

$$\Delta\nabla_{y,\text{normalized}} = \sqrt{E[\nabla^2_{y,\text{normalized}}] - E[\nabla_{y,\text{normalized}}]^2} \tag{12}$$

The interrelation between $\Delta\nabla_{y,\text{normalized}}$ and $\Delta\nabla_x$ is given by

$$\nabla_{x,\text{normalized}} = \frac{1}{\sqrt{\nabla_x^2 + \nabla_y^2}}\nabla_x \tag{13}$$

$$\Delta\nabla_{x,\text{normalized}} \approx \frac{1}{\sqrt{\nabla_x^2 + \nabla_y^2}}\Delta\nabla_x, \tag{14}$$

# Alternative to Coherence

$$\Delta\nabla_x = \sqrt{\nabla_x^2 + \nabla_y^2} \cdot \sqrt{E[\nabla^2_{x,\text{normalized}}] - E[\nabla_{x,\text{normalized}}]^2} \quad (15)$$

$$\Delta\nabla_y = \sqrt{\nabla_x^2 + \nabla_y^2} \cdot \sqrt{E[\nabla^2_{y,\text{normalized}}] - E[\nabla_{y,\text{normalized}}]^2}, \quad (16)$$

# SemiGLobal Matching

$$E(d) = \sum_{\vec{p}} \left( C(\vec{p}, d_{\vec{p}}) + \sum_{q \in N_p} \begin{cases} P1 \cdot |d_{\vec{p}} - d_{\vec{q}}| & \text{if } |d_{\vec{p}} - d_{\vec{q}}| \leq 1 \\ P2 & \text{if } |d_{\vec{p}} - d_{\vec{q}}| > 1 \end{cases} \right). \tag{17}$$

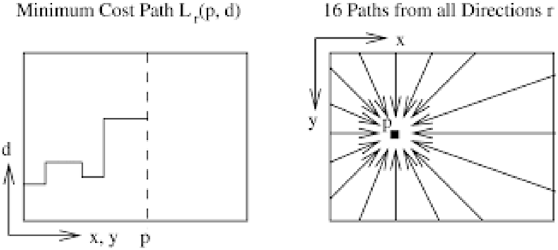



Figure: Scanlines give exact solution for 1-D minimize problem.

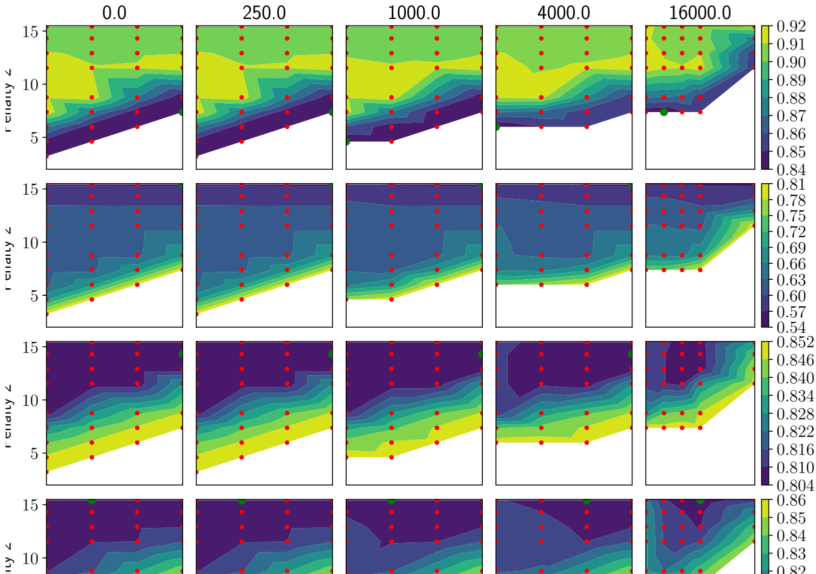
# SemiGLobal Matching

$$P2' = \frac{P2}{\sqrt{(Im_b^2 + Im_r^2 + Im_g^2)}}, \tag{18}$$

For ST-pipeline:

$$E(d) = \sum_{\vec{p}} \left( C(\vec{p}, d_{\vec{p}}) + \sum_{q \in N_p} \begin{cases} P1 \cdot |d_{\vec{p}} - d_{\vec{q}}| & \text{if } |d_{\vec{p}} - d_{\vec{q}}| \leq 1 \\ P2 & \text{if } d_{\vec{p}} - d_{\vec{q}} > 1 \\ P3 & \text{if } d_{\vec{p}} - d_{\vec{q}} < -1 \end{cases} \right). \tag{19}$$

# Evaluation: Semiglobal Matching



# Evaluation: Table

| Method | Time(s) | MSE | | | |
|---|---|---|---|---|---|
| | | boxes | cotton | dino | sideboard |
| Old Pipeline | **4.78** | 17.03 | 6.16 | 2.09 | 3.89 |
| Sandclock | 6.81 | 18.55 | 6.78 | 2.23 | 4.14 |
| epi-bilateralfilter | 43.96 | 19.26 | 6.41 | 2.22 | 4.16 |
| bilateralfilter | 20.18 | 18.95 | 6.38 | 2.10 | 4.32 |
| Thresholding | 6.06 | 15.57 | 4.38 | 1.39 | 3.03 |
| occl. segm. | 11.28 | 18.08 | 3.39 | 1.78 | 3.91 |
| altern. coh. +Treshold | 14.15 | 15.85 | 4.30 | 1.25 | 3.38 |
| SGM | 8.90 | 14.98 | 3.84 | 1.75 | 3.18 |
| SGM+Threshold | 12.75 | **13.31** | **2.96** | **1.11** | **2.43** |

# Evaluation: Postprocessing

| Method | Time(s) | MSE | | | |
|---|---|---|---|---|---|
| | | boxes | cotton | dino | sideboard |
| pp Gauss 3 | | 12.59 | 4.80 | 1.68 | 2.92 |
| pp Gauss 5 | | 11.95 | 4.54 | 1.59 | 2.72 |
| pp Gauss 7 | | 11.51 | 4.31 | 1.50 | 2.58 |
| pp Gauss 9 | | **11.34** | 4.16 | 1.46 | 2.52 |
| pp SGM | | 12.0 | **2.15** | **1.08** | **1.98** |
| pp Median 3 | | 13.21 | 4.96 | 1.83 | 3.35 |
| pp Median 5 | | 12.73 | 4.76 | 1.76 | 3.20 |