User Directed Multi-View-Stereo

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UCCV, November 2014

UCL Centre for
Virtual Environments,
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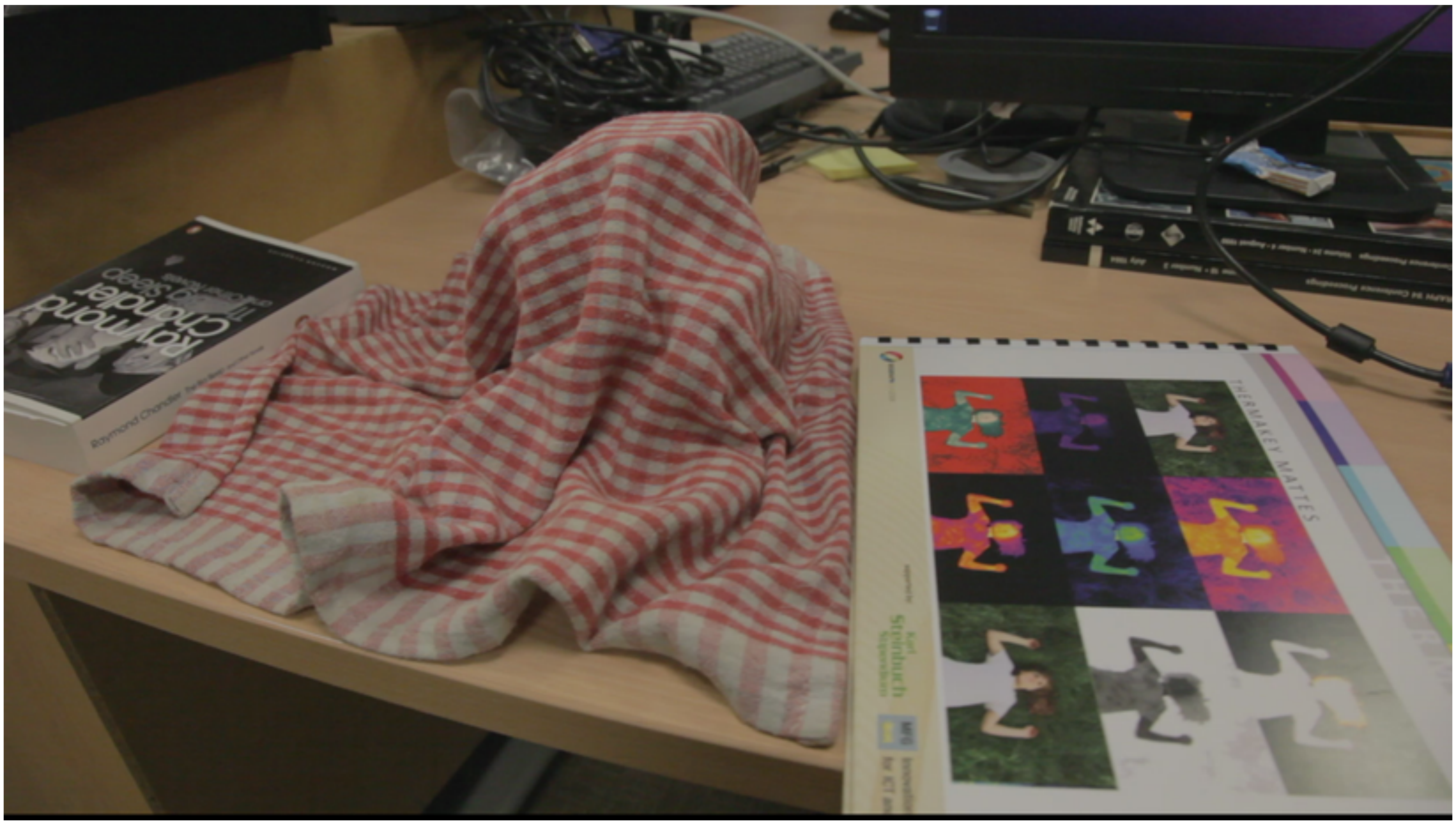
Multi-View-Stereo Failure Cases



Reference frame from image sequence

Multi-View-Stereo Failure Cases

Baseline depth result [Newcombe 2011]

Multi-View-Stereo Failure Cases

Problems at occlusion boundaries

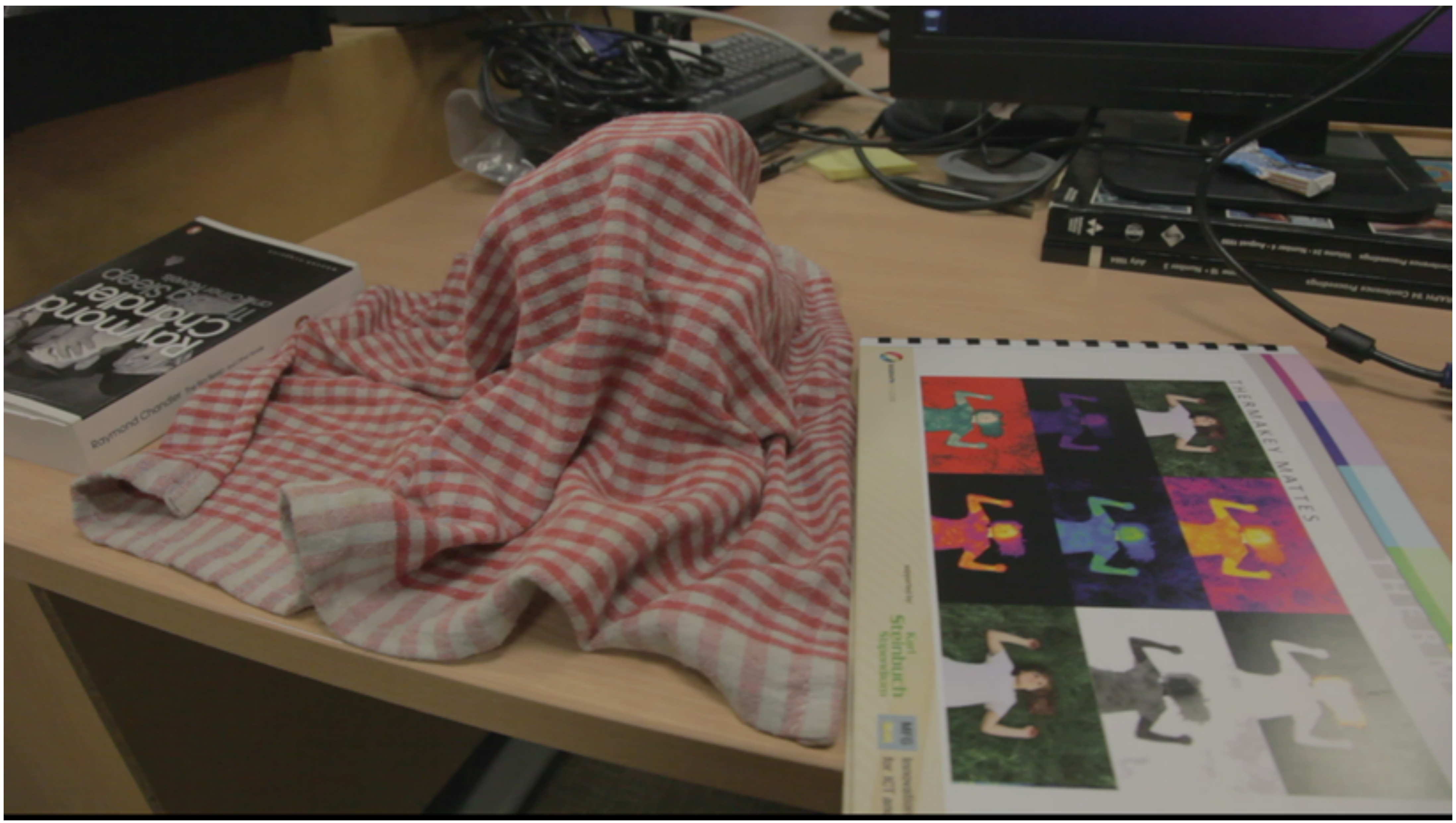
Baseline depth result

Multi-View-Stereo Failure Cases

Glossy surfaces

Baseline depth result

Multi-View-Stereo Failure Cases



Reference frame from image sequence

Multi-View-Stereo Failure Cases

Low texture

Baseline depth result

User-Guided Multi-View-Stereo

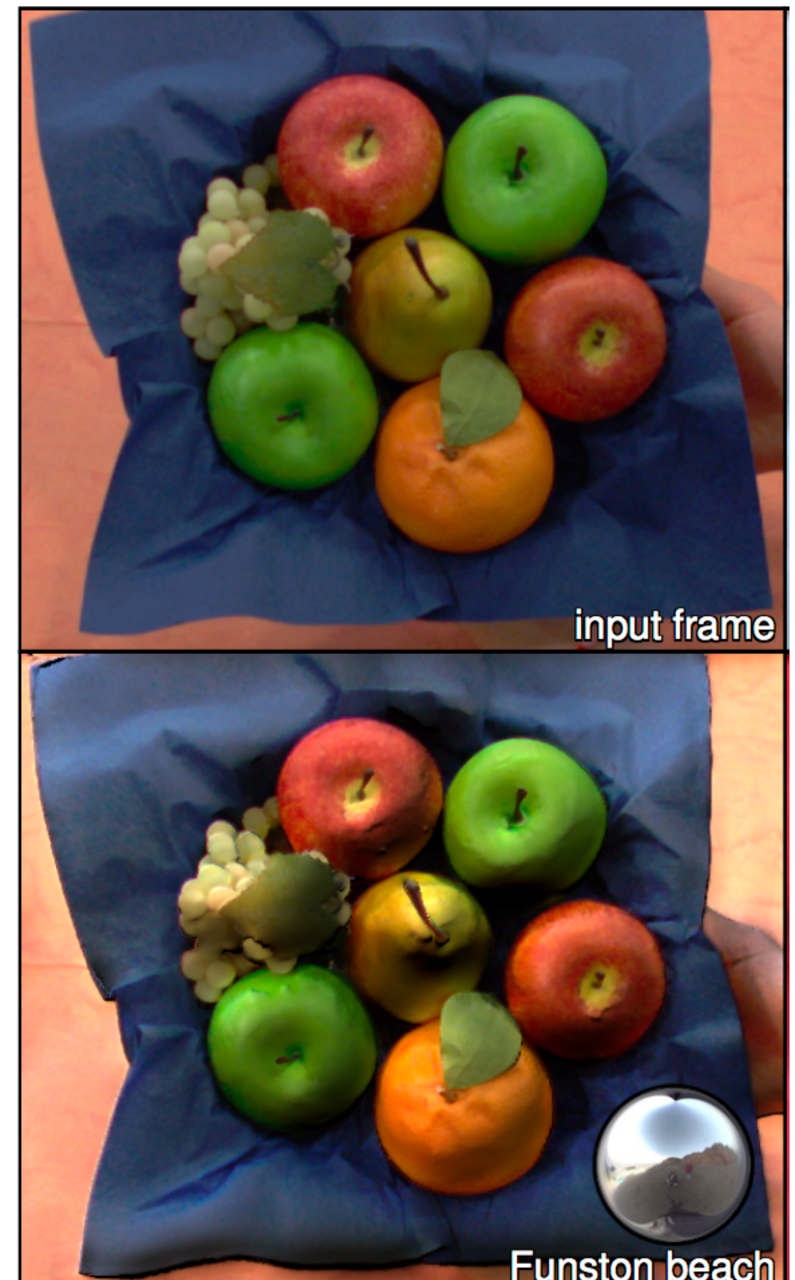
Depth result after user markup

Depth Map Applications

Synthetic Depth of Field

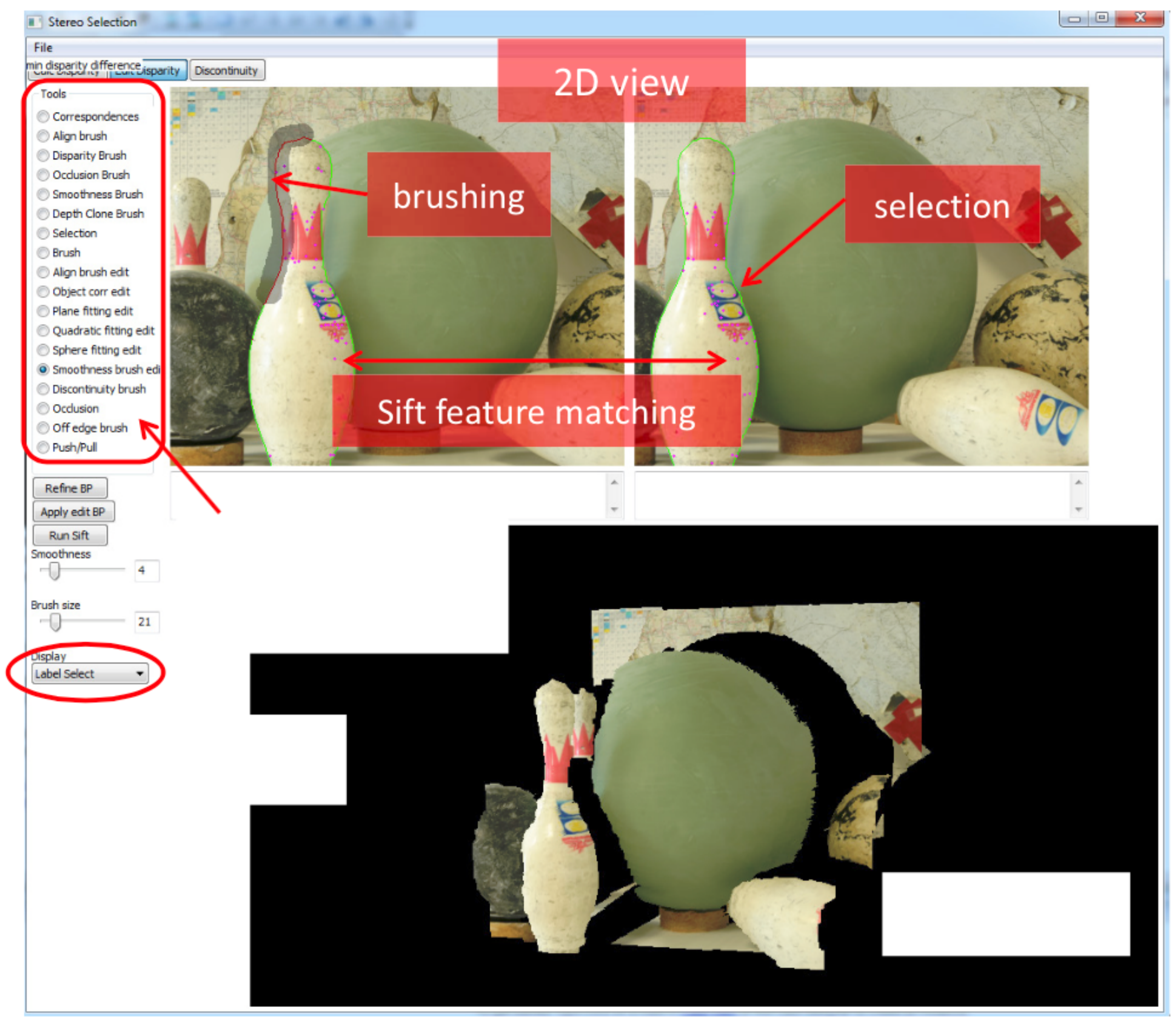
Lens Blur, Google Camera app

Relighting



[Richardt *et al.* 2012]

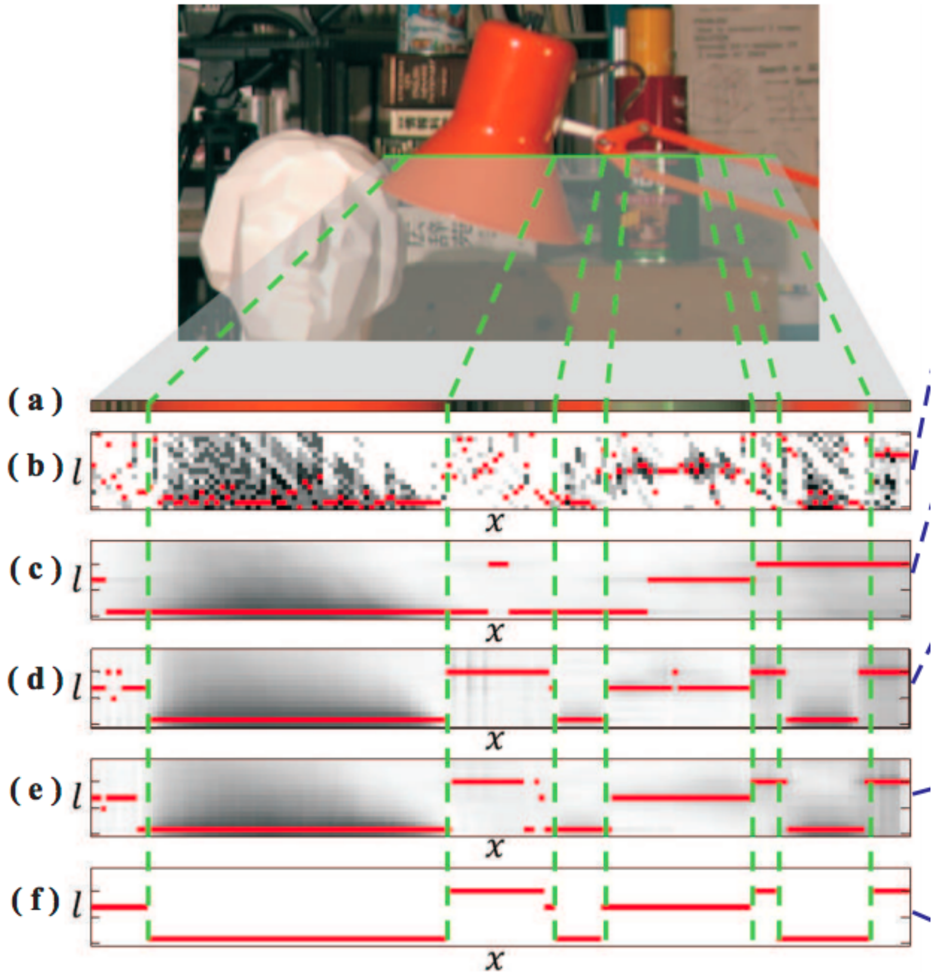
Related Work



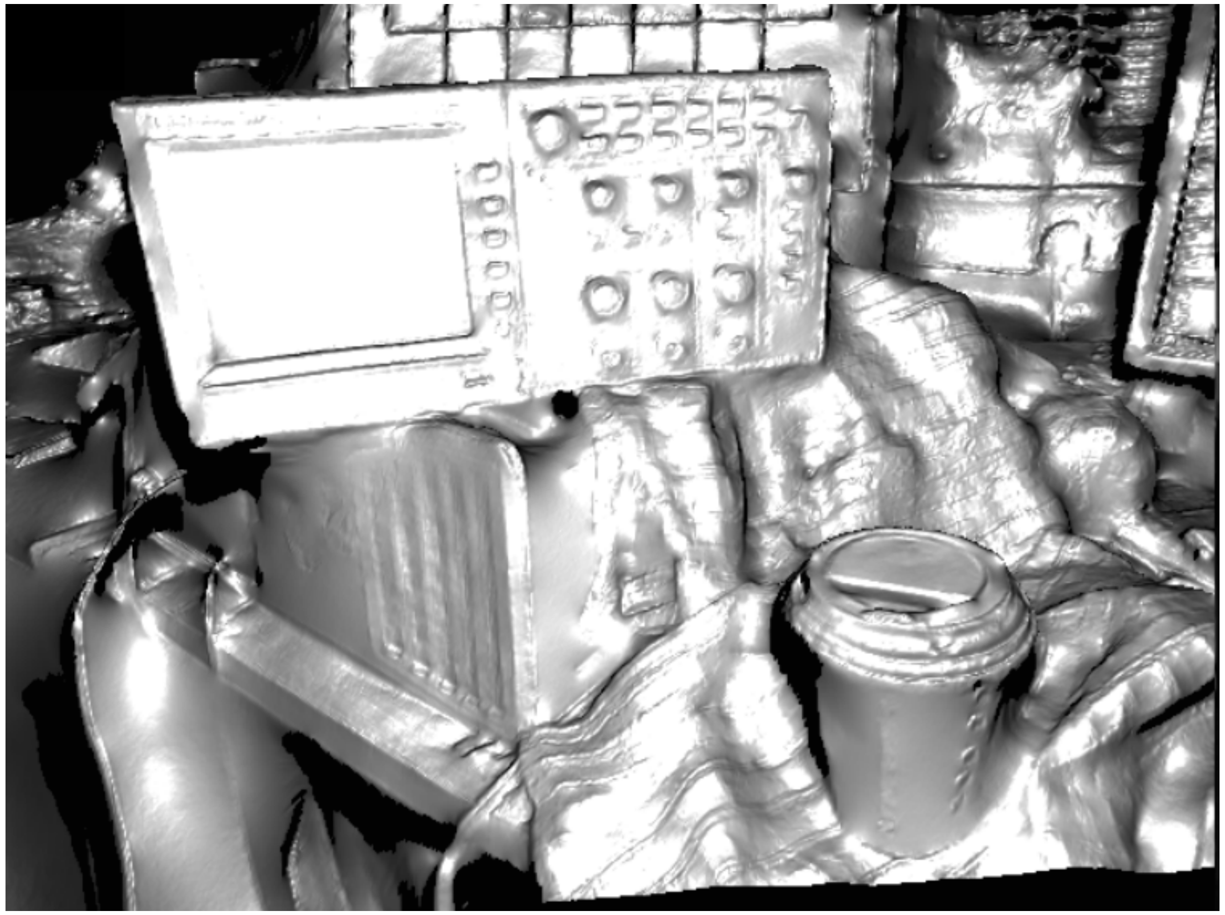
[Shen, 2011]
[Bousseau 2009]

[Zhang, 3DV 2013]

Related Work



Fast local filtering
[Rhemann 2011]



Fast global optimisation
[Newcombe 2011]

Multi-View-Stereo Failure Cases

Assumption	**Assumption violated**
Image edges ~ depth changes	Depth blurs across object edges Discontinuity on smooth surface
Textured surfaces	Poor localisation / noisy depth
Lambertian surfaces	Grossly incorrect depth / holes

Our Method

- Users correct depth only where needed
- Accept coarse input - don’t rely on accurate object segmentation
- Base on method that can achieve interactive rates [Newcombe 2011]

Energy Model

$$E\left[\,d(x)\,\right] = \int_{\Omega} \lambda\, C(x, d(x)) + \boxed{g(x)\, \|\nabla d(x)\|_{\epsilon}}\, \mathrm{d}x$$

Smoothness prior on depth

“Image edges ~ Depth edges” assumption encoded by weighting $g(x) = \exp\left(-\gamma\, \|\nabla I_{\mathrm{s}}\|\right)$

[Newcombe 2011]

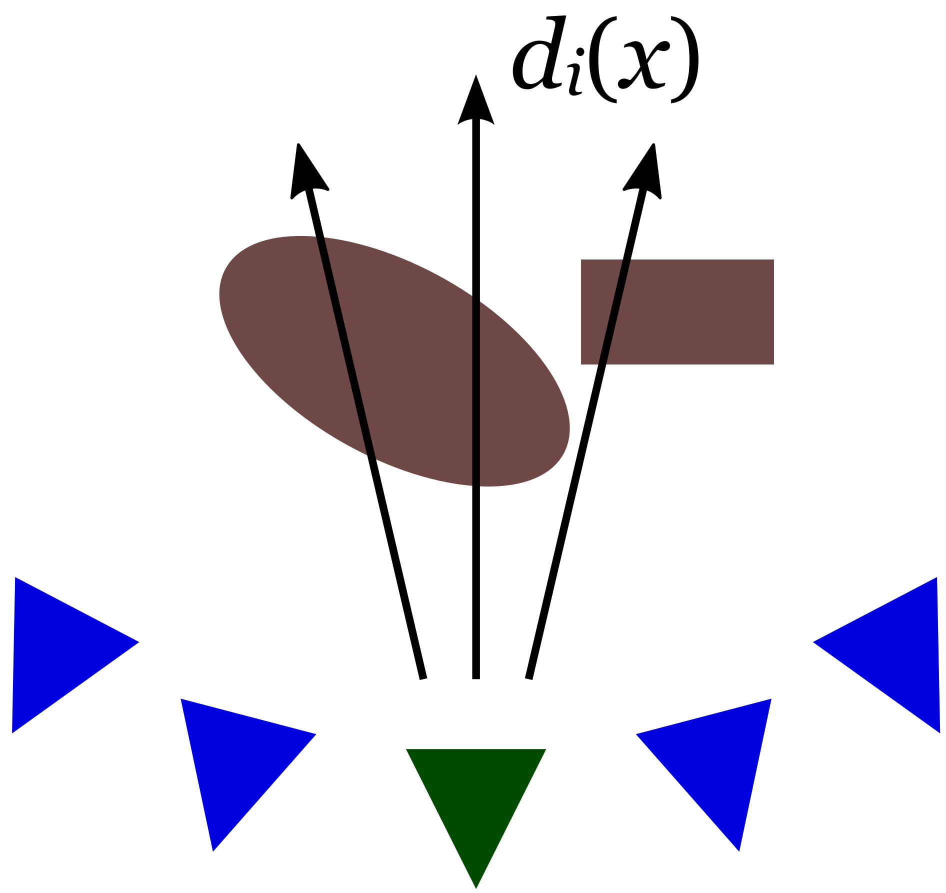
Energy Model

$$E\left[\,d(x)\,\right] = \int_{\Omega} \lambda \boxed{C(x, d(x))} + g(x) \left\|\nabla d(x)\right\|_{\epsilon} \, \mathrm{d}x$$

Correspondence term, encodes textured Lambertian surface assumption

[Newcombe 2011]

Correspondence Term



Reference frame
Neighbouring frames

Test a range of discrete depths d_i along ray through each pixel x in reference frame

Cache correspondence error in **cost volume** C

[Newcombe 2011]

Changing the Energy with User Edits

$$E\left[\,d(x)\,\right] = \int_{\Omega} \boxed{\lambda} C(x, d(x)) + g(x)\,\|\nabla d(x)\|_{\epsilon}\,\mathrm{d}x$$

$$g(x) = \exp\left(-\boxed{\gamma}\,\|\nabla I_{\mathrm{s}}\|\right)$$

Allow spatially varying parameters

Changing the Energy with User Edits

$$E\left[\, d(x) \,\right] = \int_{\Omega} \boxed{\lambda} C(x, d(x)) + g(x) \left\| \nabla d(x) \right\|_{\epsilon} \, \mathrm{d}x$$

$$g(x) = \exp\left(-\gamma \left\| \nabla I_{\mathrm{s}} \right\|\right)$$

Smoothness brush

Downweight data term locally to increase influence of regularisation term

Changing the Energy with User Edits

$$E\left[\,d(x)\,\right] = \int_{\Omega} \boxed{\lambda} C(x, d(x)) + g(x) \left\|\nabla d(x)\right\|_{\epsilon} \,\mathrm{d}x$$

$$g(x) = \exp\left(\boxed{-\gamma}\, \|\nabla I_{\mathrm{s}}\|\right)$$

Discontinuity brush

Increase edge sensitivity locally

Downweight data term locally

Changing the Energy with User Edits

Inequality / Ordering brush

Requires both front and back strokes

Add linear constraint term for minimum separation between pairs of pixels on strokes

$$\Phi\left[d\right] + t_{\mathrm{dist}}\mathbf{1} < \mathbf{0}$$

Front-back pixel correspondences encoded in sparse matrix $\boldsymbol{\Phi}$

Optimisation

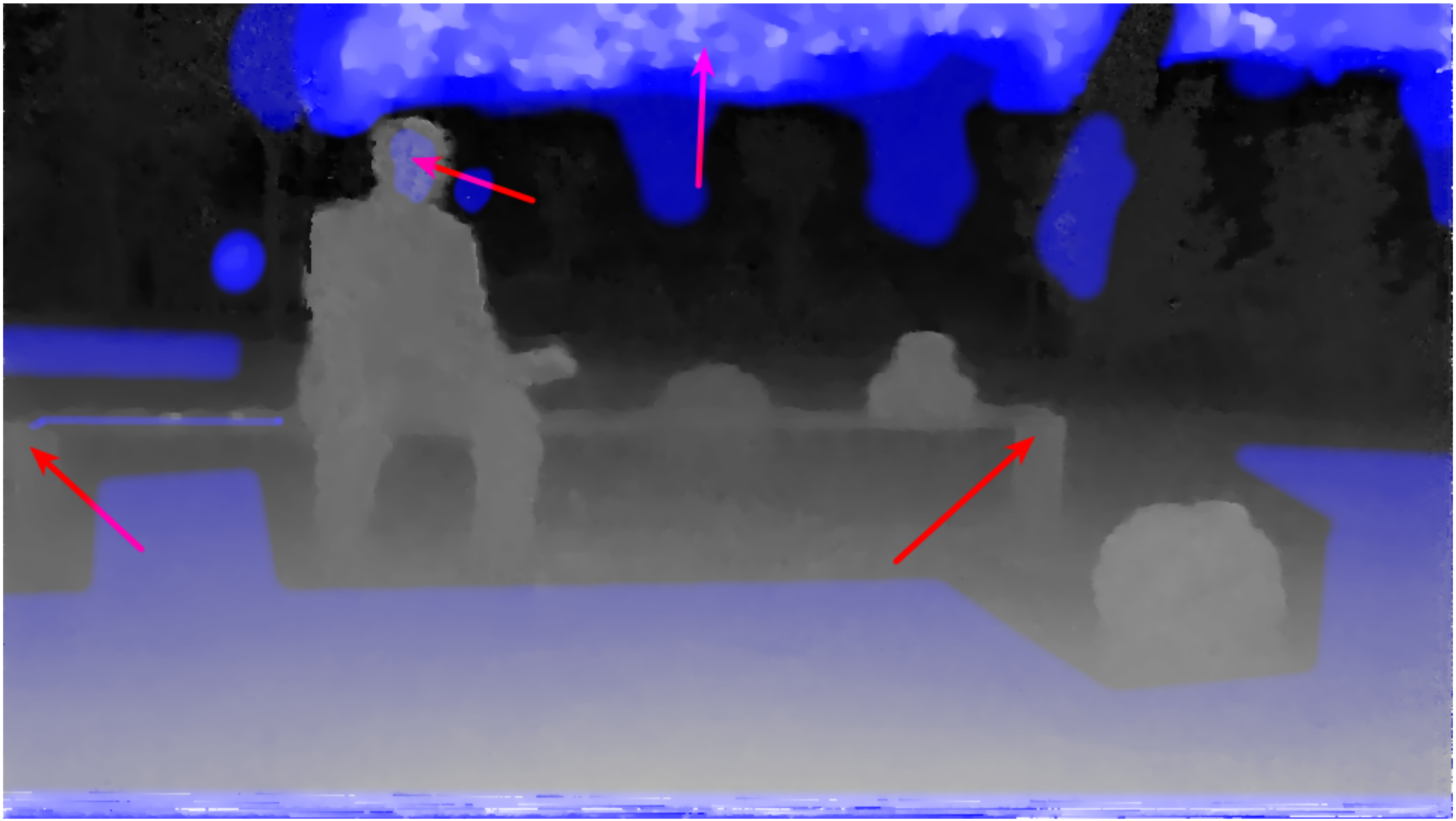
- Energy made up of convex and non-convex terms
- First-order primal-dual solver for convex terms
- Use quadratic relaxation to minimize cost-volume term in alternation [Steinbrücker 2009, Newcombe 2011]
- Please see our paper for full details

Lawn

[Zhang 2009]

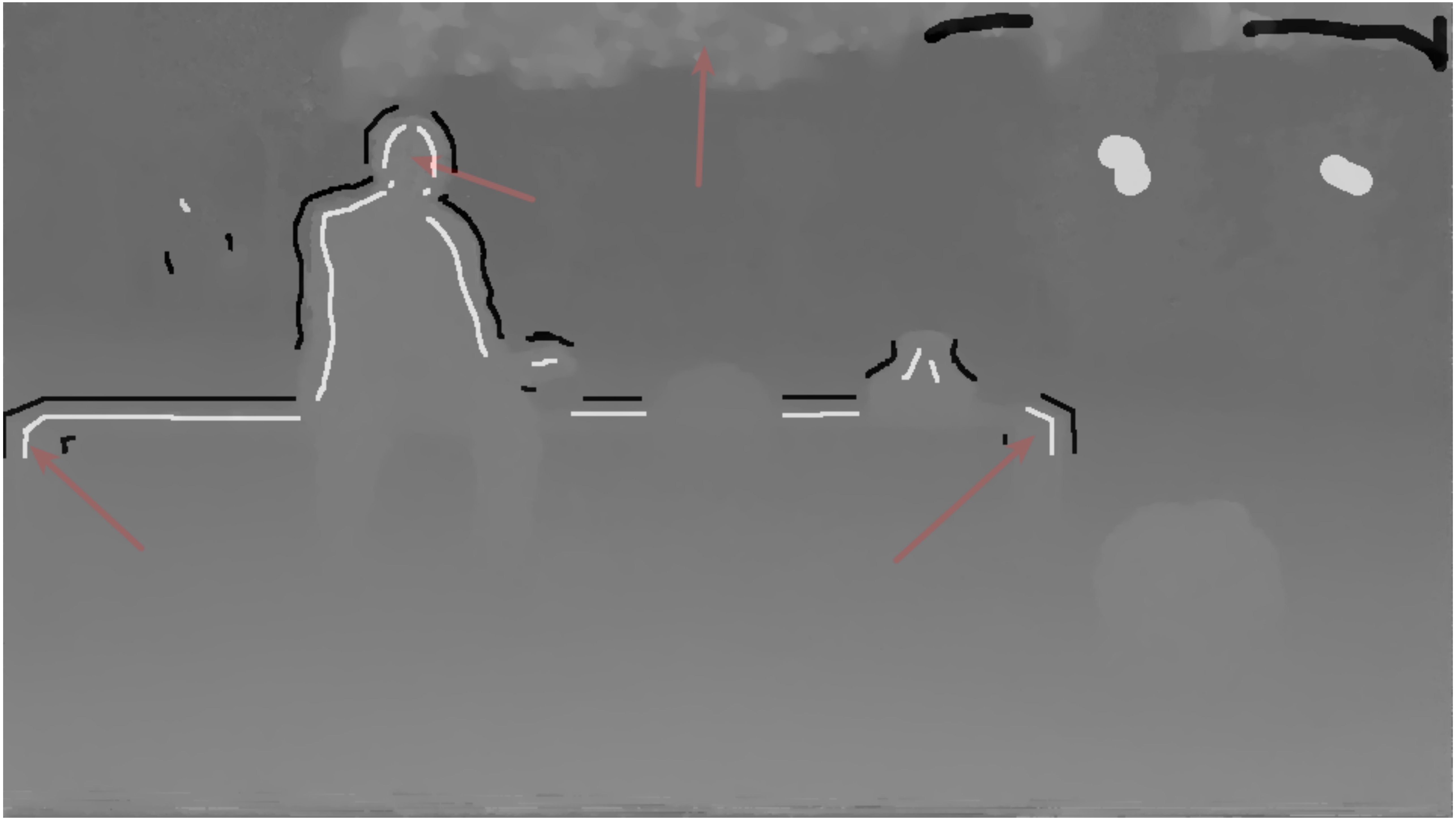
Lawn - Baseline

Lawn - Smoothness



Lawn - Discontinuity

Lawn - Ordering

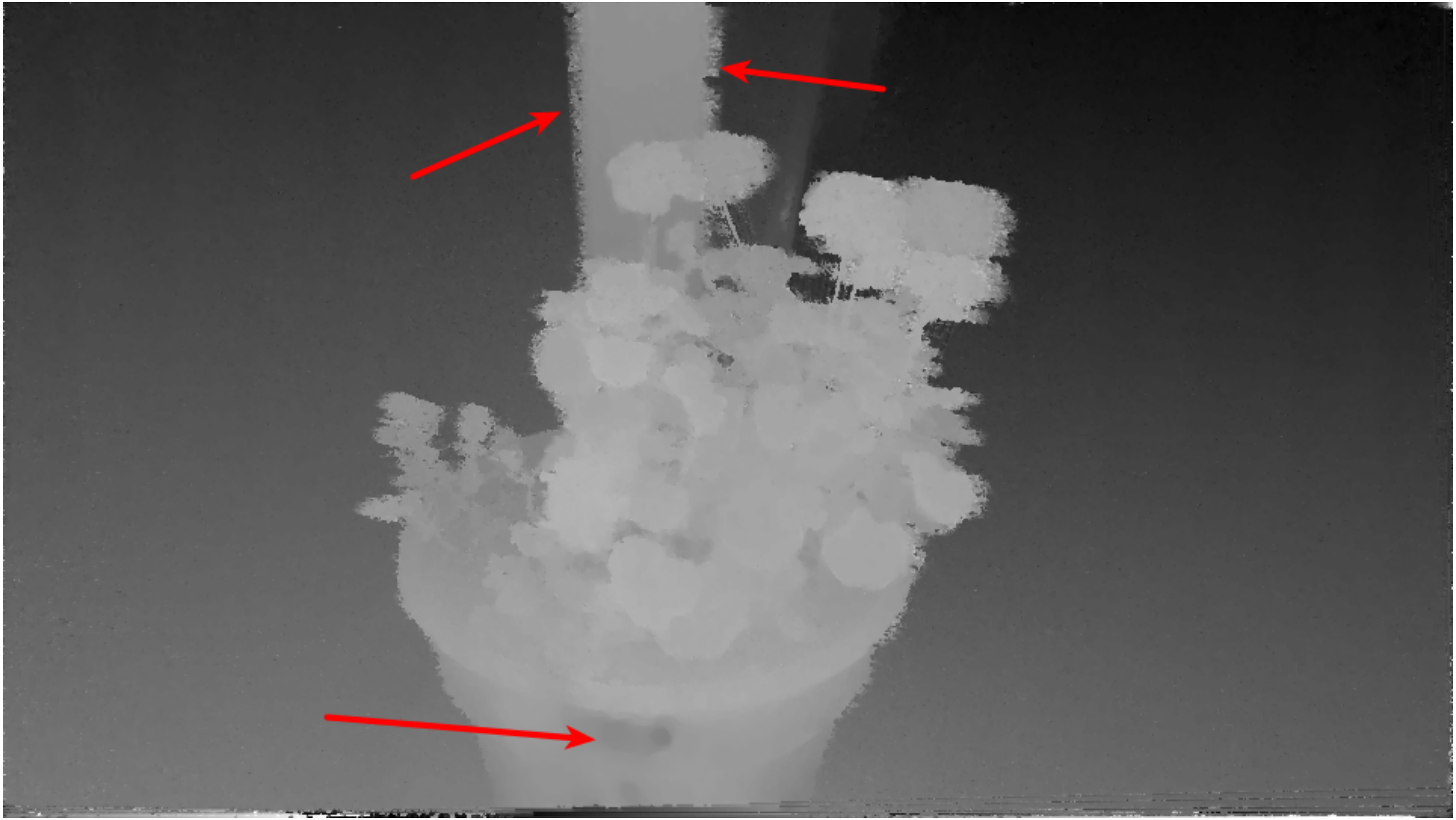


Lawn - Result

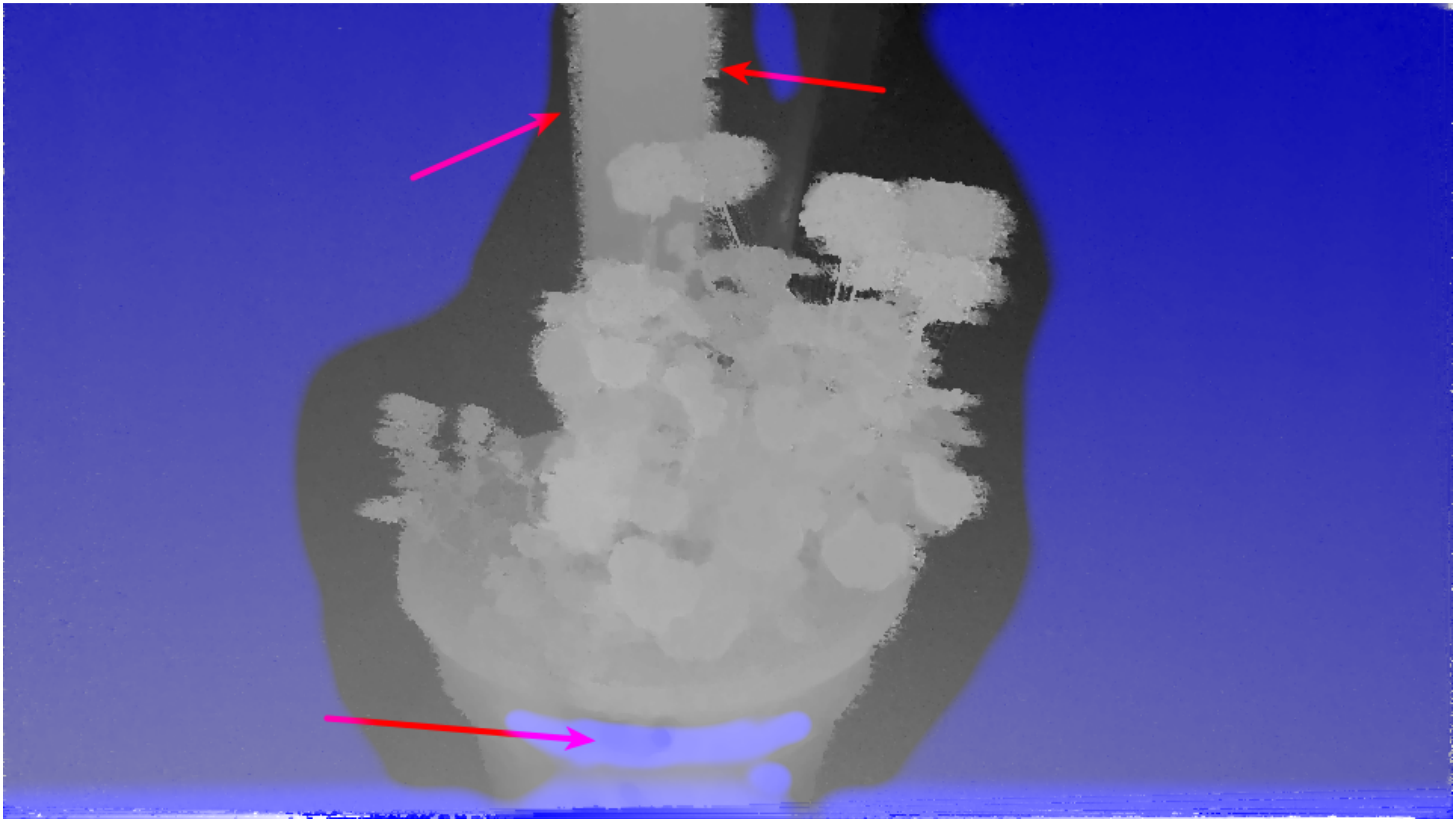
Lawn - Baseline

Flower

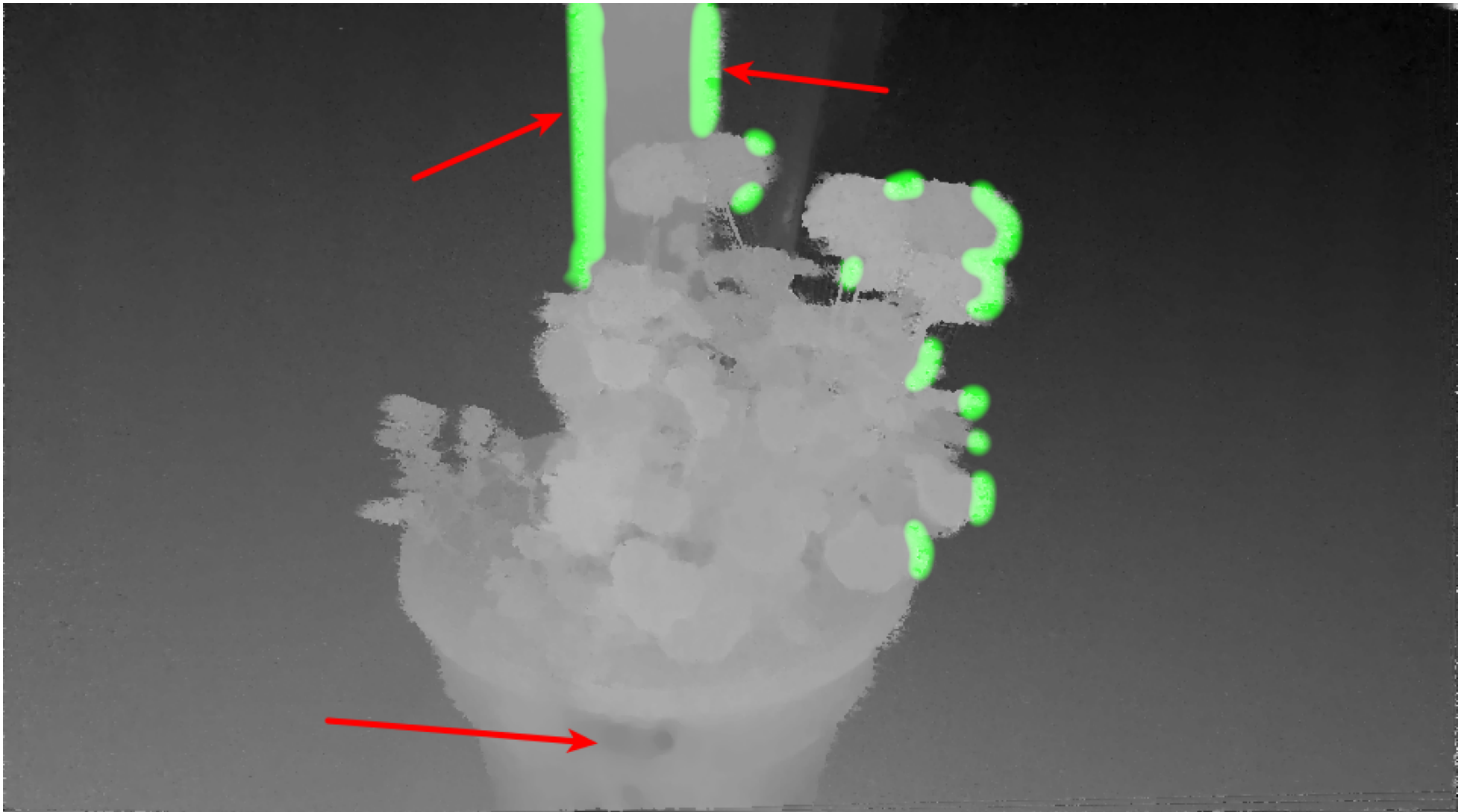
Flower - Baseline



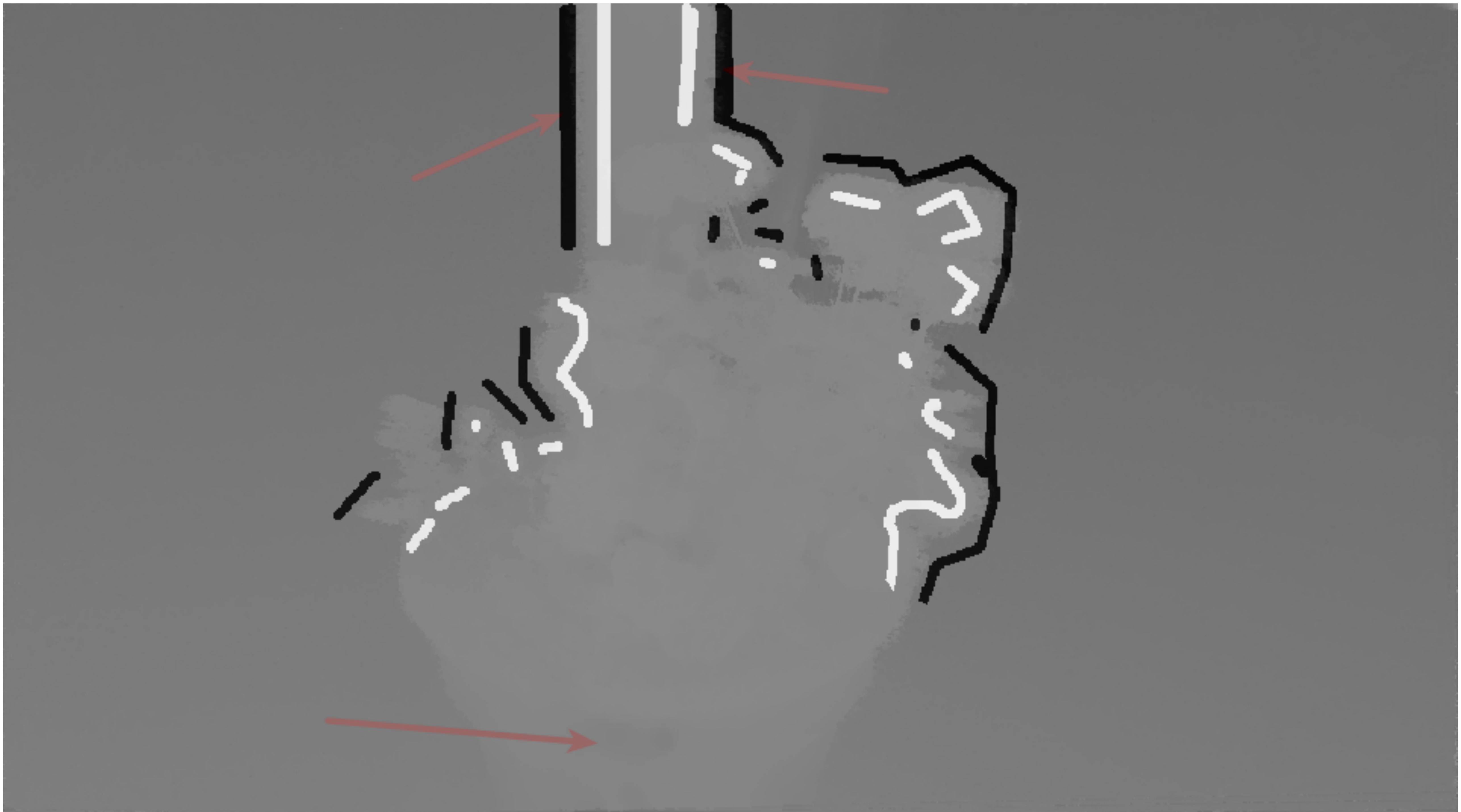
Flower - Smoothness



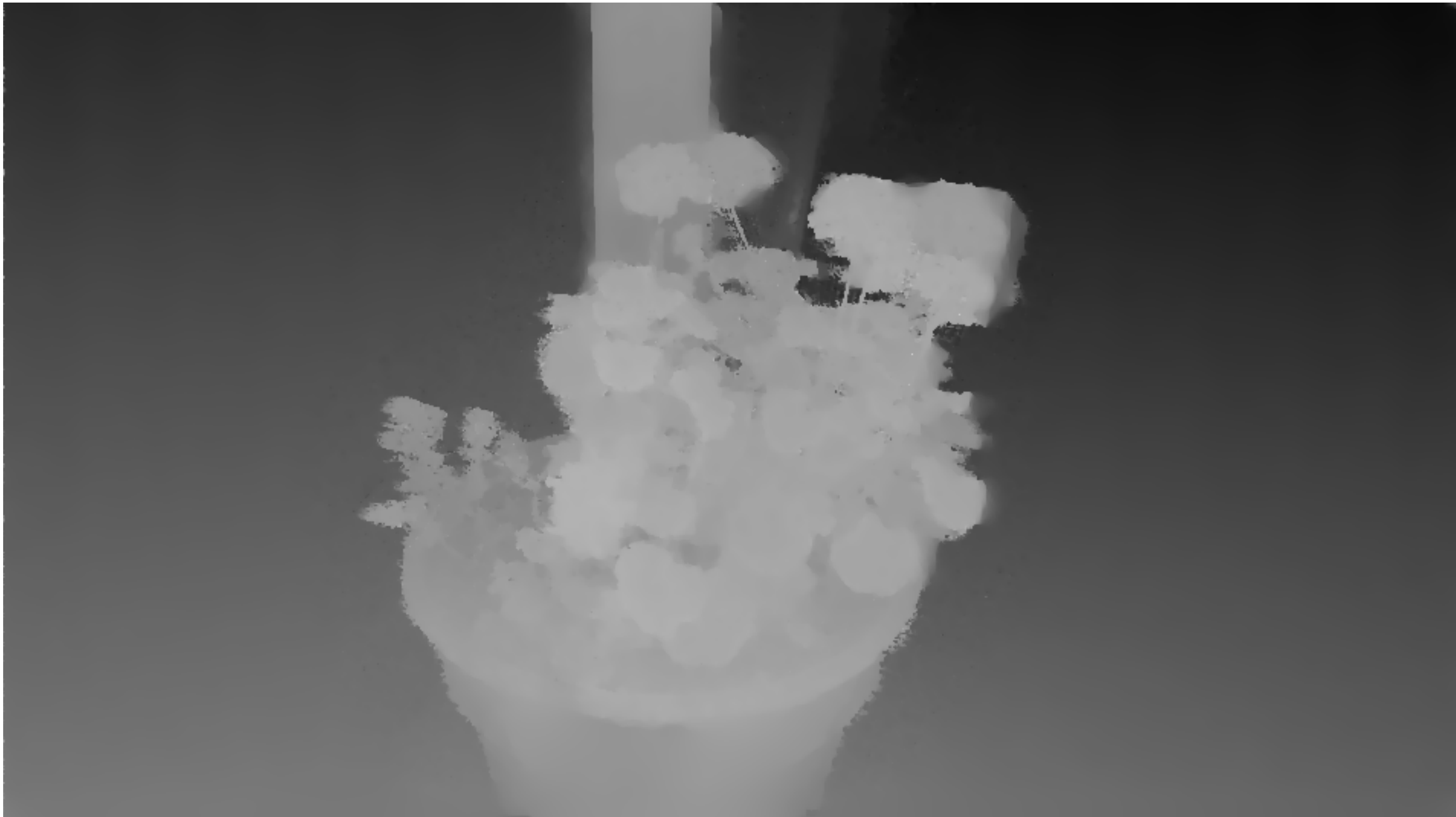
Flower - Discontinuity



Flower - Ordering

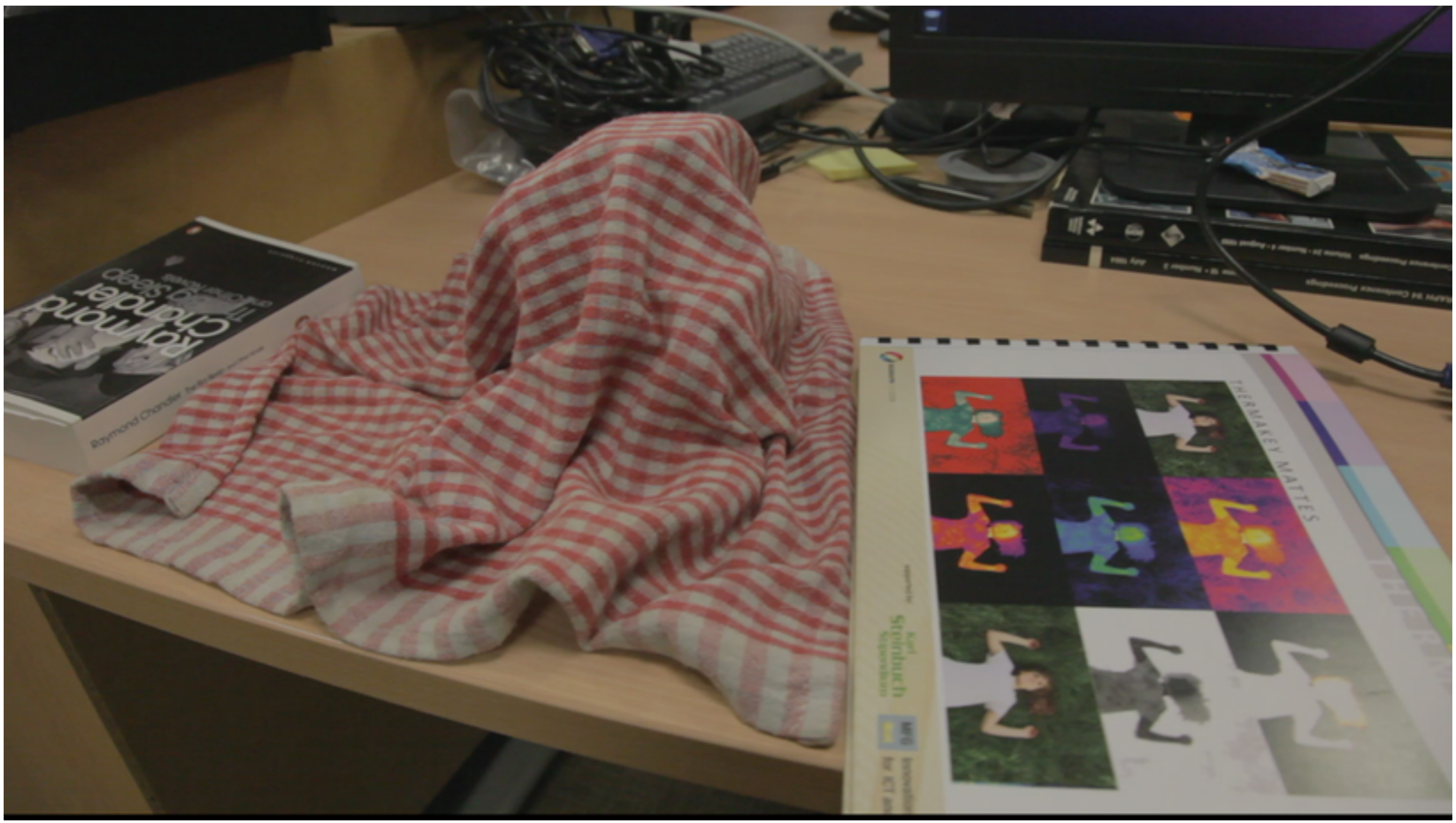


Flower - Result



Flower - Baseline

Desk



Desk - Baseline

Desk - Result

Desk - Failures

Conclusion

- Enhance multi-view-stereo with user-interaction
- User edits are incorporated into energy model
- High level markup can improve depth map recovery
- **Limitations:** Edge refinement not always successful. Discontinuity and inequality normally used together and could be combined in workflow. Some smoothness edits take many iterations to converge with current solver.
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