STANFORD COMPUTATIONAL IMAGING

dgd.vision

Richardson-Lucy Deblurring for Moving Light Field Cameras

Donald Dansereau[1], Anders Eriksson[2] and Jürgen Leitner[2,3]

[1]Stanford University, [2]Queensland University of Technology, [3]ARC Centre of Excellence for Robotic Vision

AUSTRALIAN CENTRE FOR ROBOTIC VISION

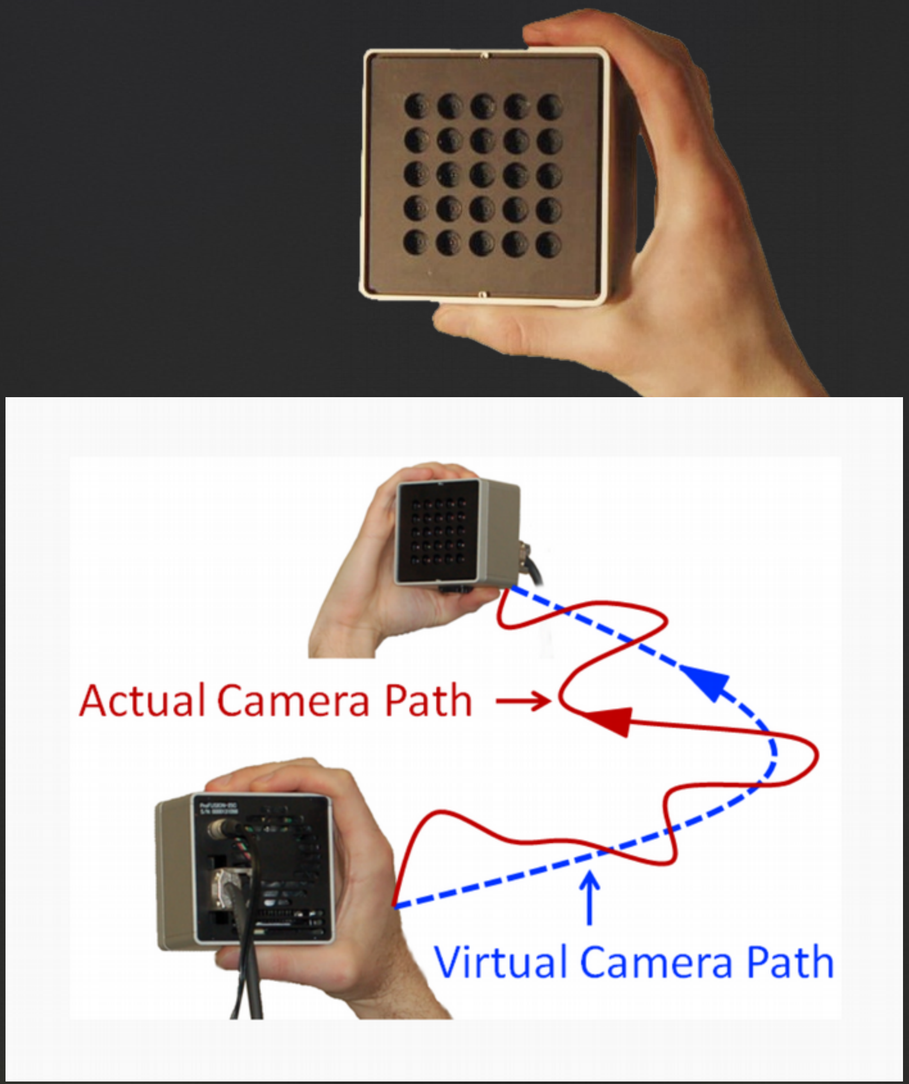
CVPR:LF4CV Workshop
2017 July 26

3D Motion Complicates Vision

Scene-dependent nonuniform apparent motion

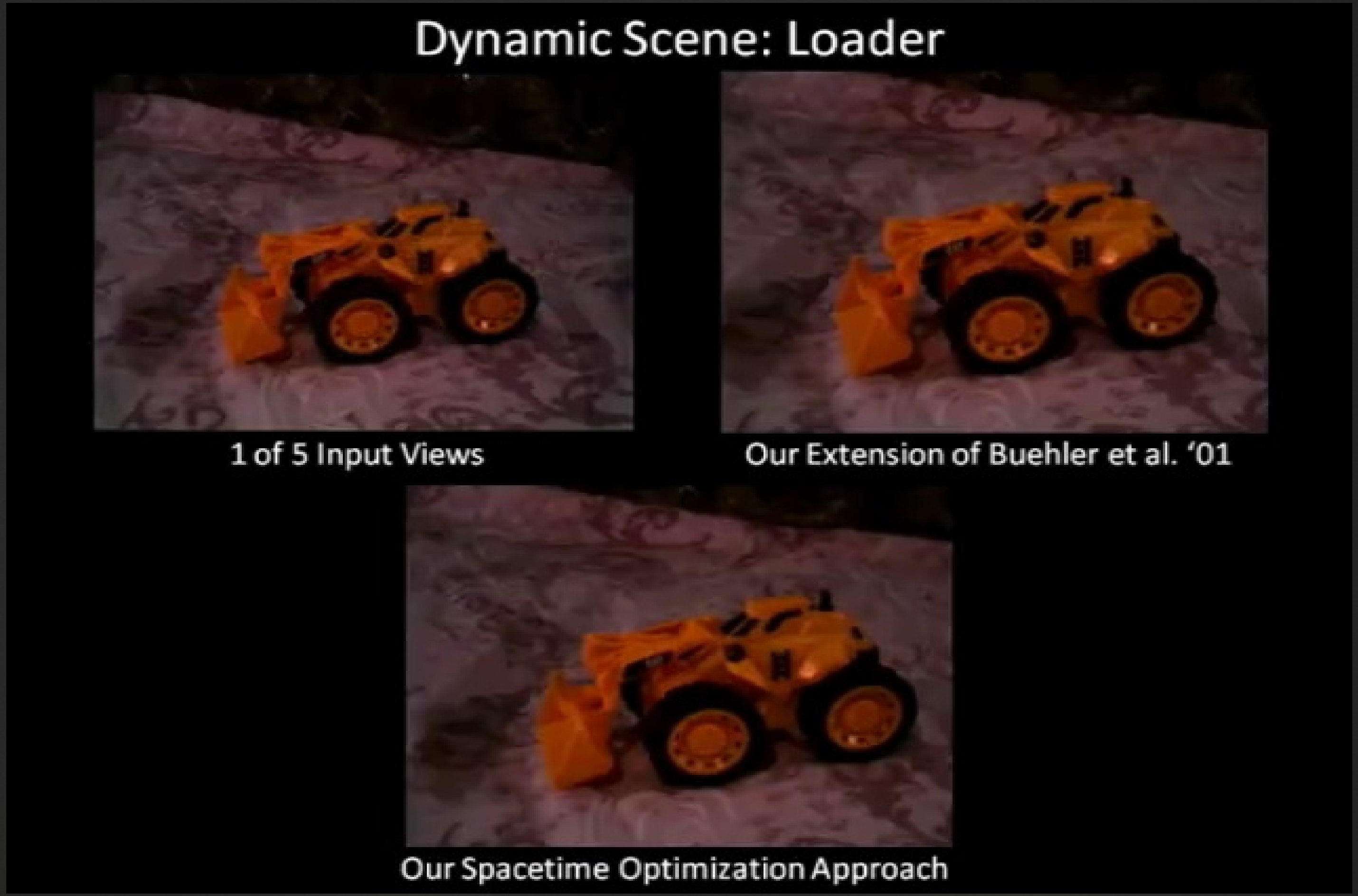
3D is Easier in 4D

We have 6-DOF virtual camera control



Video Stabilization

[video]



http://pages.cs.wisc.edu/~lizhang/projects/lfstable/

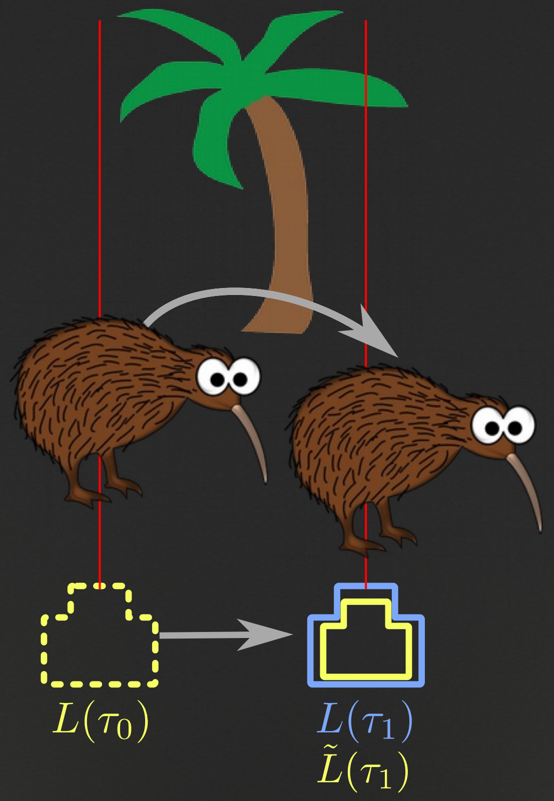
[Smith2009]

3D is Easier in 4D

We can fix the camera's position

Per-pixel still-camera methods

- Change detection
- Tracking/segmentation
- Velocity & temporal filtering



Closed-Form
Change Detection

[dansereau2016]

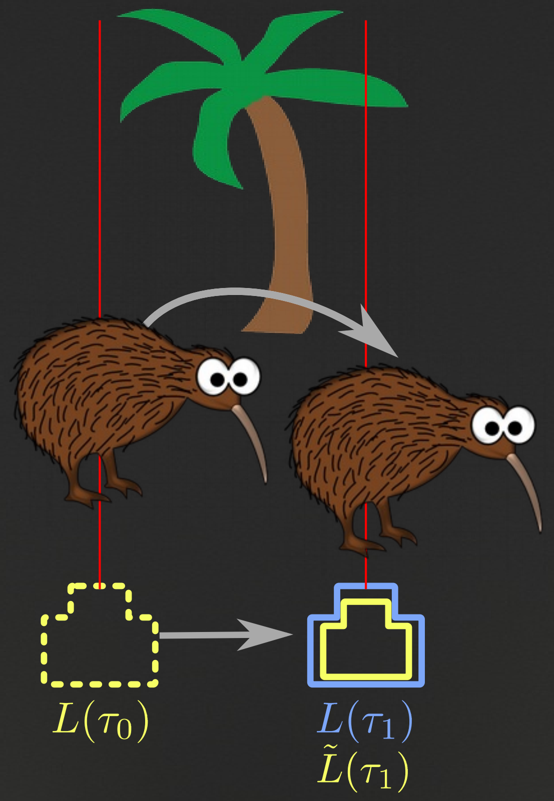
http://dgd.vision/Projects/LFChangeDet/

3D is Easier in 4D

We can fix the camera's position

Per-pixel still-camera methods

- Change detection
- Tracking/segmentation
- Velocity & temporal filtering



Closed-Form
Change Detection

[dansereau2016]

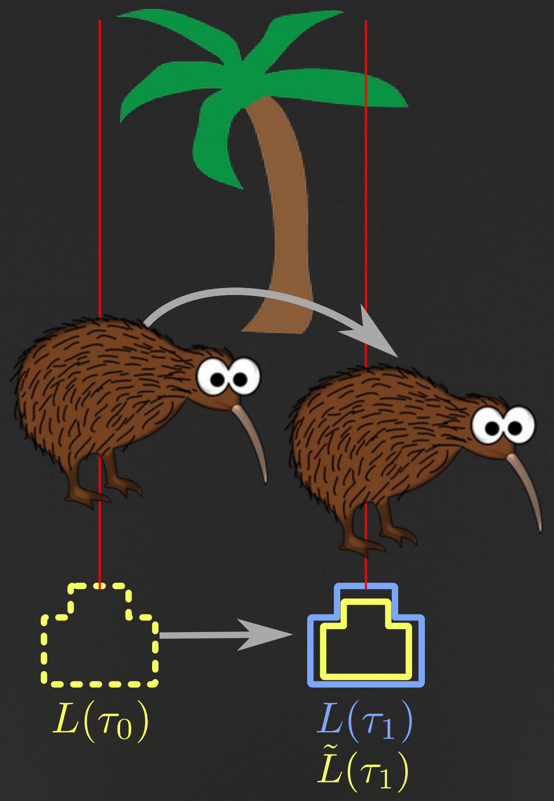
http://dgd.vision/Projects/LFChangeDet/

3D is Easier in 4D

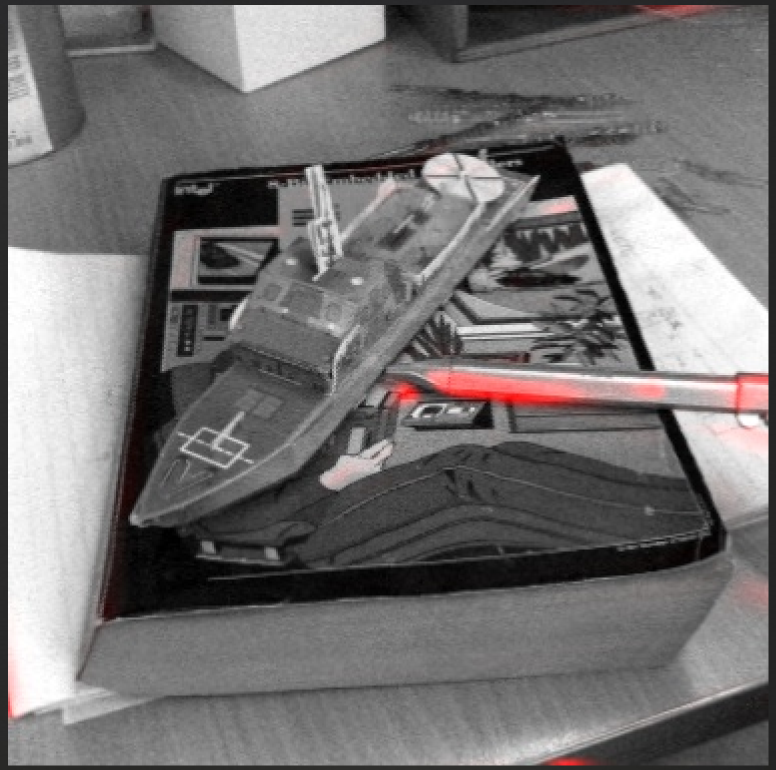
We can fix the camera's position

Per-pixel still-camera methods

- Change detection
- Tracking/segmentation
- Velocity & temporal filtering



Closed-Form
Change Detection



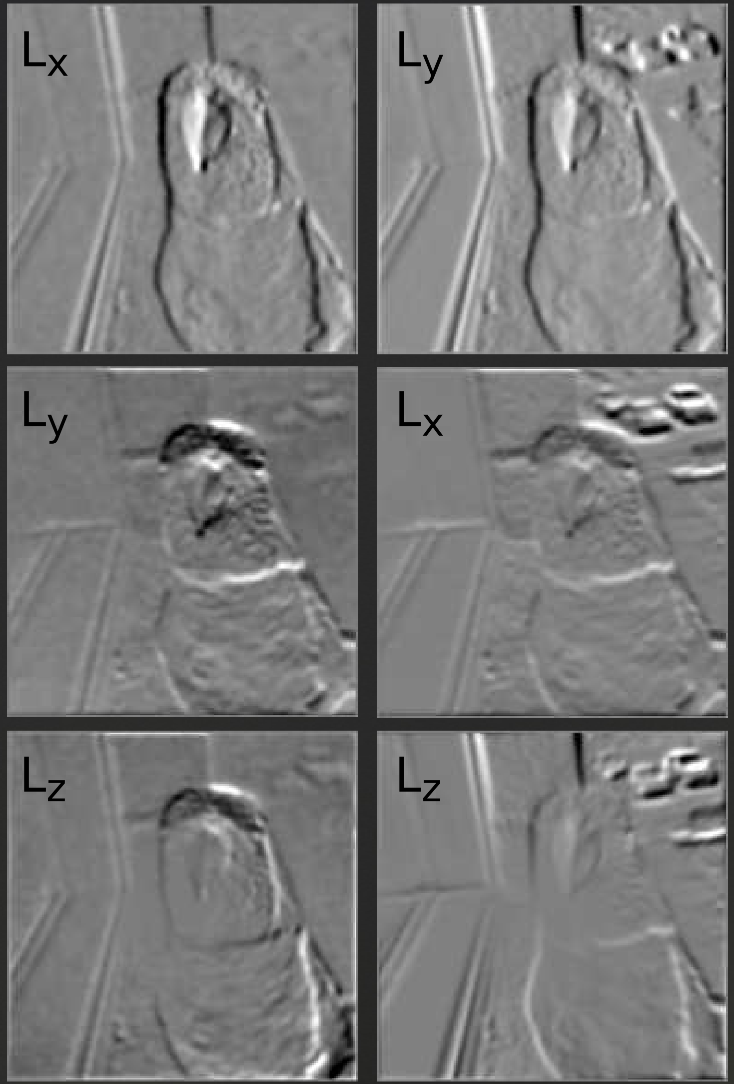
[dansereau2016]

http://dgd.vision/Projects/LFChangeDet/

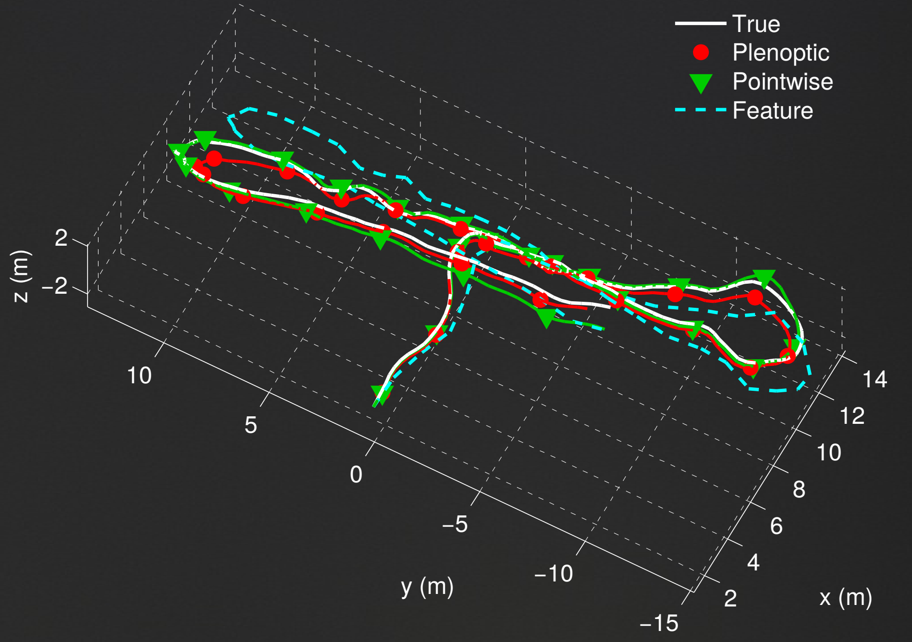
3D is Easier in 4D

Lukas-Kanade optical flow generalizes to 6-DOF

Linearize Apparent Motion



Closed-form 6-DOF Odometry

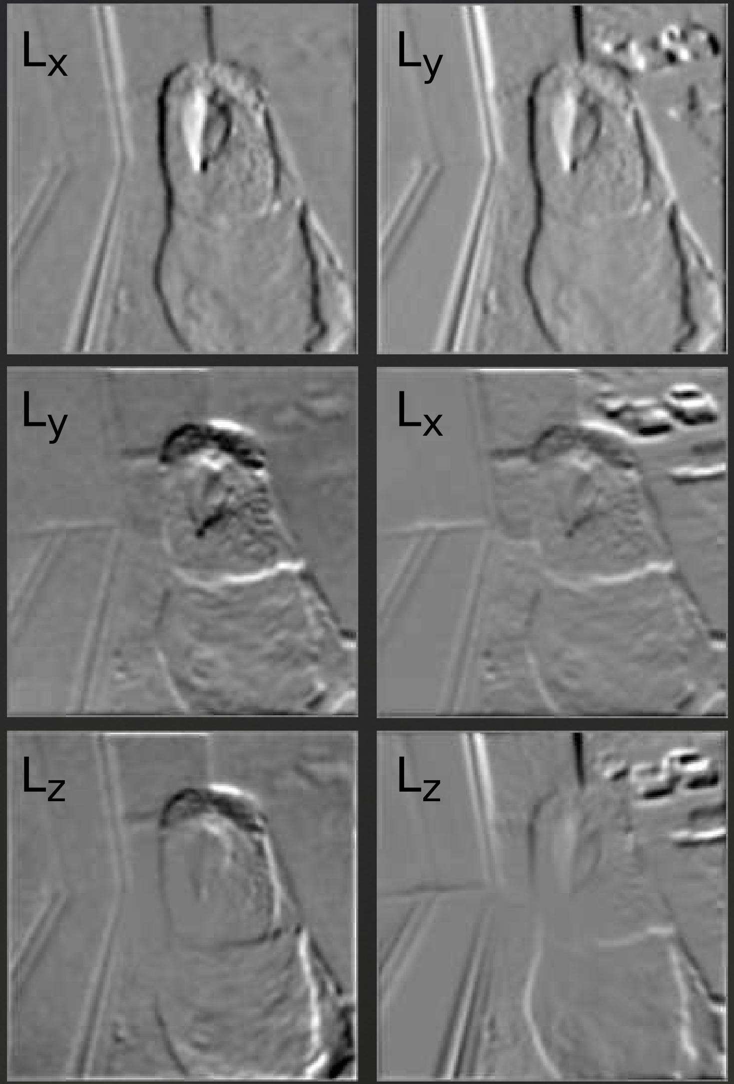


[Neumann2002, Dansereau2011, Dong2013]

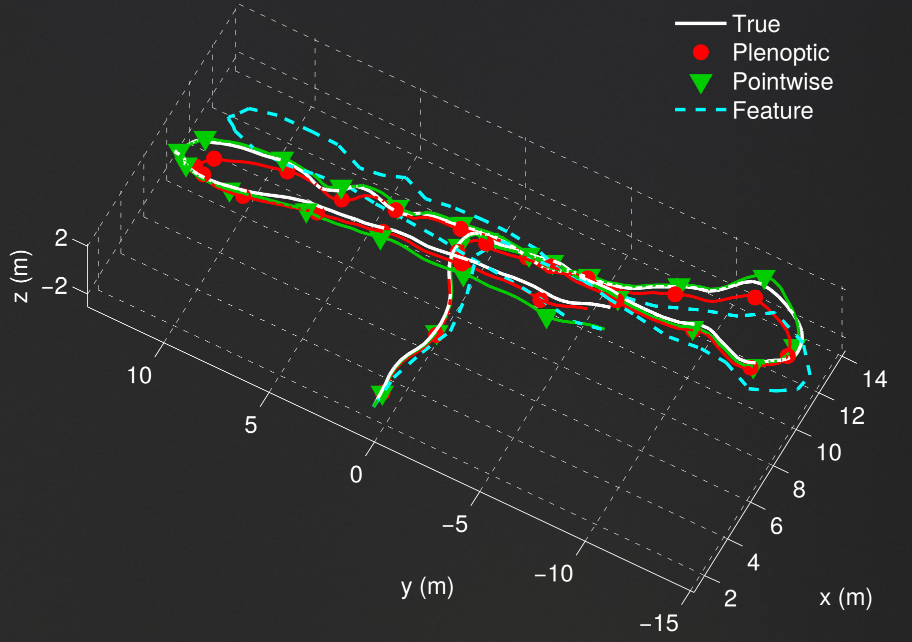
3D is Easier in 4D

Lukas-Kanade optical flow generalizes to 6-DOF

Linearize Apparent Motion



Closed-form 6-DOF Odometry



[Neumann2002, Dansereau2011, Dong2013]

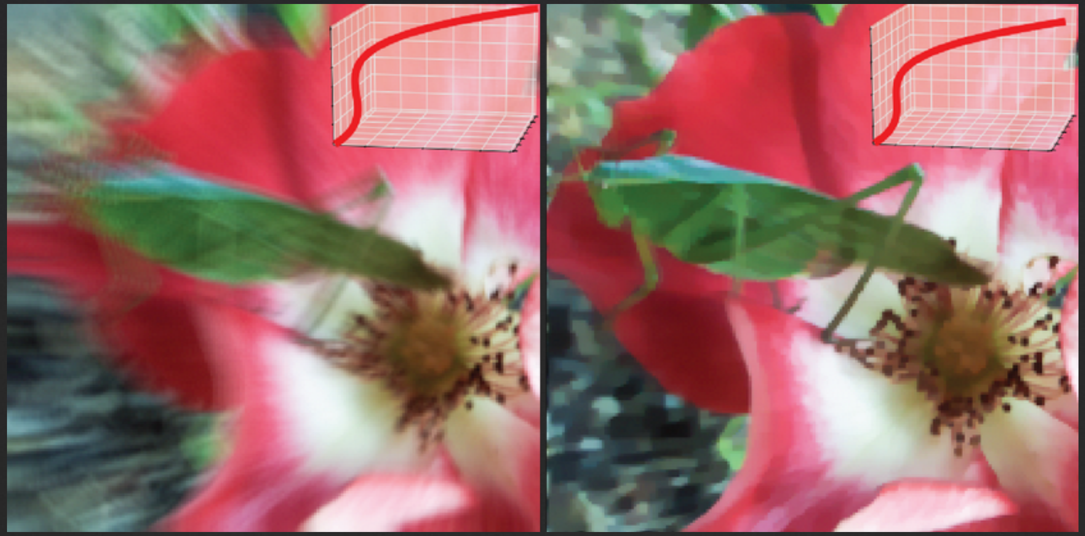
Blur in 3D Scenes

Convolution models blurring in 2D…

Can we replace convolution with LF rendering in 3D scenes?

Related Work

"Light Field Blind Motion Deblurring" [Srinivasan 2017]



$$\min_{\mathbf{l},\mathbf{p}(t)} ||\hat{\mathbf{f}}(\mathbf{l},\mathbf{p}(t)) - \mathbf{f}||_2^2 + \lambda\psi(\mathbf{l})$$

- 3-DOF
- Insights on blur manifestation in LF
- Blind
- Modern optimization (ADAM)

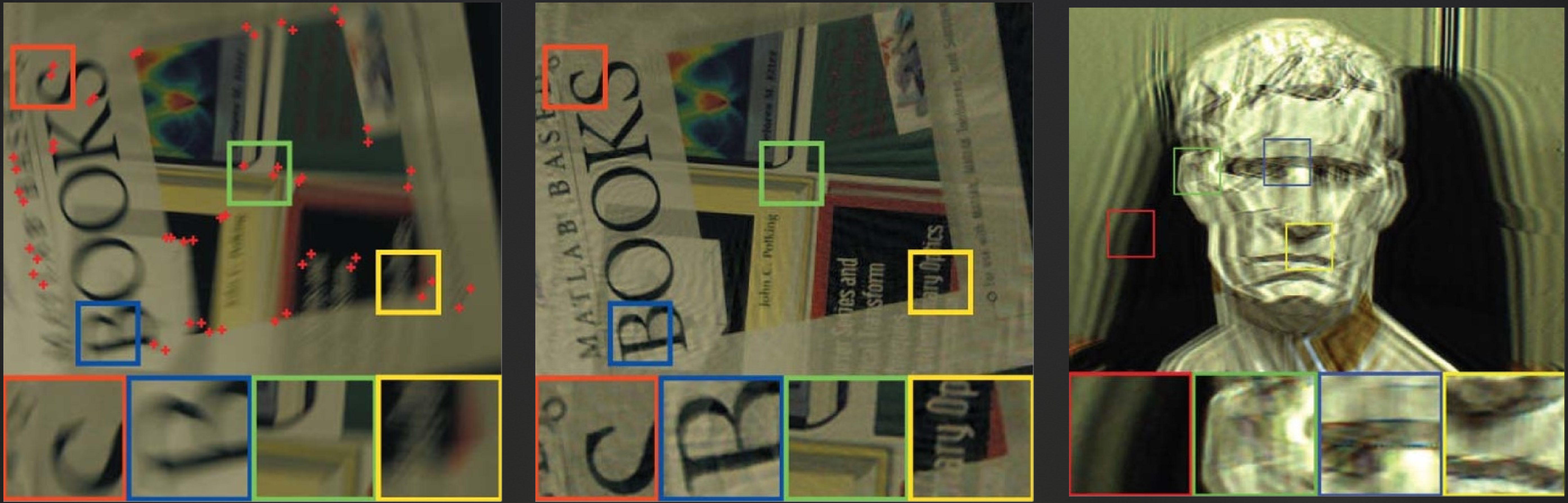
LF-RL

- Requires extension to be blind
- 6-DOF
- Proof of convergence to ML estimate (see paper)
- New LF equiparallax regularizer

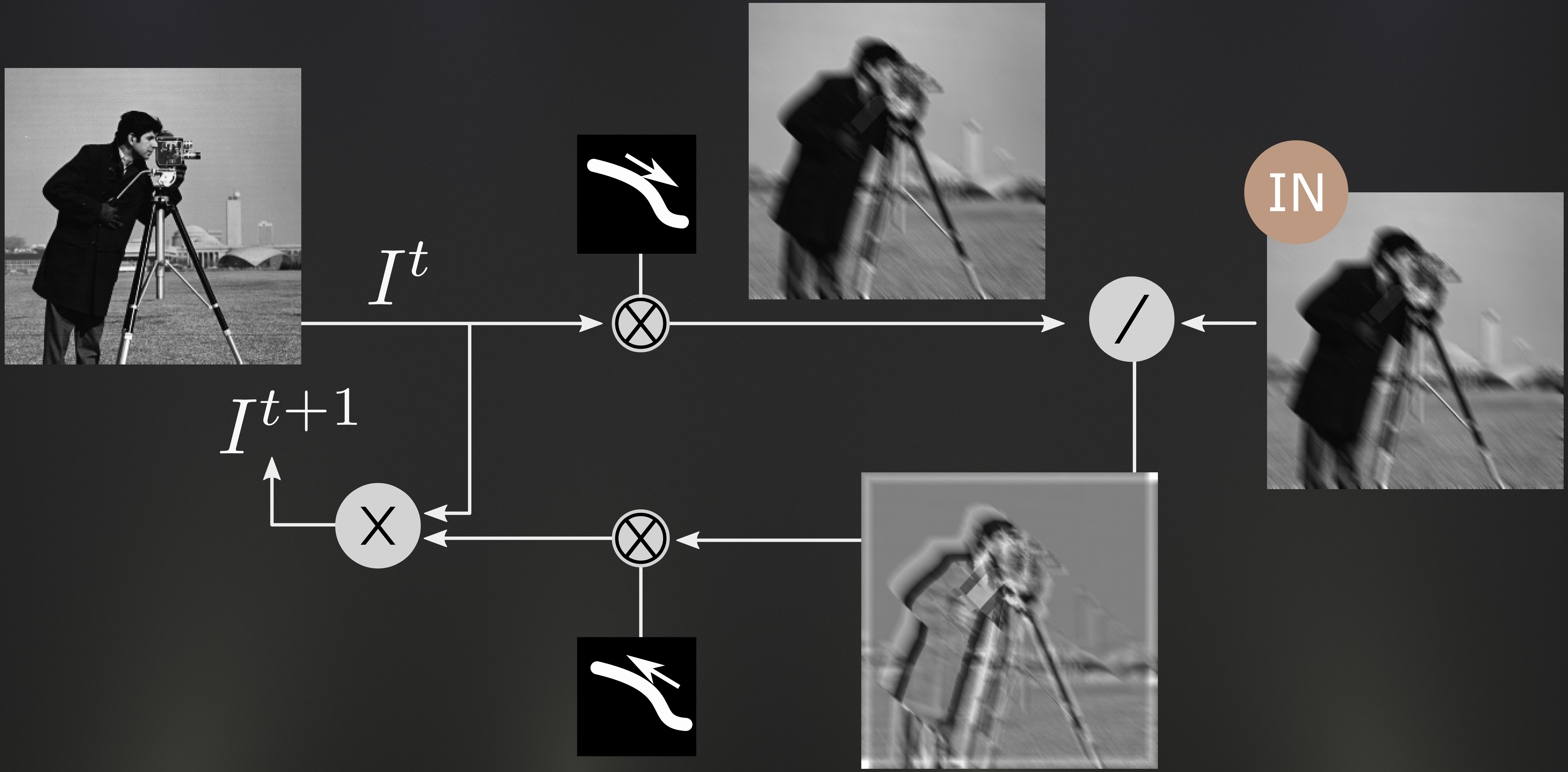
Related Work

"Richardson-Lucy Deblurring for Scenes under a Projective Motion Path"

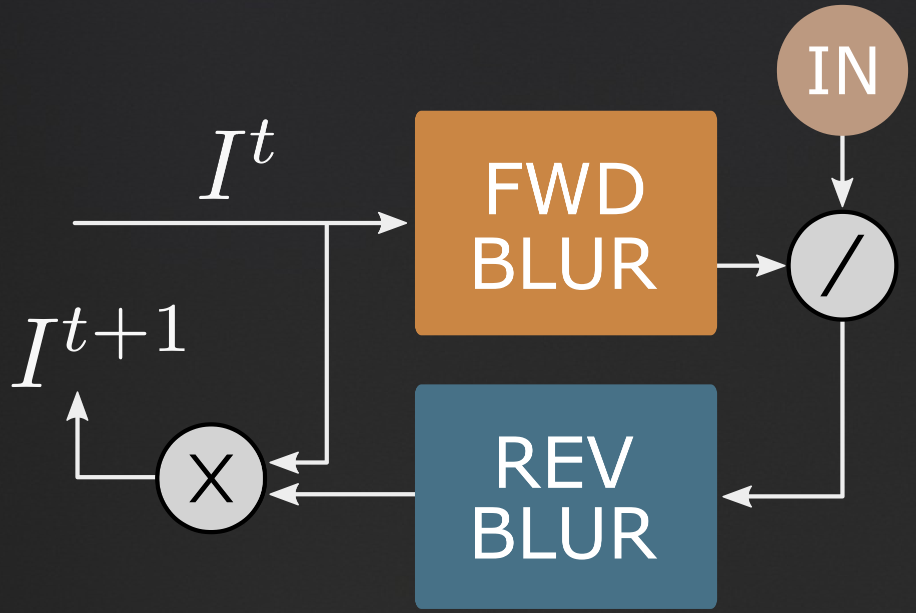
[Tai et al. 2011]



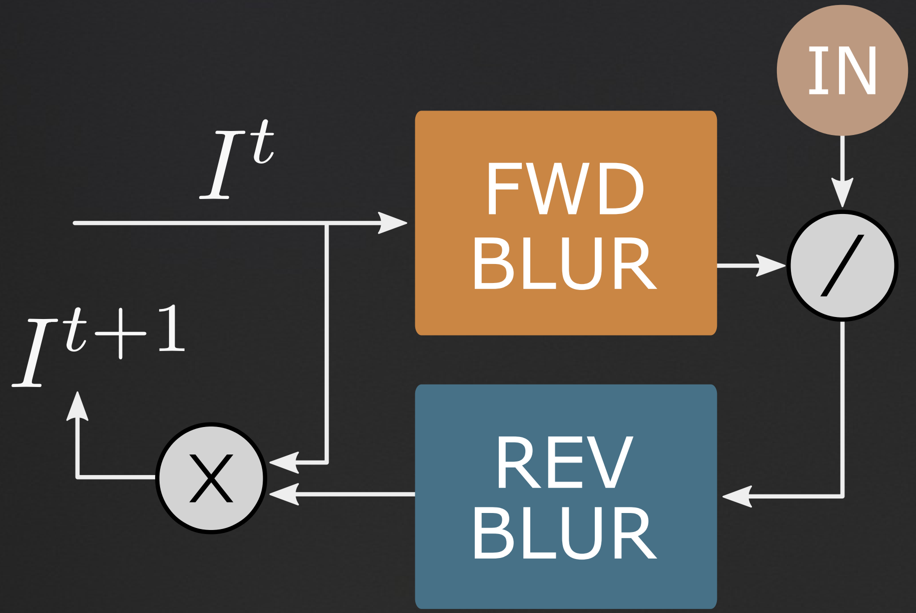
Richardson-Lucy Deblurring



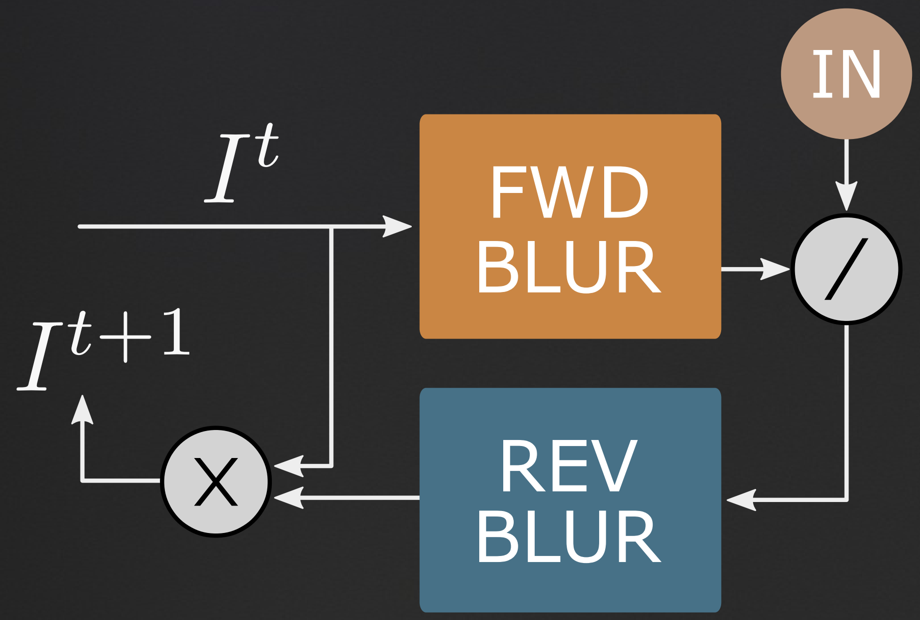
Light Field Richardson-Lucy



Light Field Richardson-Lucy



Light Field Richardson-Lucy



Regularization

Anisotropic total variation

Favour textural edges

[Goldluecke & Wanner 2013, Heber2013]

$$R_{tv}(\nabla L) = \int_{\Omega} \sqrt{\nabla L(\omega)^T D \nabla L(\omega) + \epsilon} \, d\omega,$$

Equiparallax

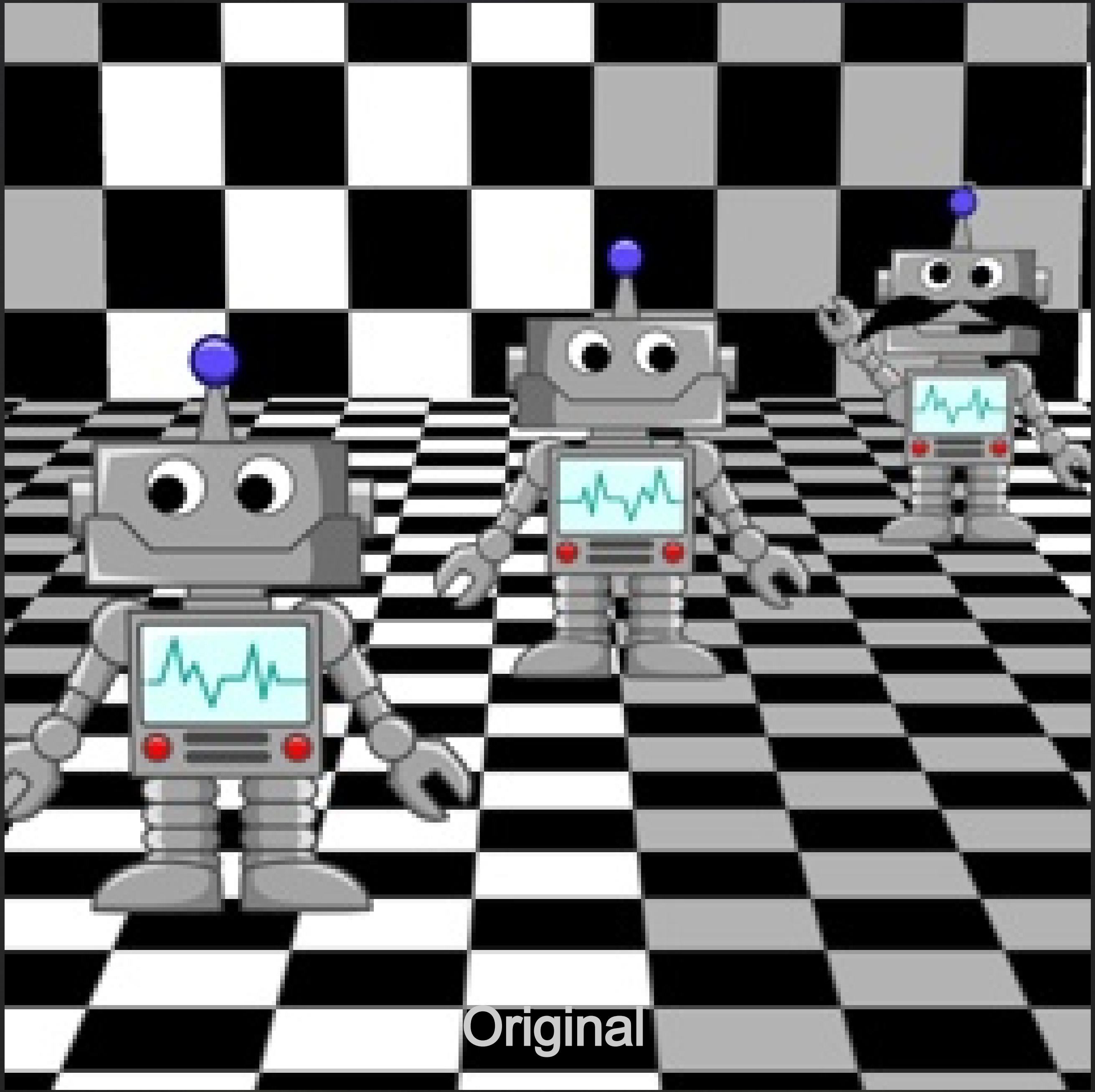
Favour equal slopes in s,u and t,v

$$\frac{\nabla_s L(w)}{\nabla_u L(w)} = \frac{\nabla_t L(w)}{\nabla_v L(w)},$$

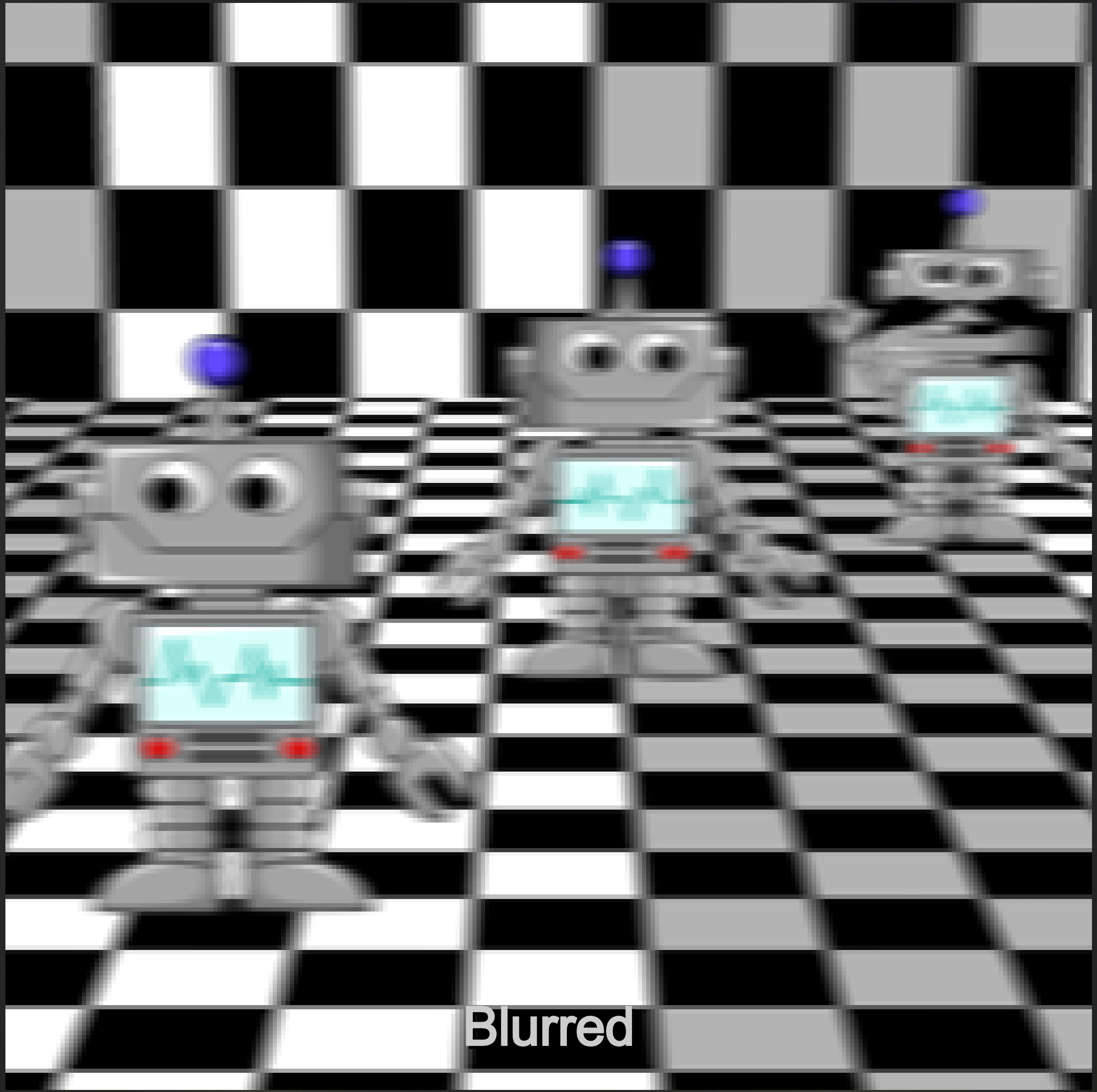
$$R_{ep}(\nabla L) = \int_{\Omega} \sqrt{g(\omega)^2 + \epsilon} \, d\omega,$$

$$g(\omega) = \nabla_s L(\omega) \nabla_v L(\omega) - \nabla_u L(\omega) \nabla_t L(\omega),$$

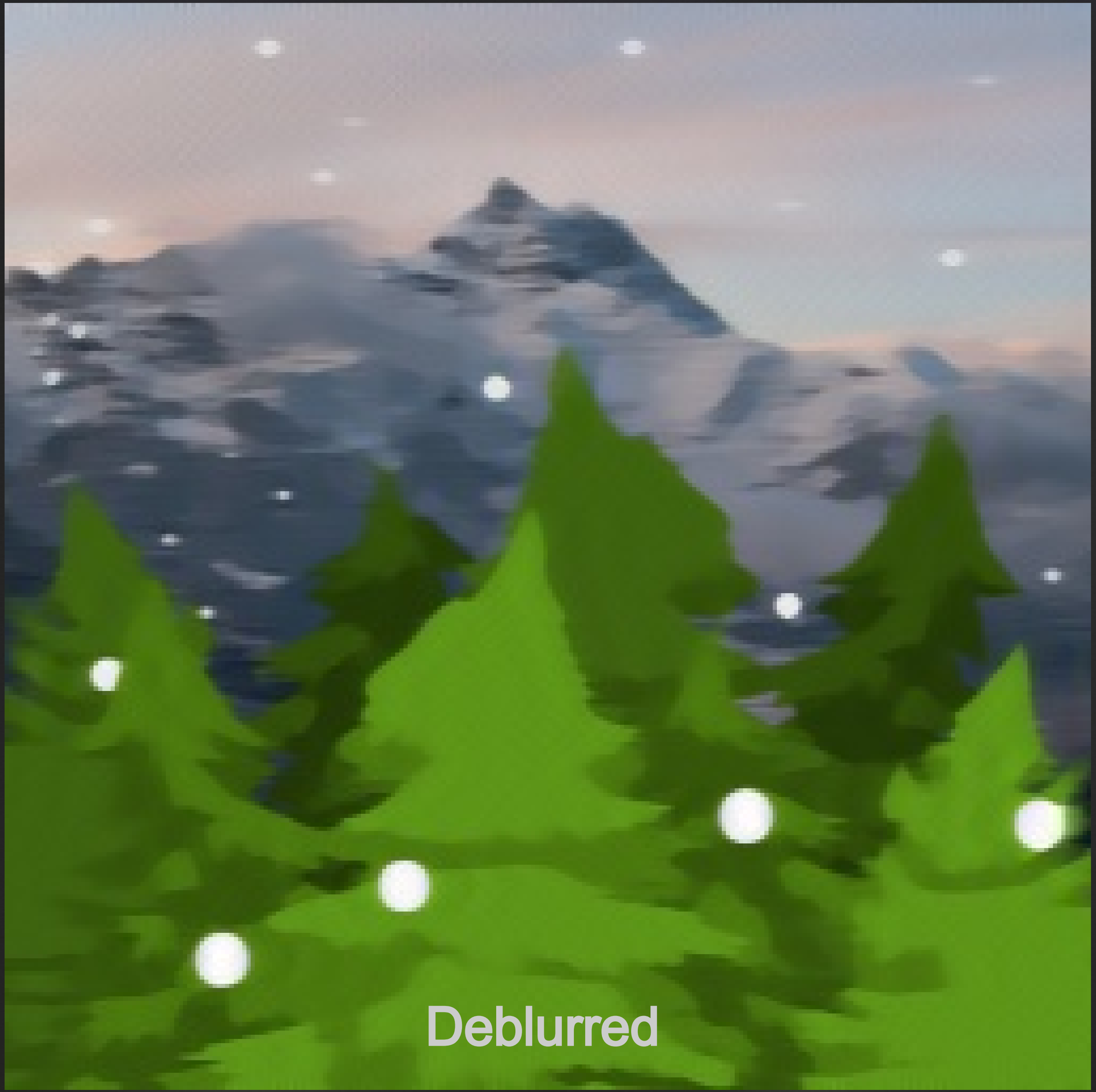
Rendered Results: Rot about *y*

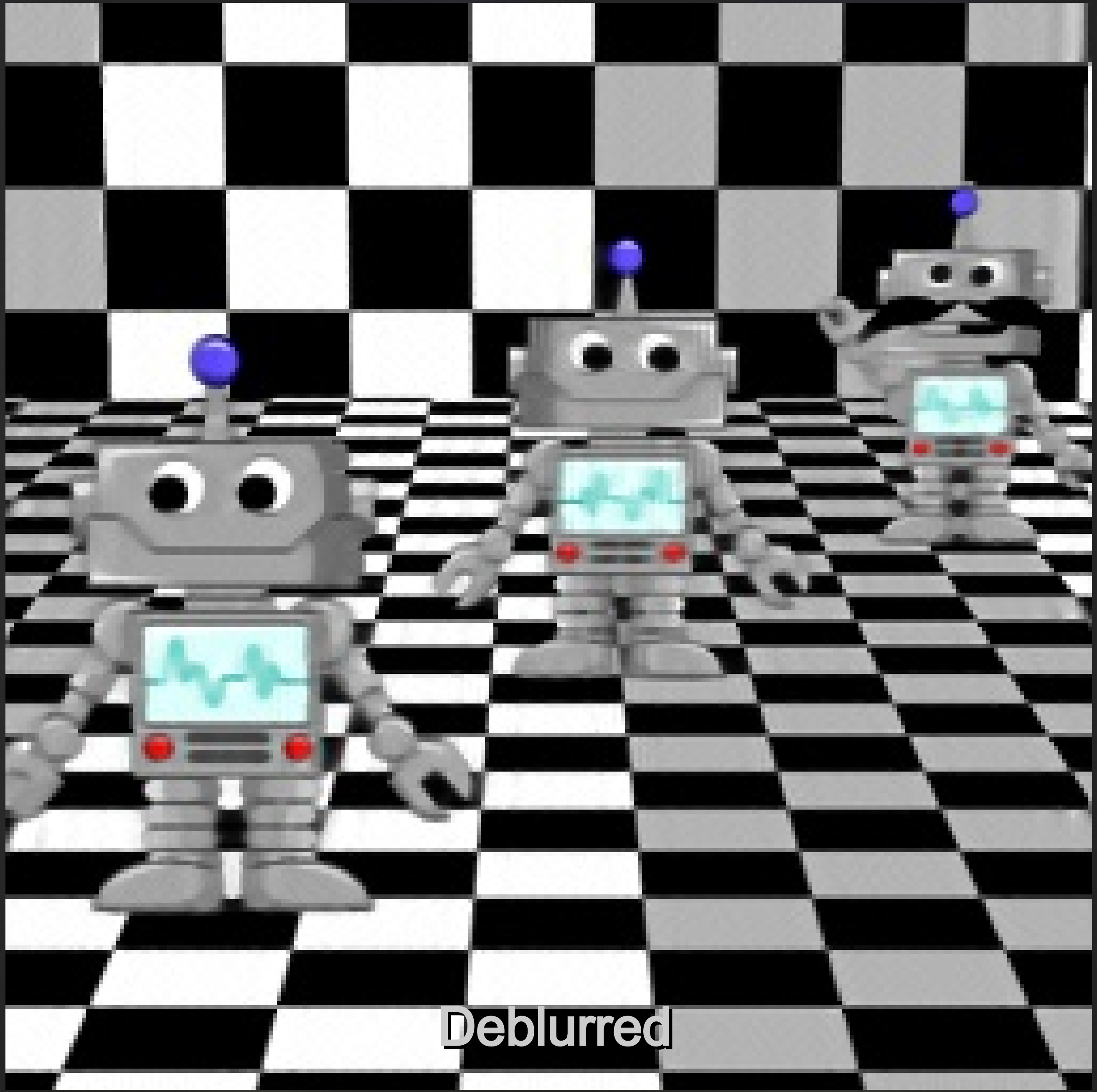


Rendered Results: Rot about y

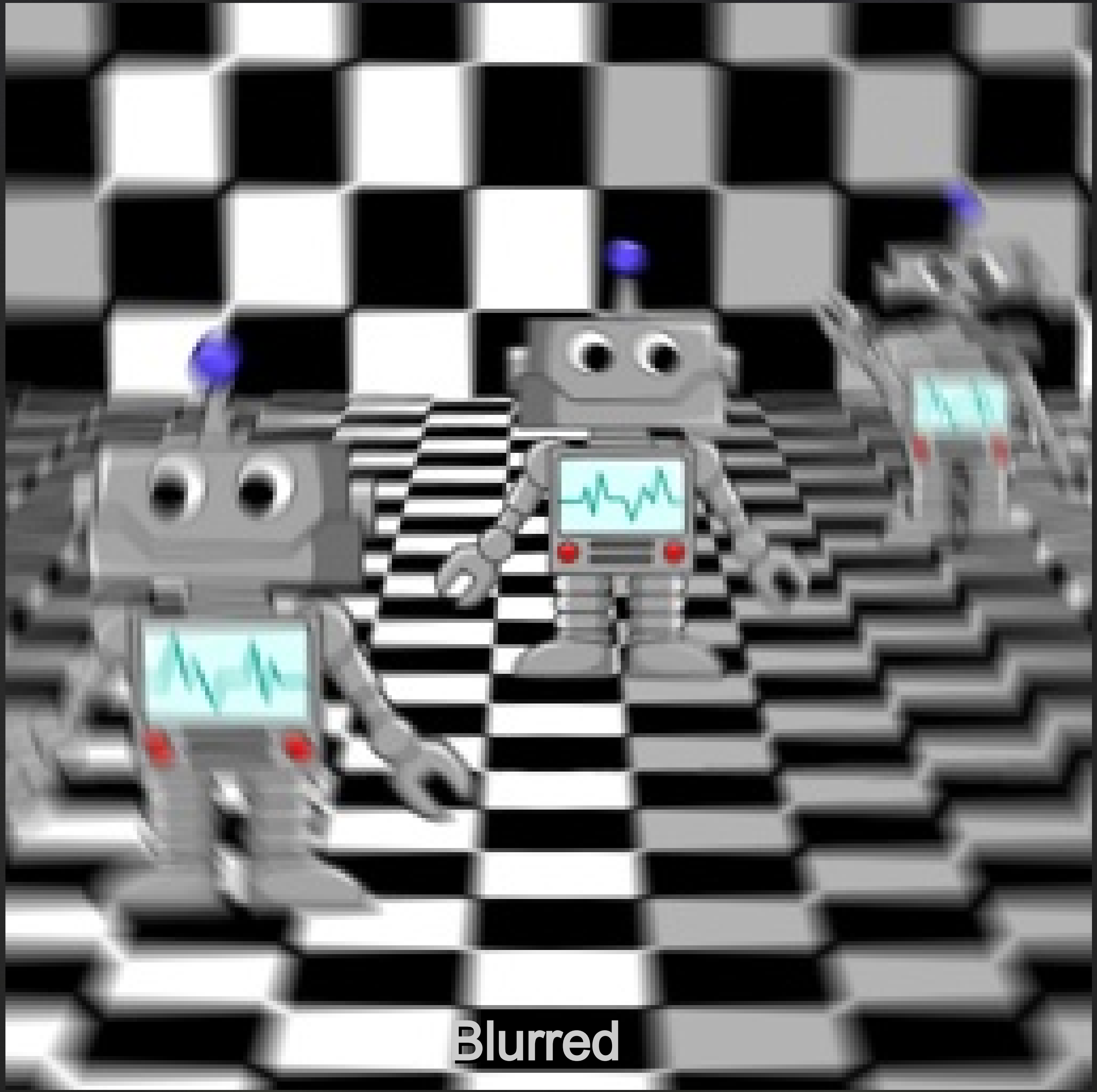


Rendered Results: Rot about y

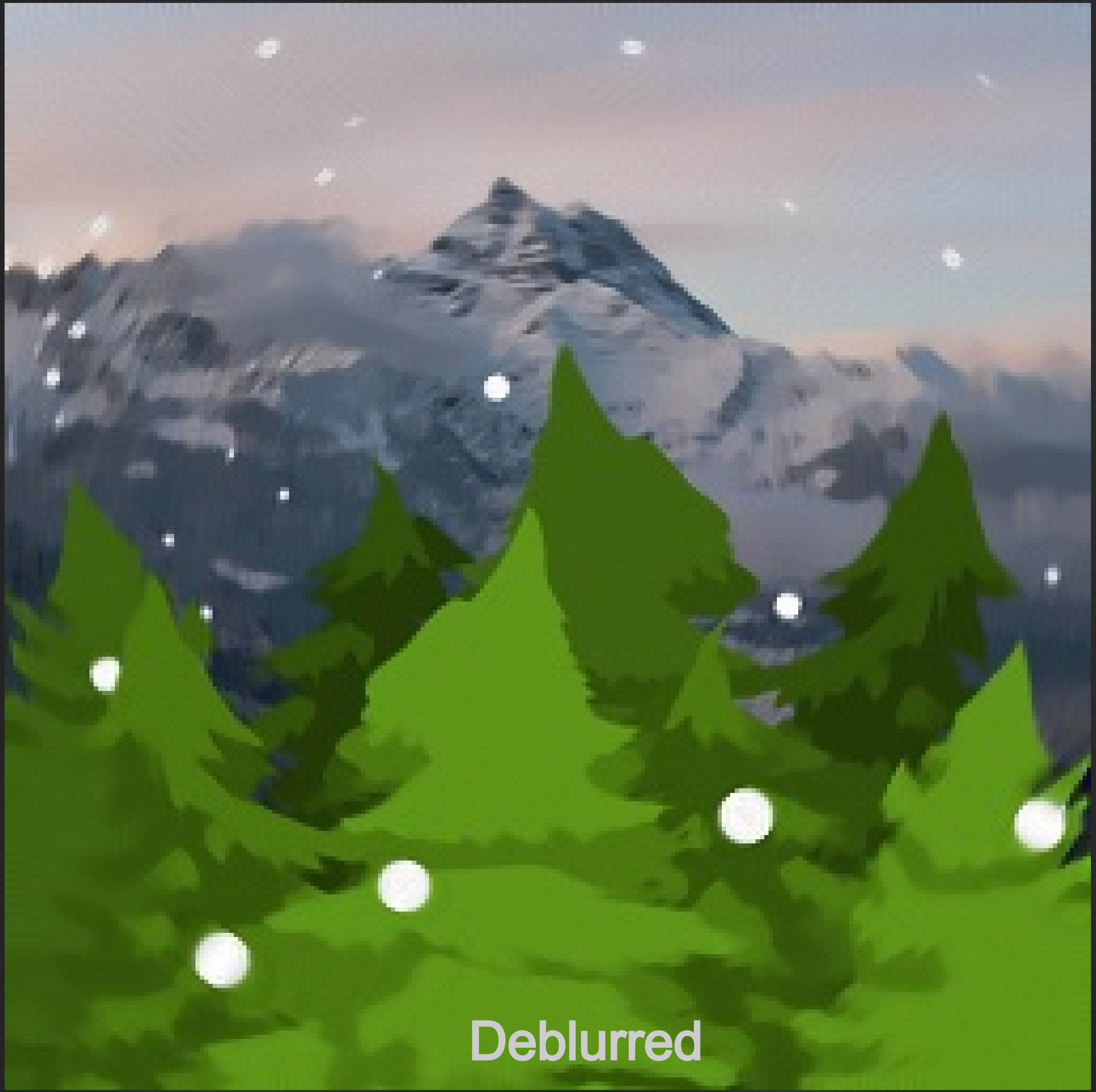


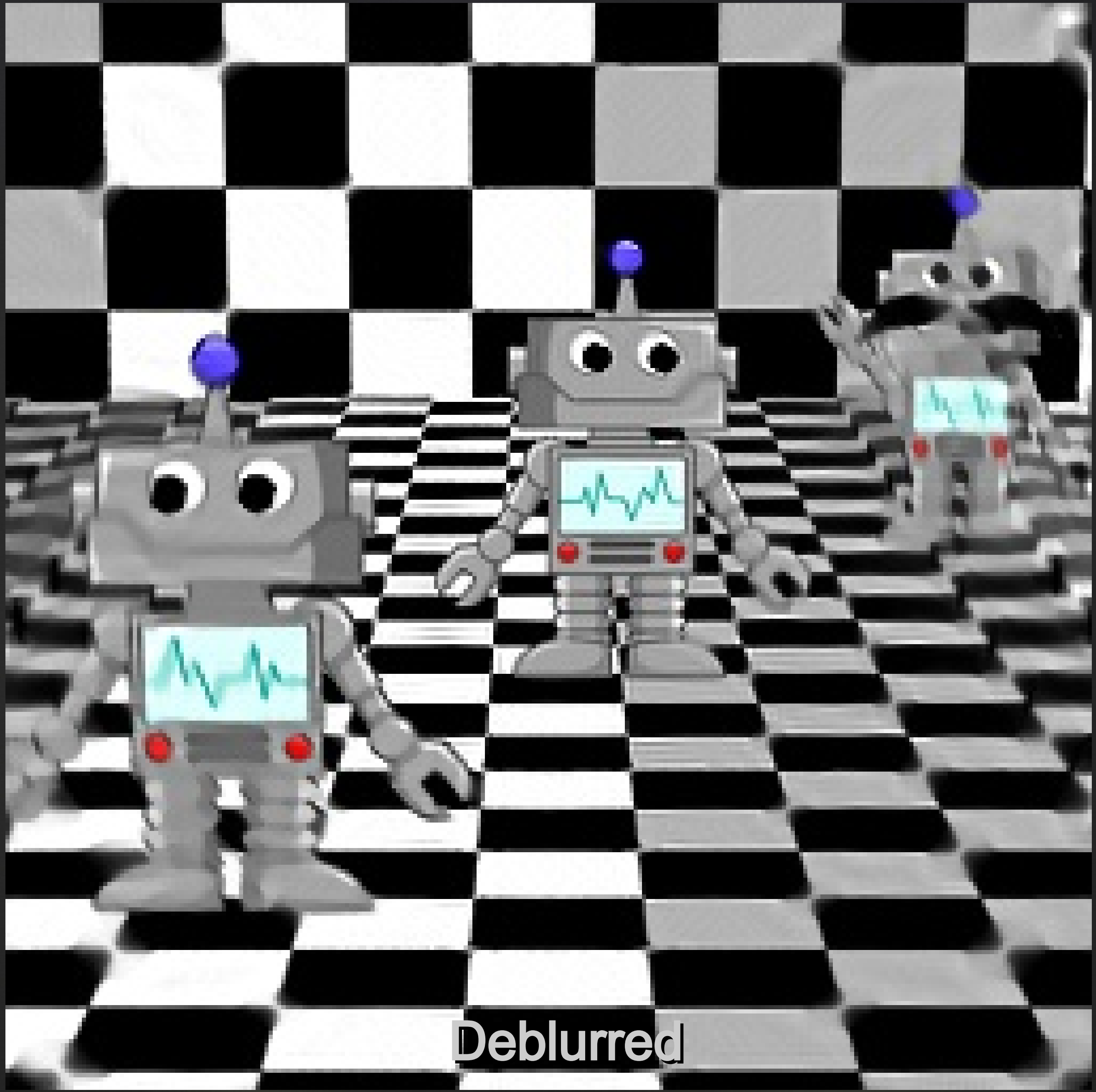


Rendered Results: Rot about z

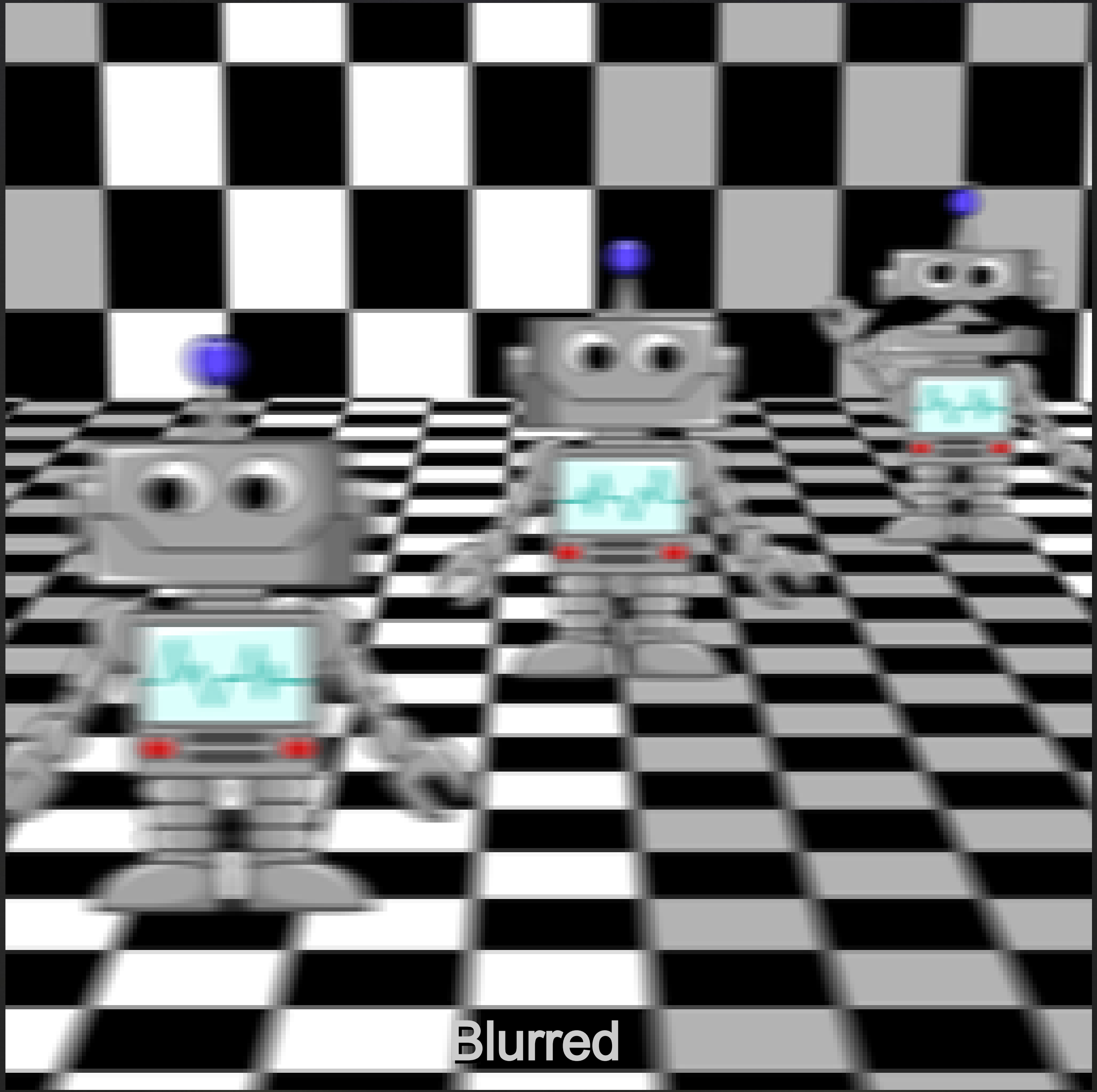


Rendered Results: Rot about z

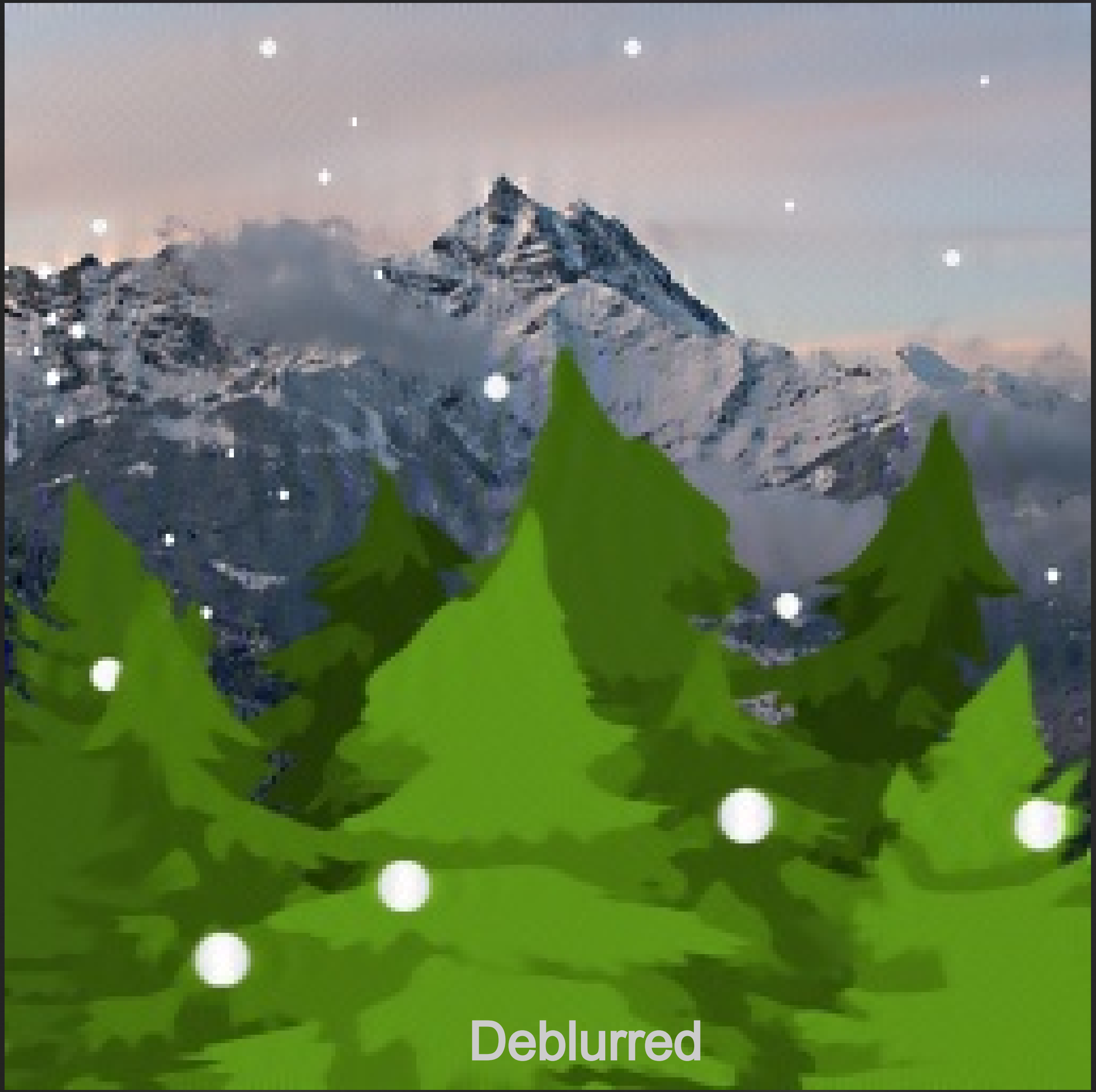


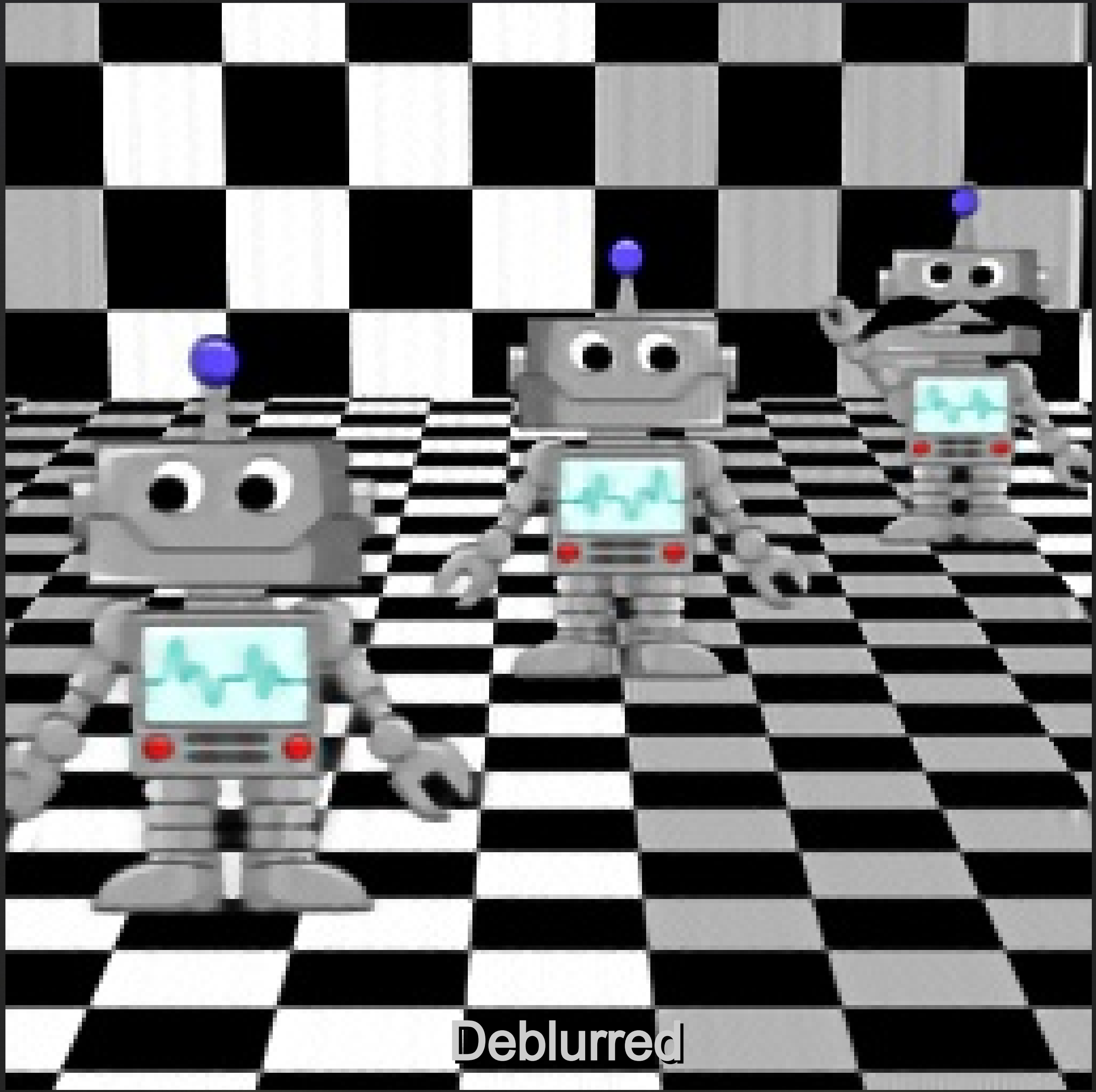


Rendered Results: Trans along x

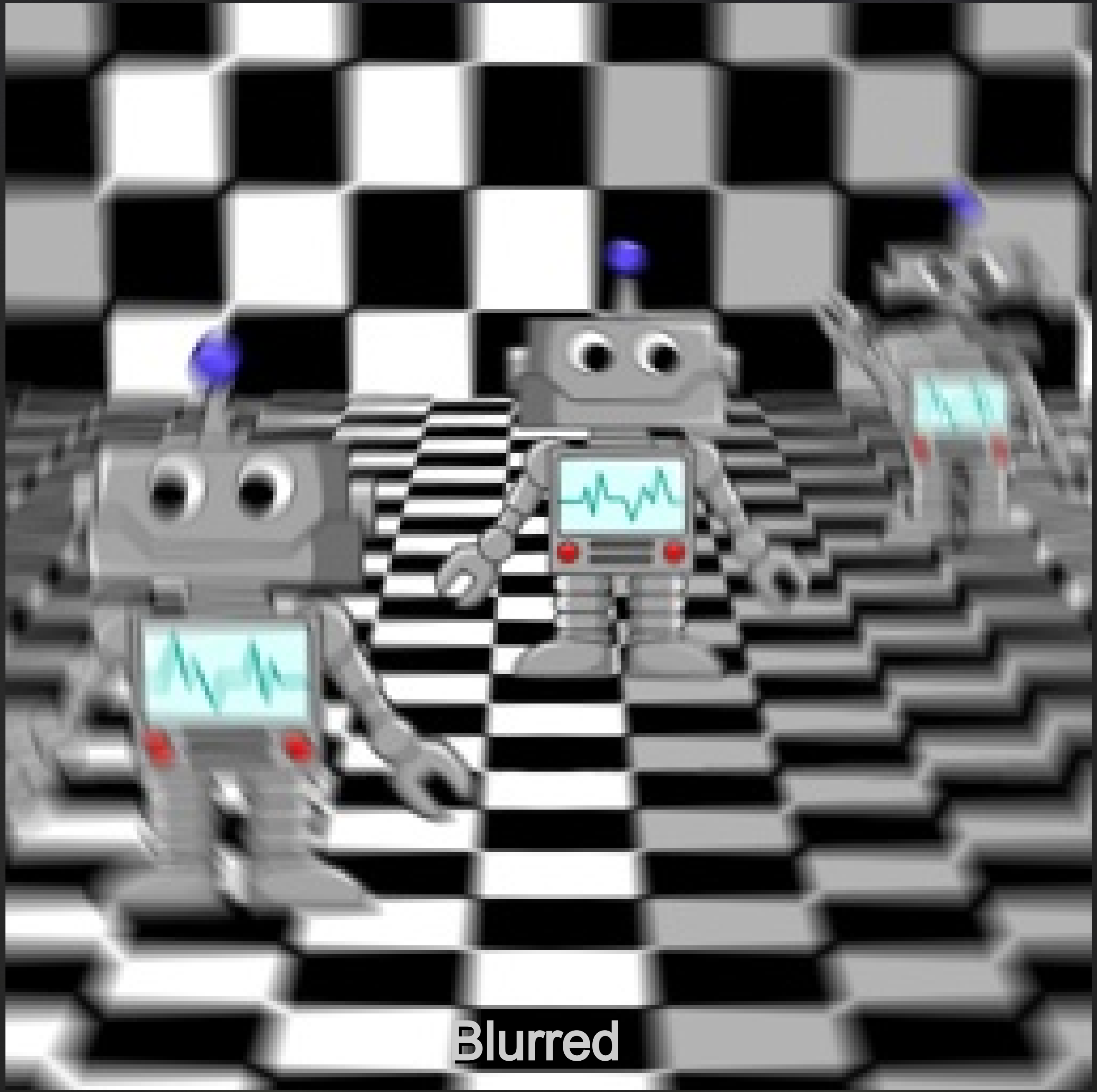


Rendered Results: Trans along x

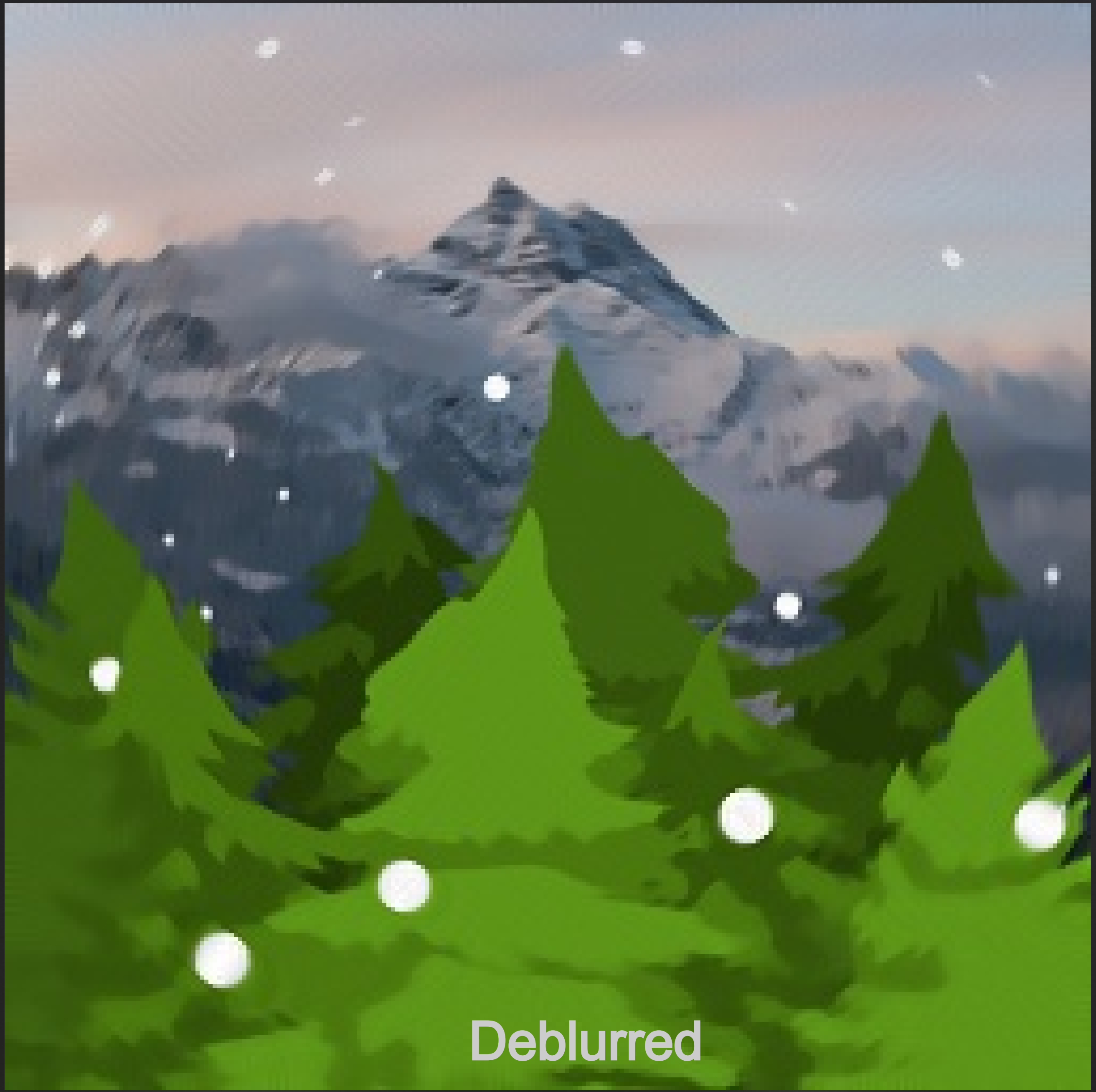


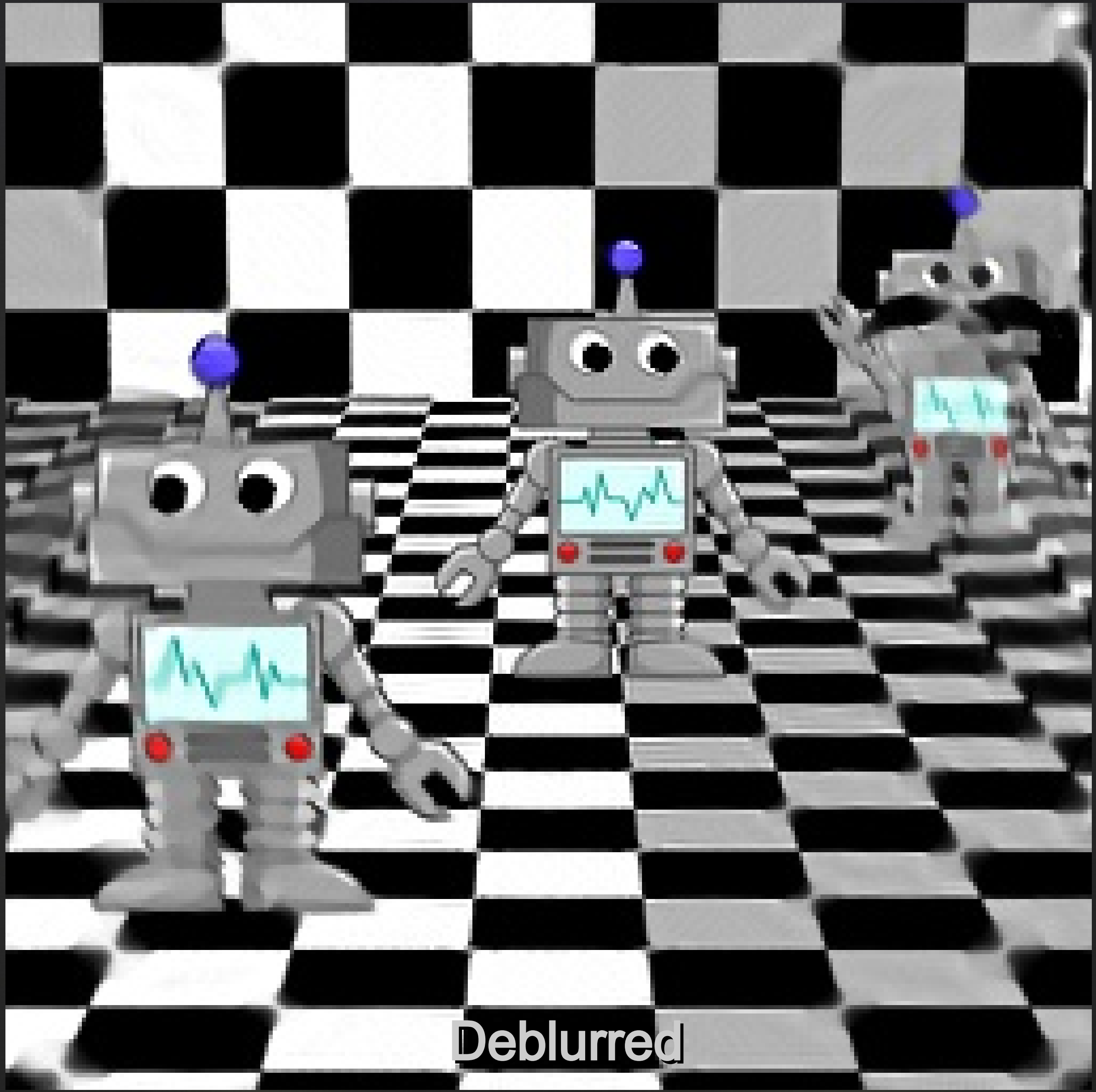


Rendered Results: Rot about z

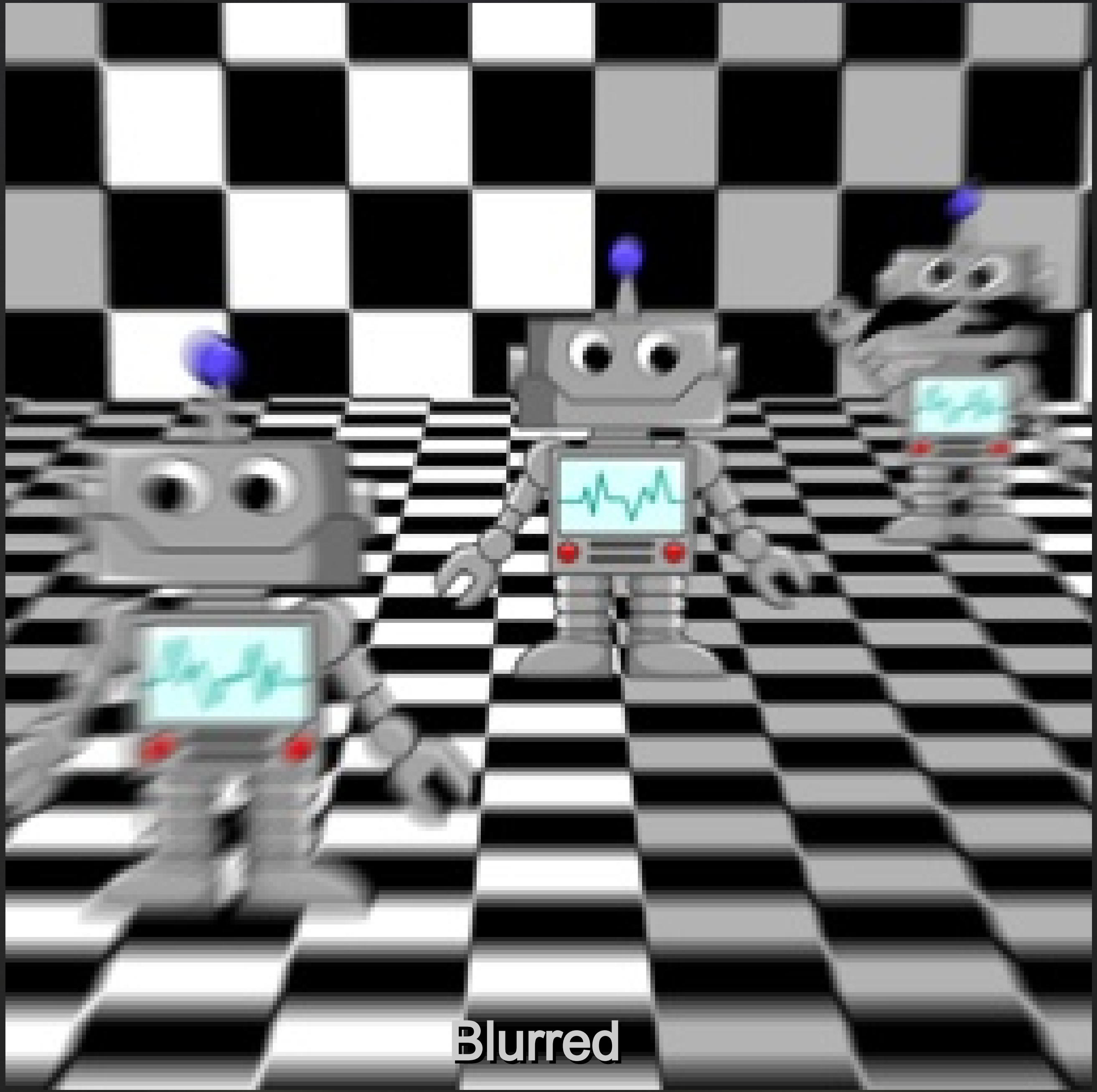


Rendered Results: Rot about z

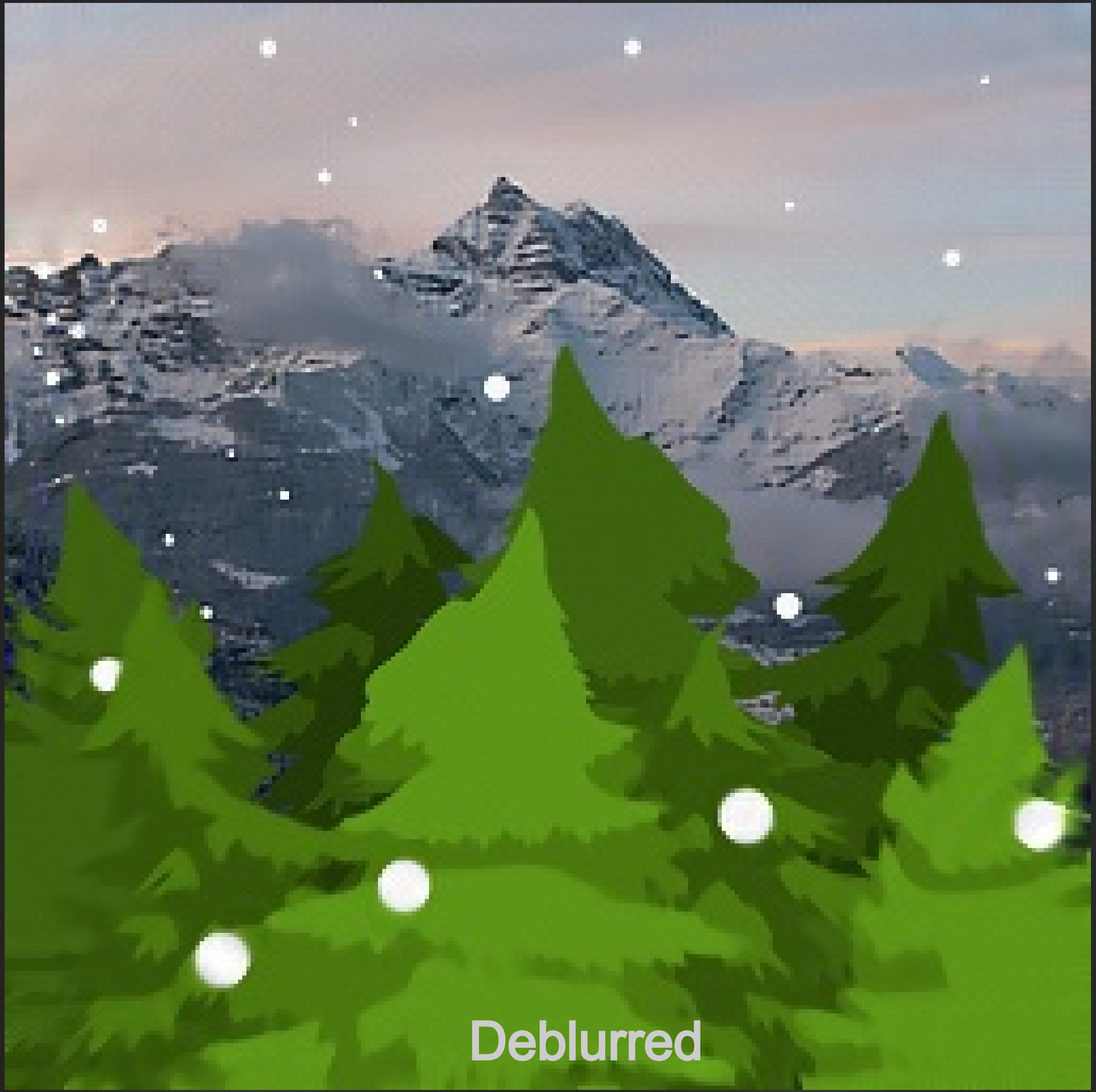


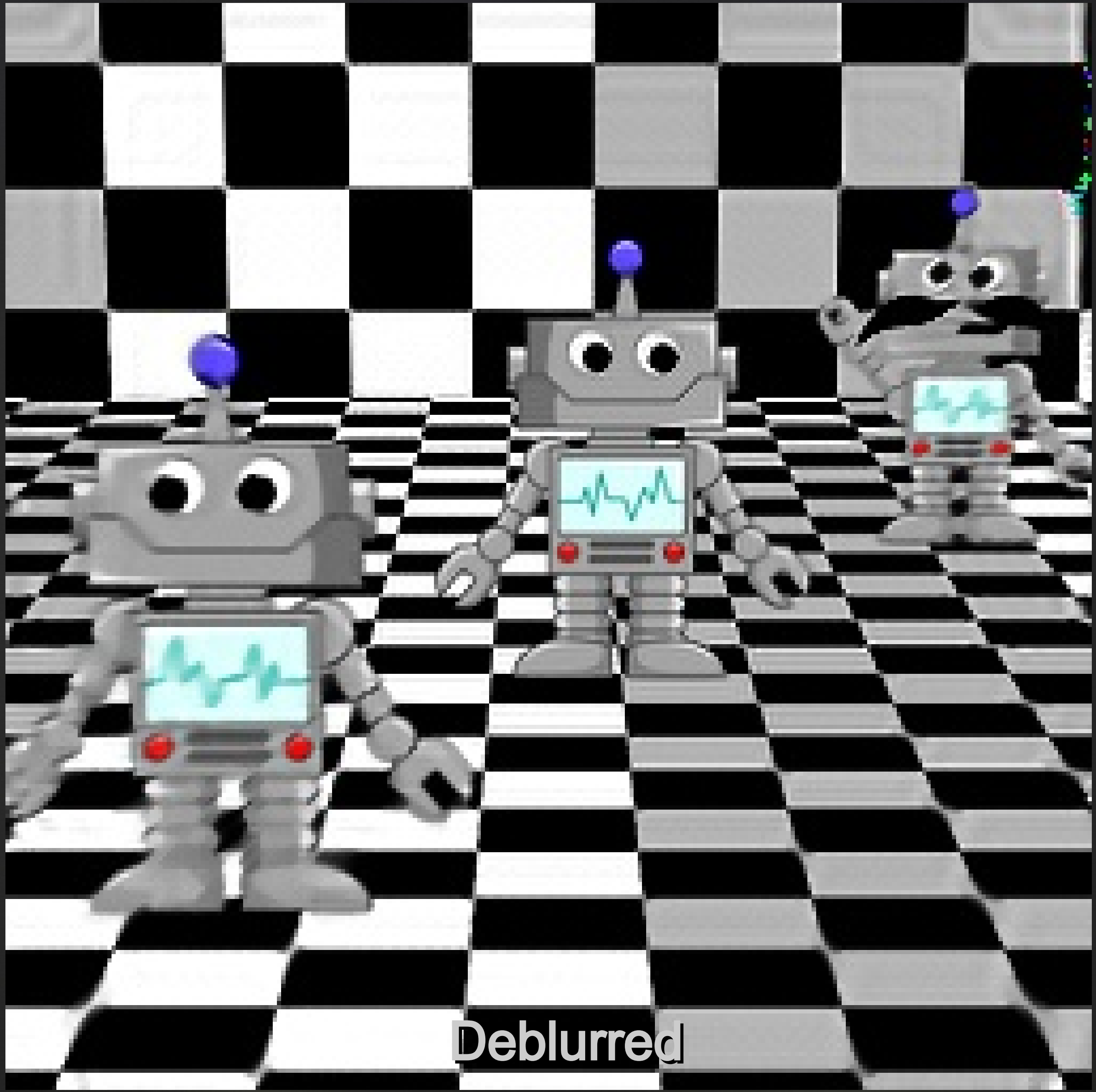


Rendered Results: Trans along z

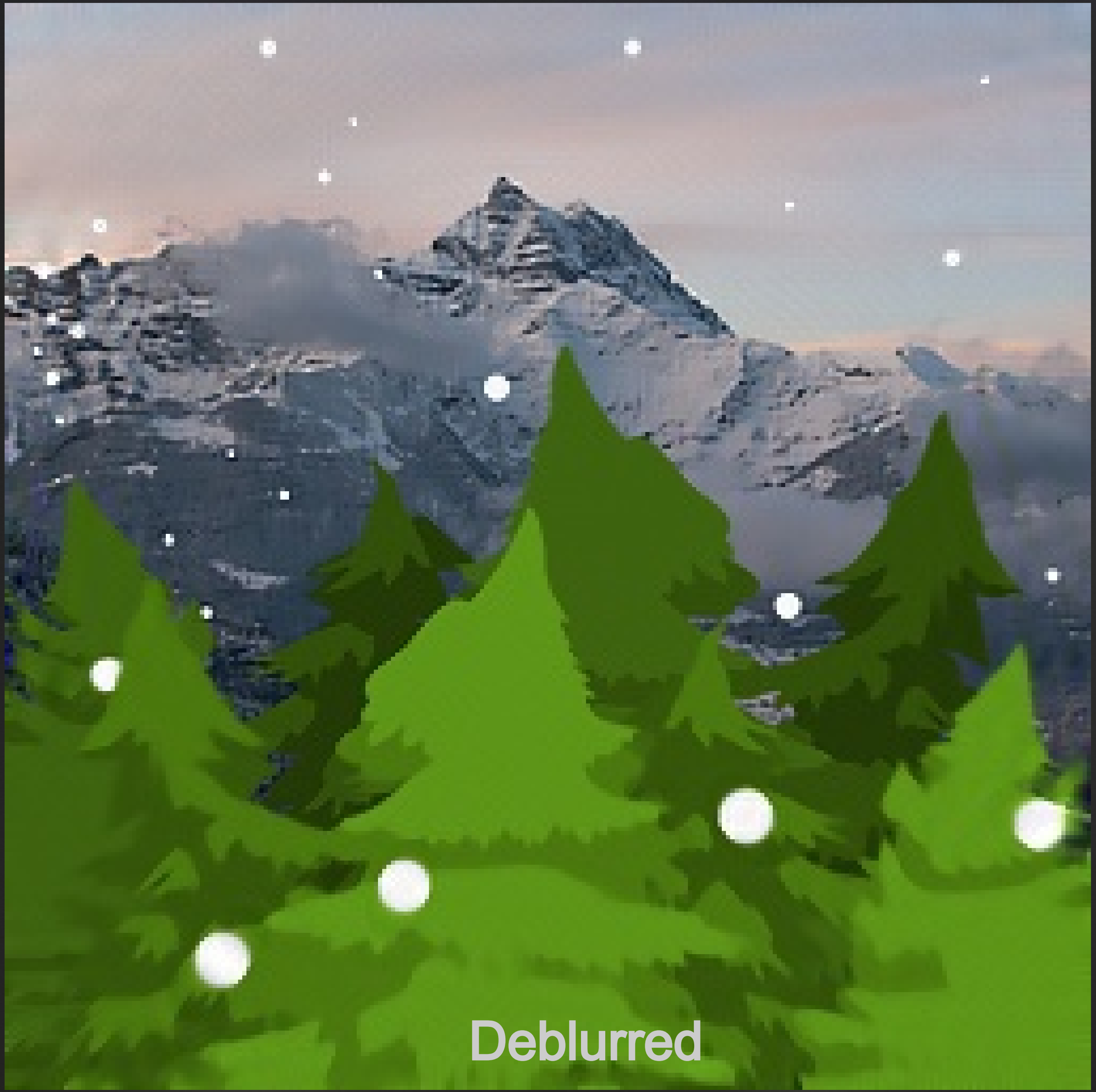


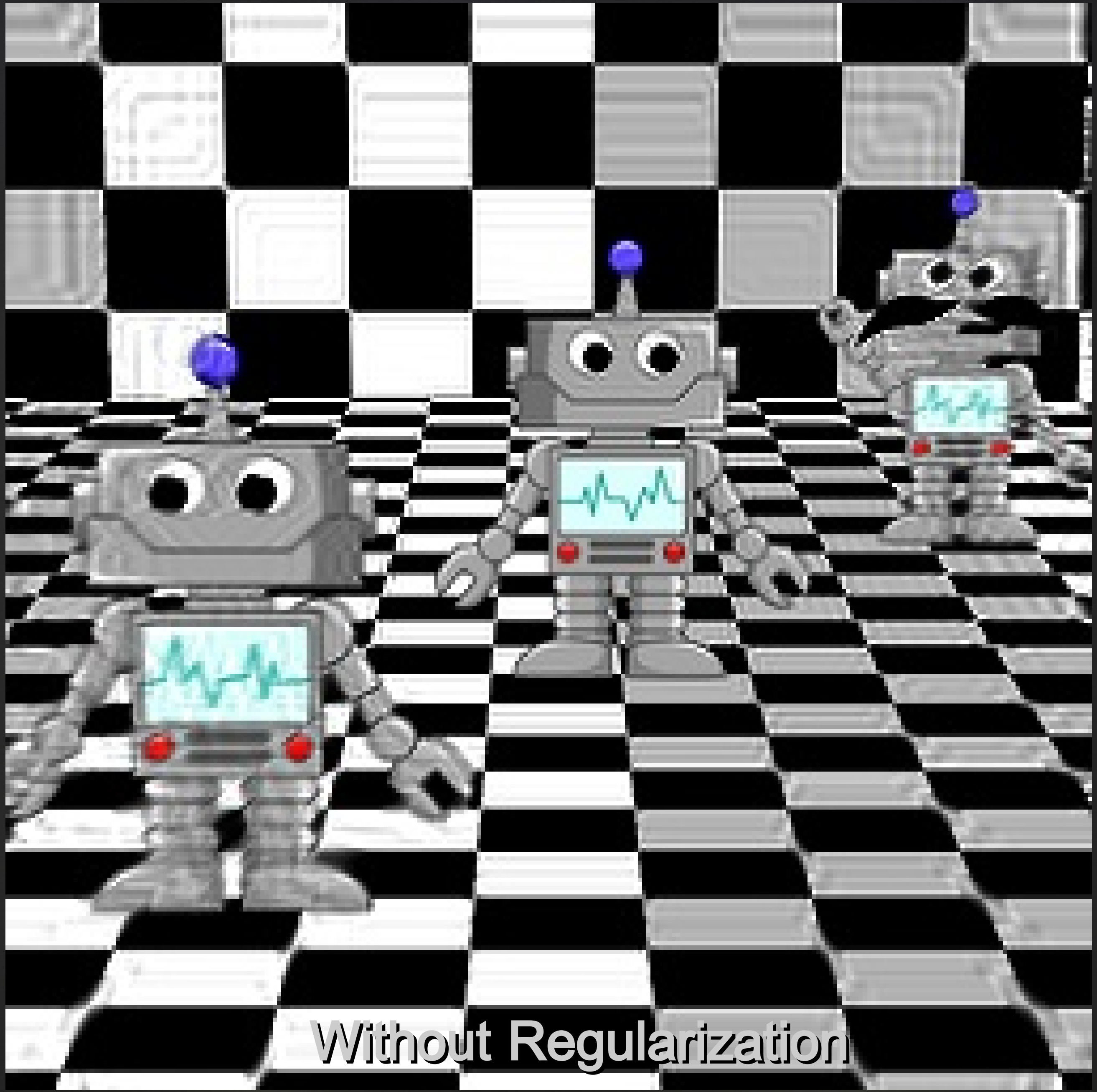
Rendered Results: Trans along z





Rendered Results: Trans along z





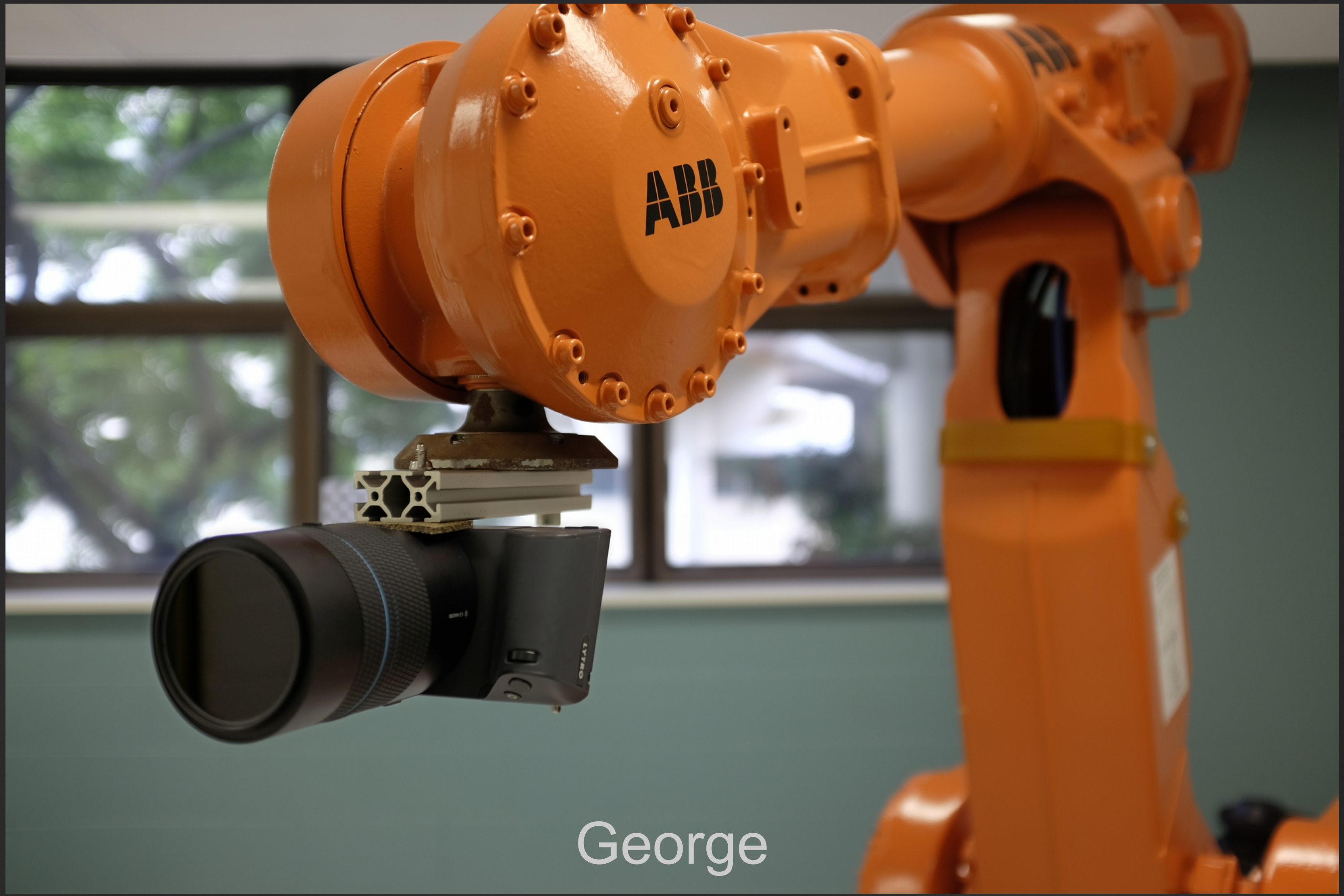
Results: Captured

Quantitative Evaluation

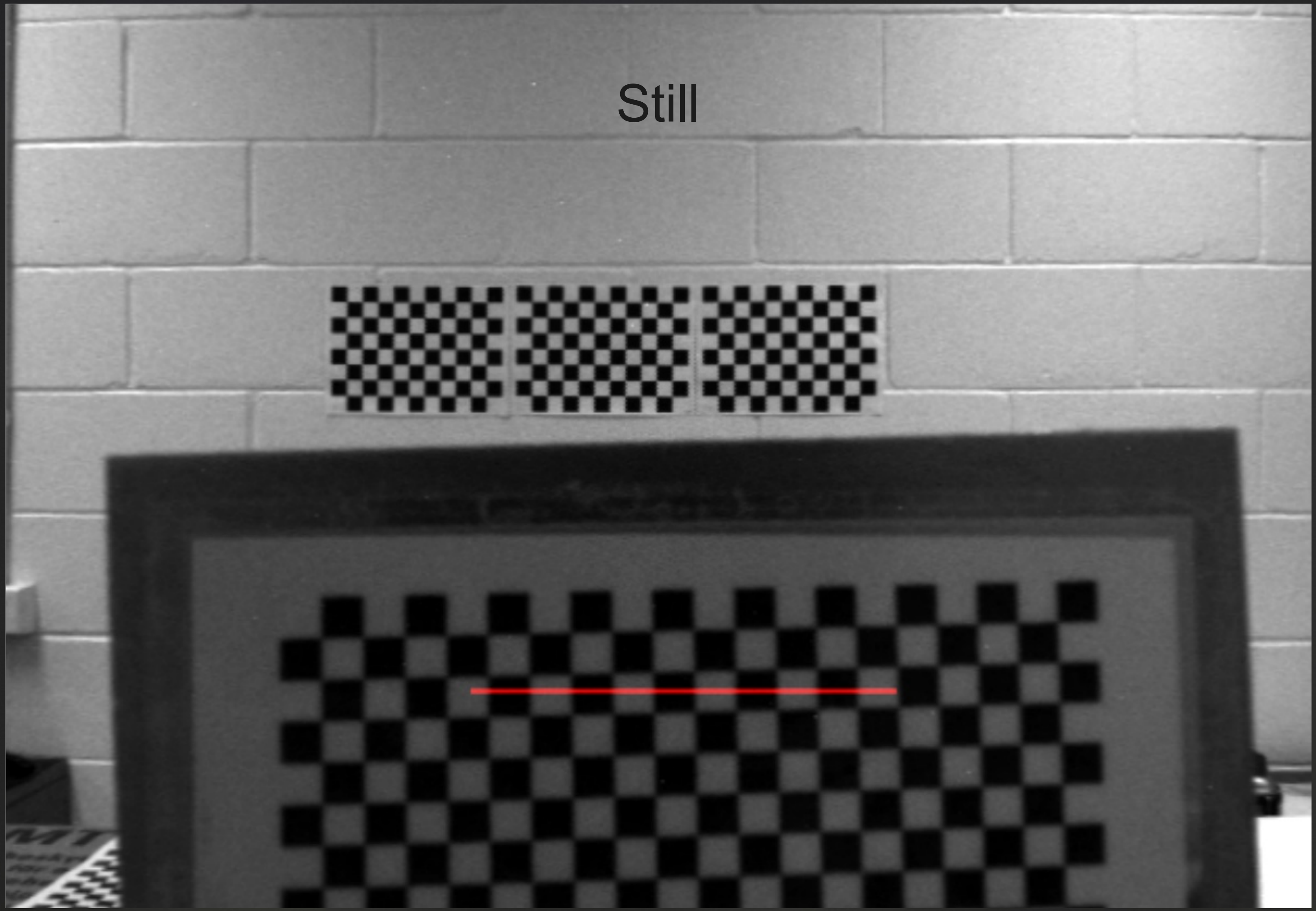
Repeatable camera motion

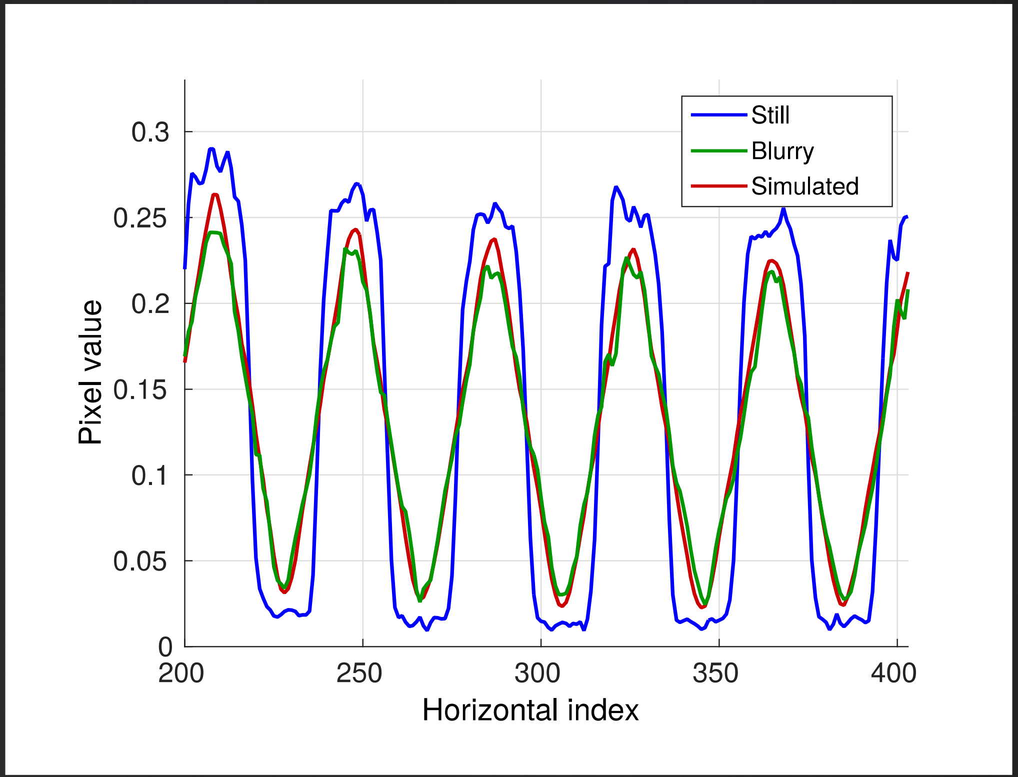
Isolated dimensions

Known magnitudes



Validating Calibration & Rendering





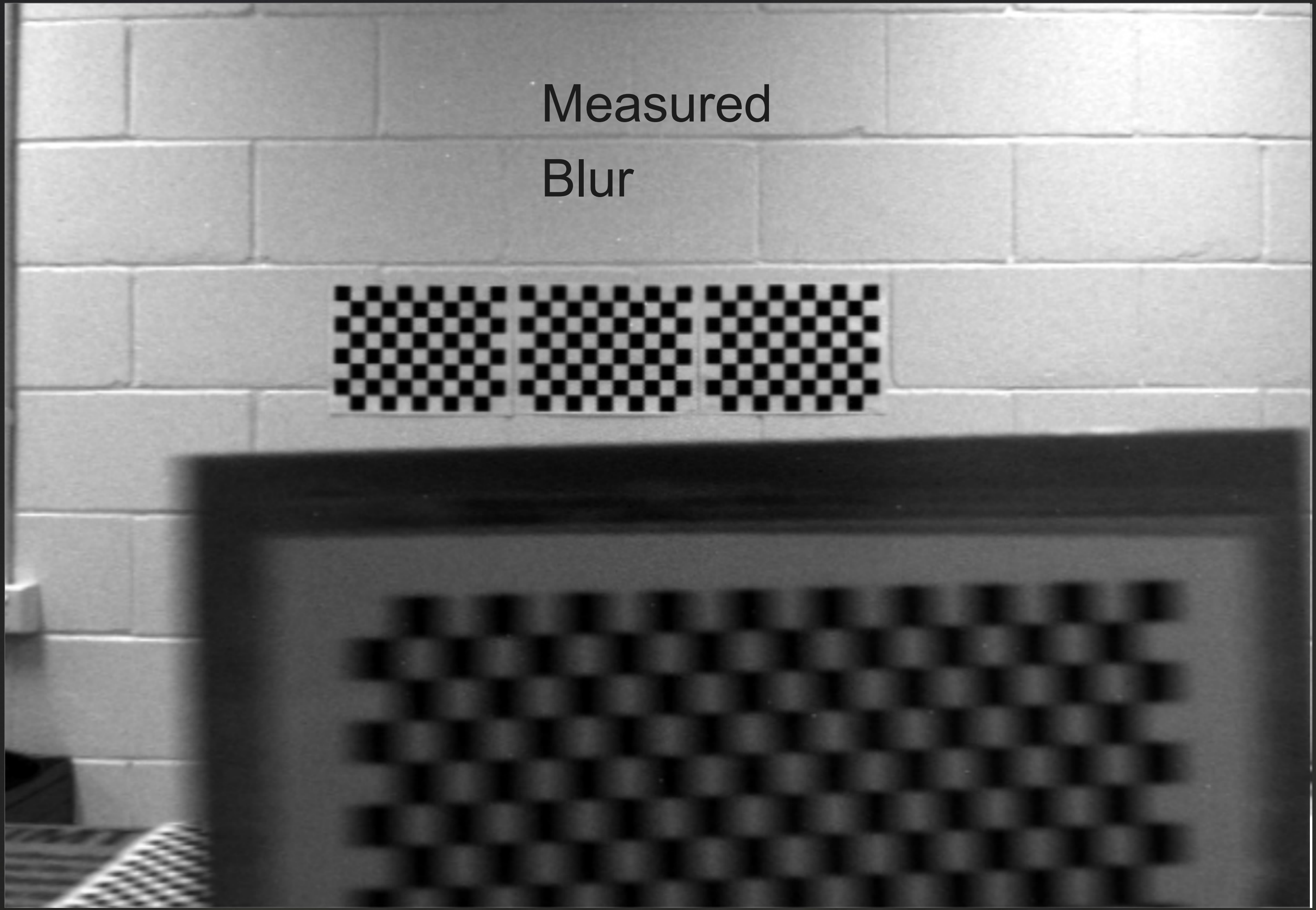
Camera calibration, rectification

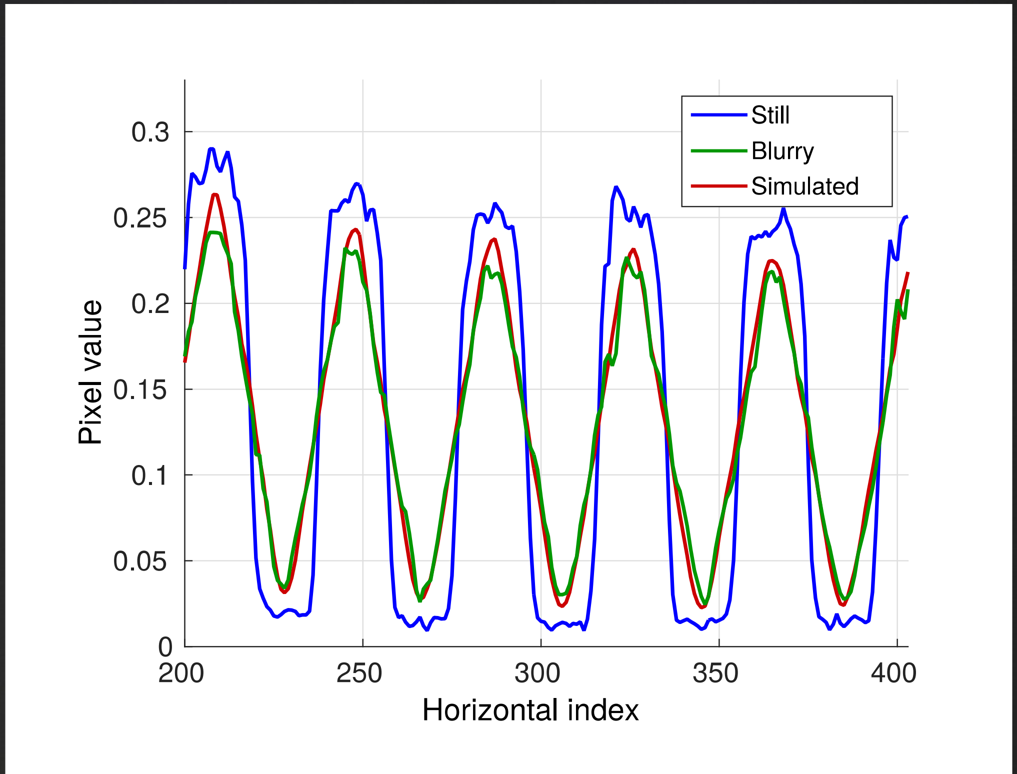
Metric blur simulation

Metric robot motion

Camera-to-robot calibration

Validating Calibration & Rendering





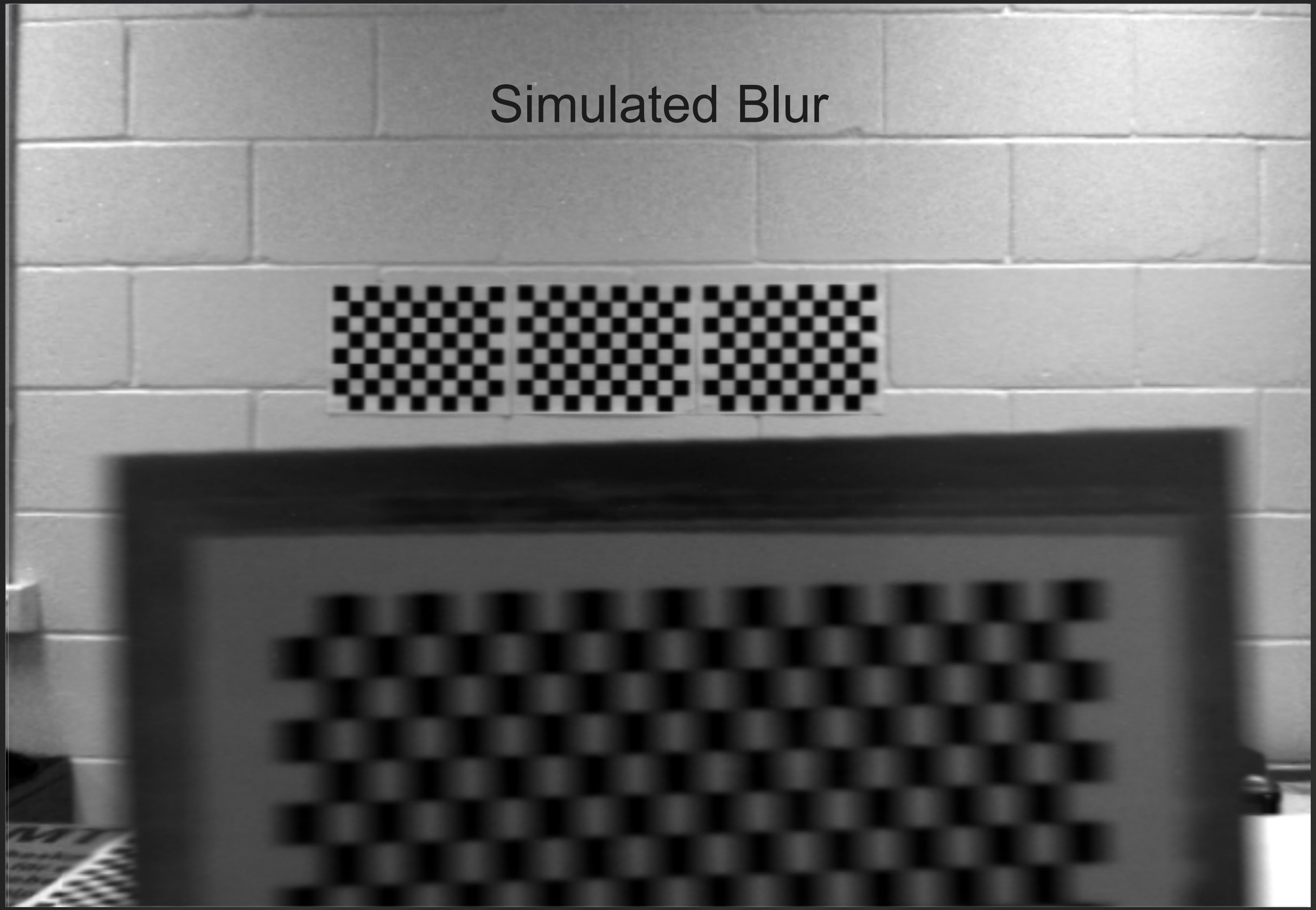
Camera calibration, rectification

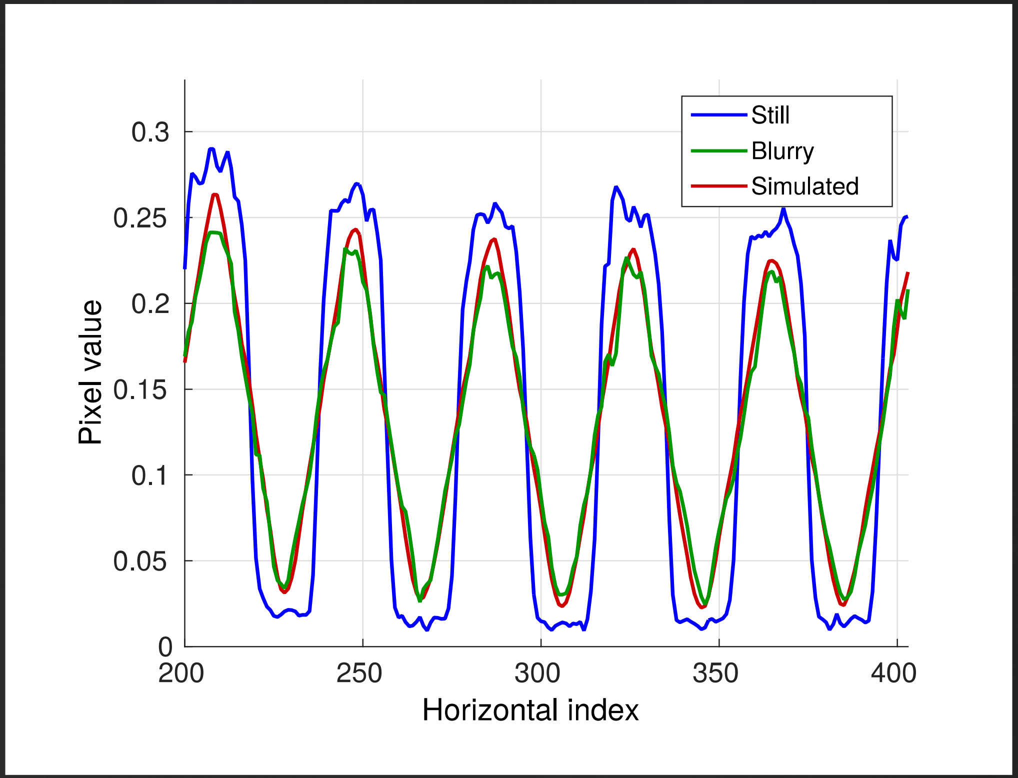
Metric blur simulation

Metric robot motion

Camera-to-robot calibration

Validating Calibration & Rendering





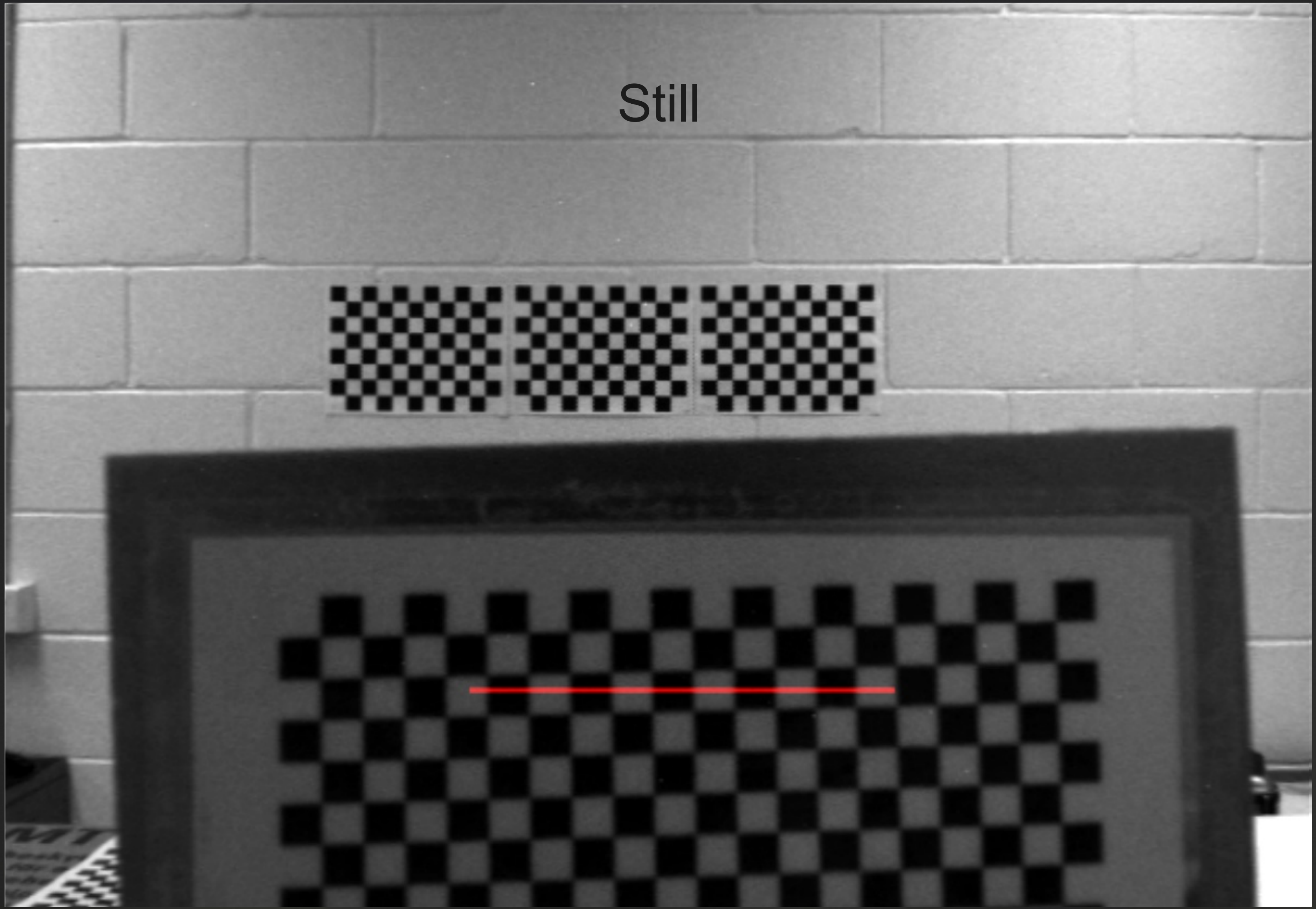
Camera calibration, rectification

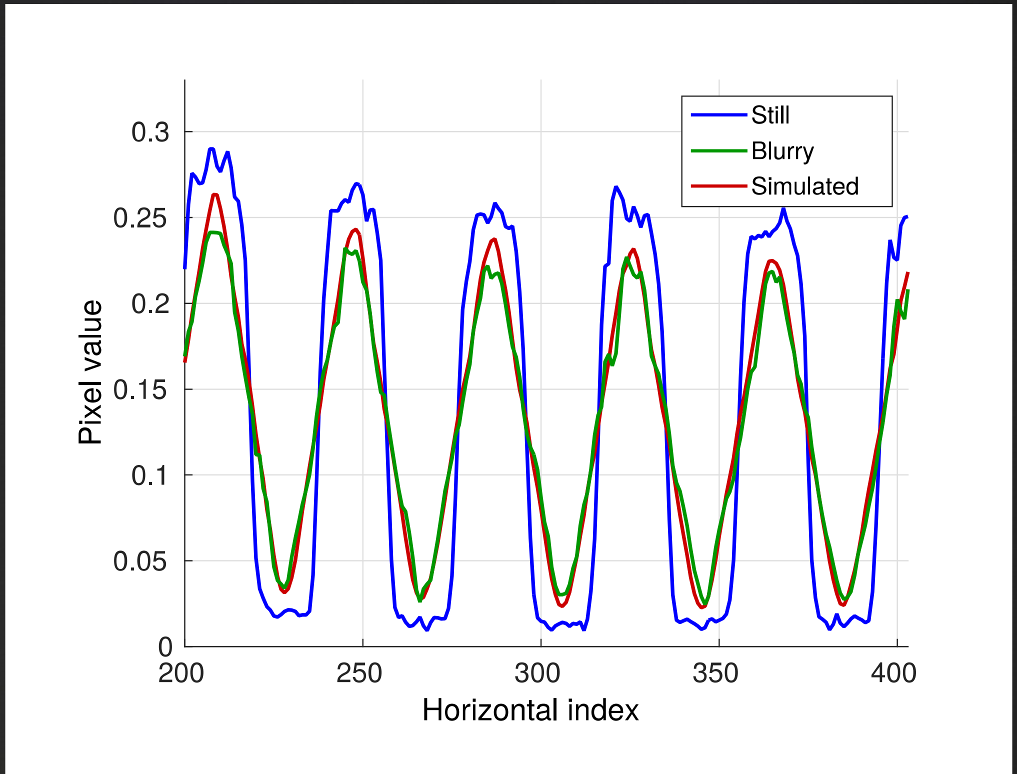
Metric blur simulation

Metric robot motion

Camera-to-robot calibration

Validating Calibration & Rendering





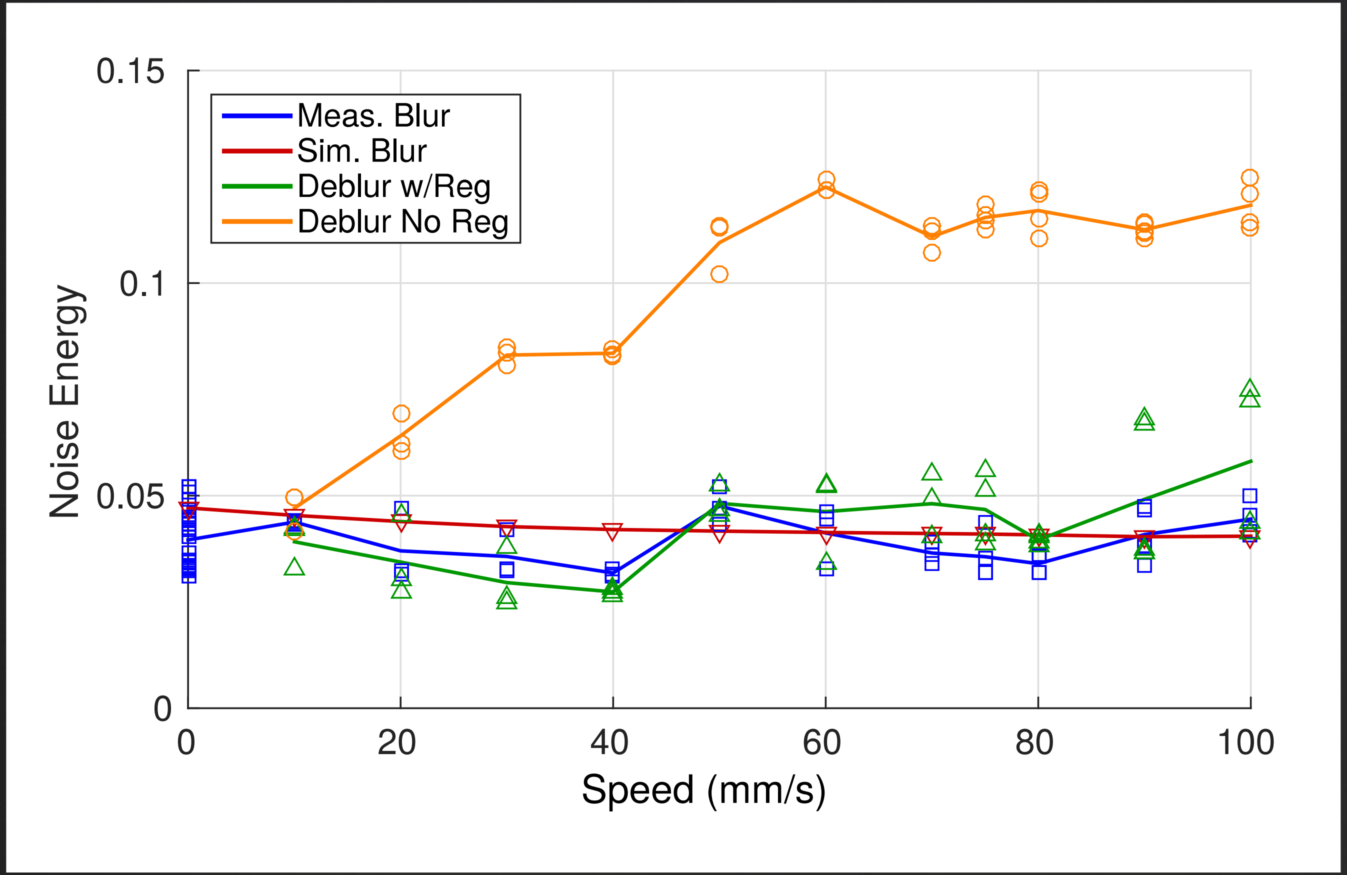
Camera calibration, rectification

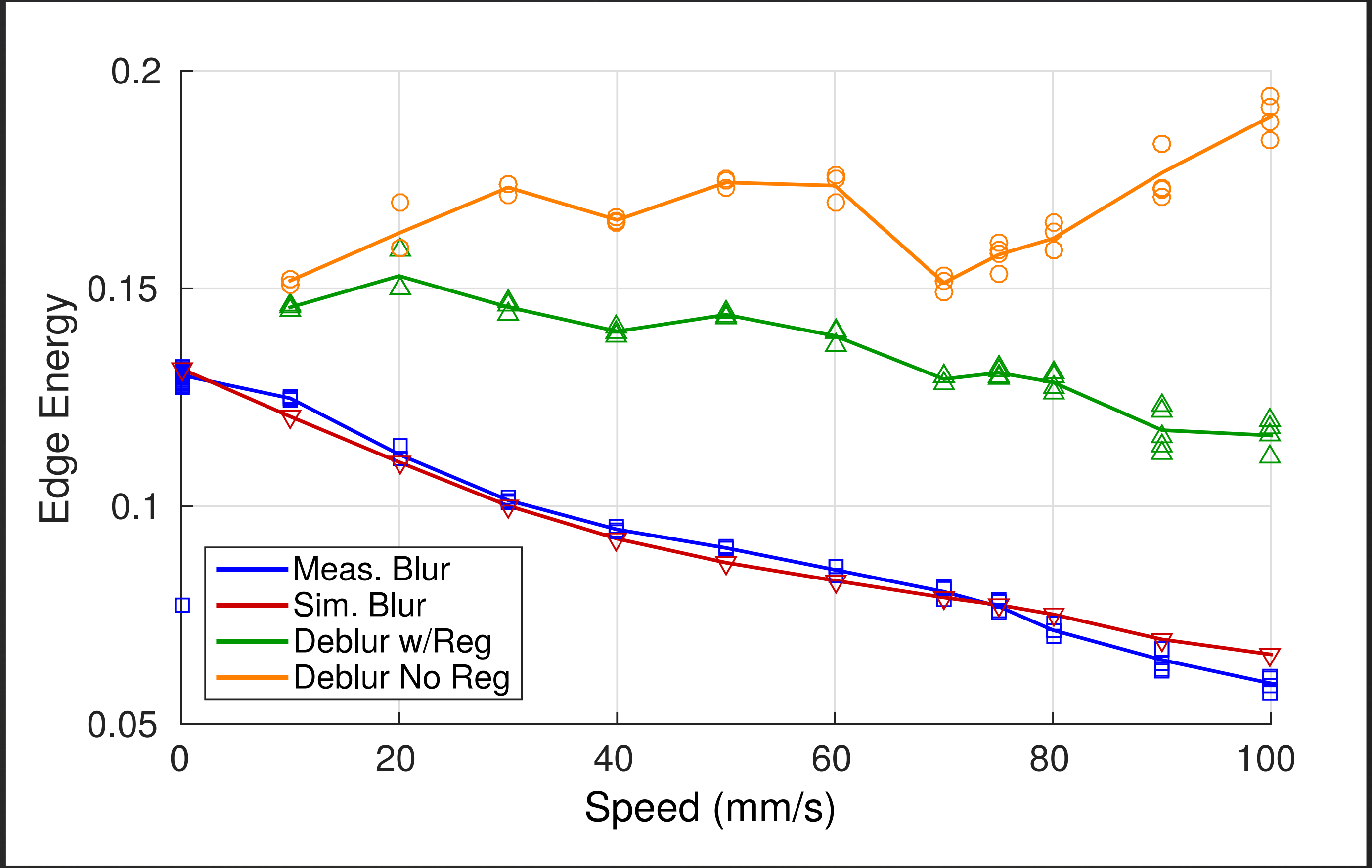
Metric blur simulation

Metric robot motion

Camera-to-robot calibration

Results: Captured



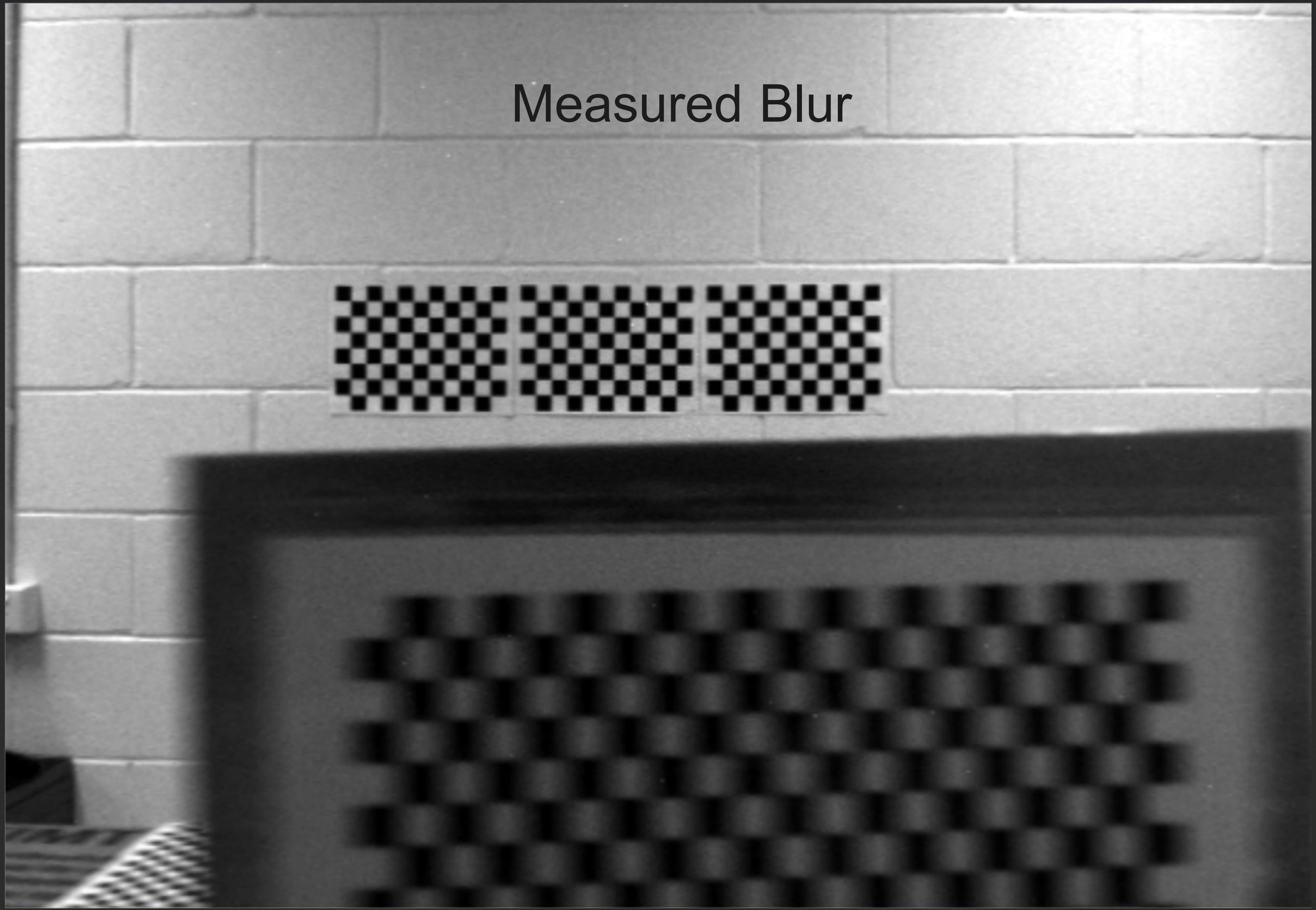


No increase in noise

Regularization is helping

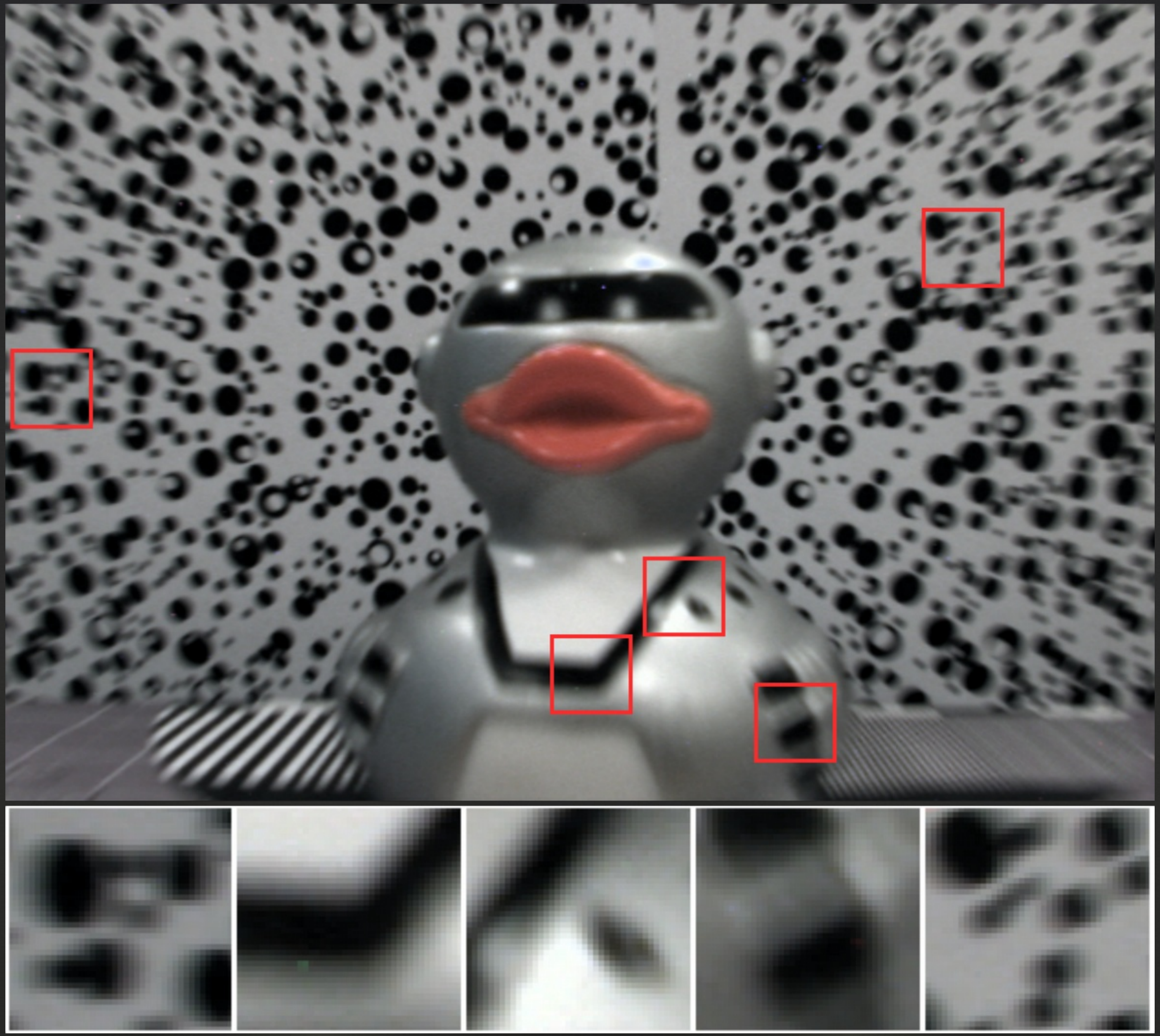
Large increase in sharpness

Results: Captured

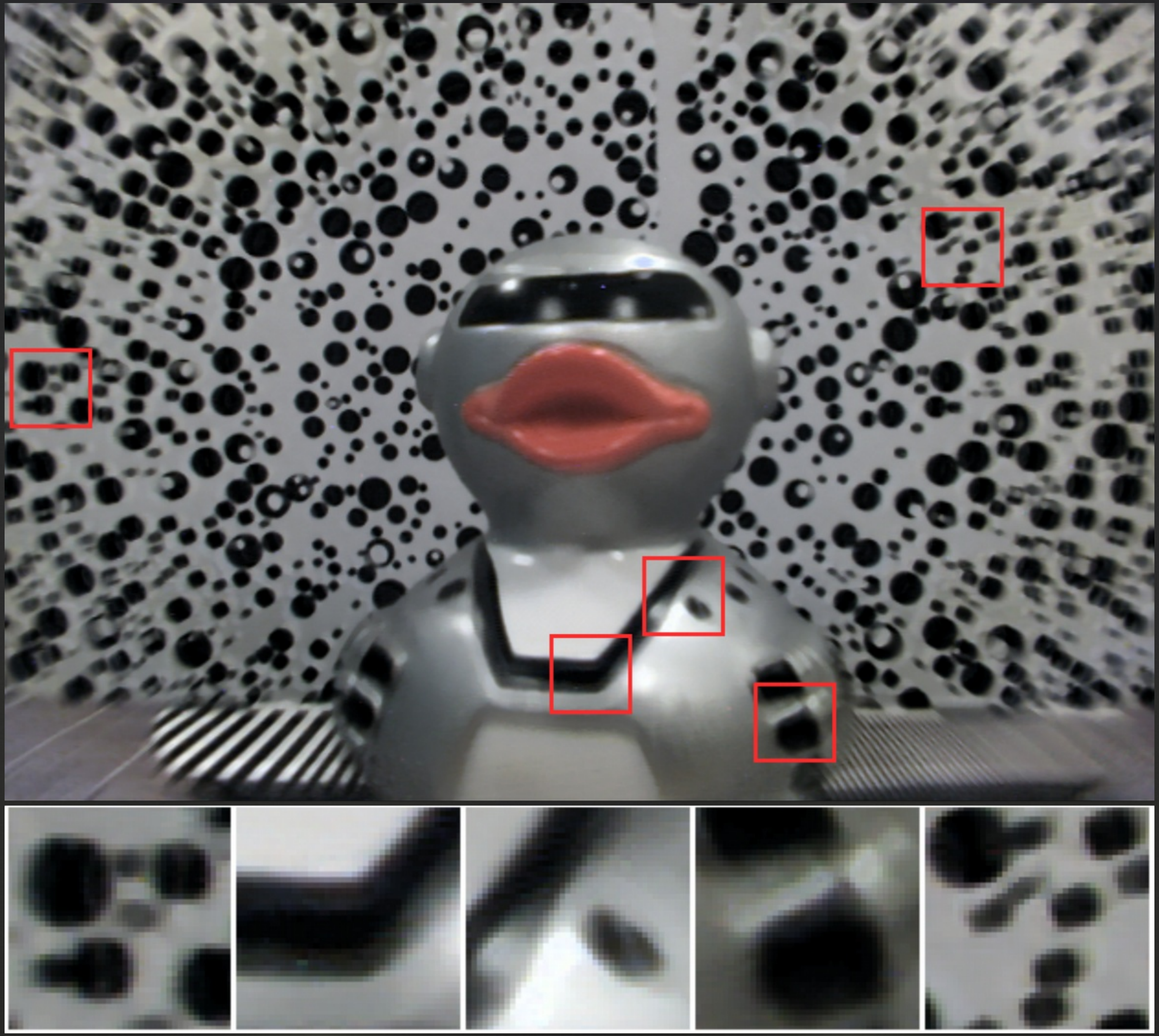


Results: Captured

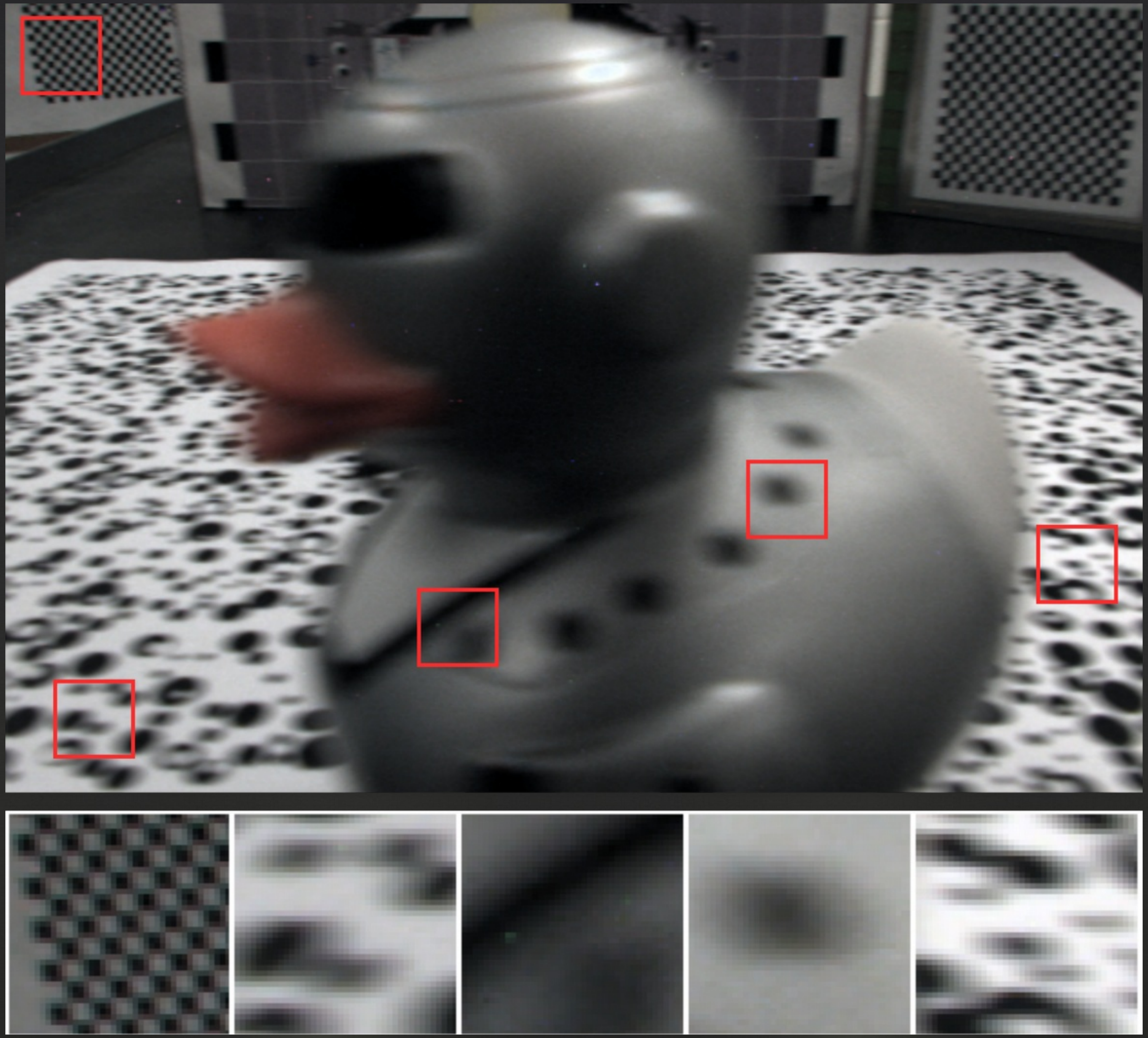
Results: Captured



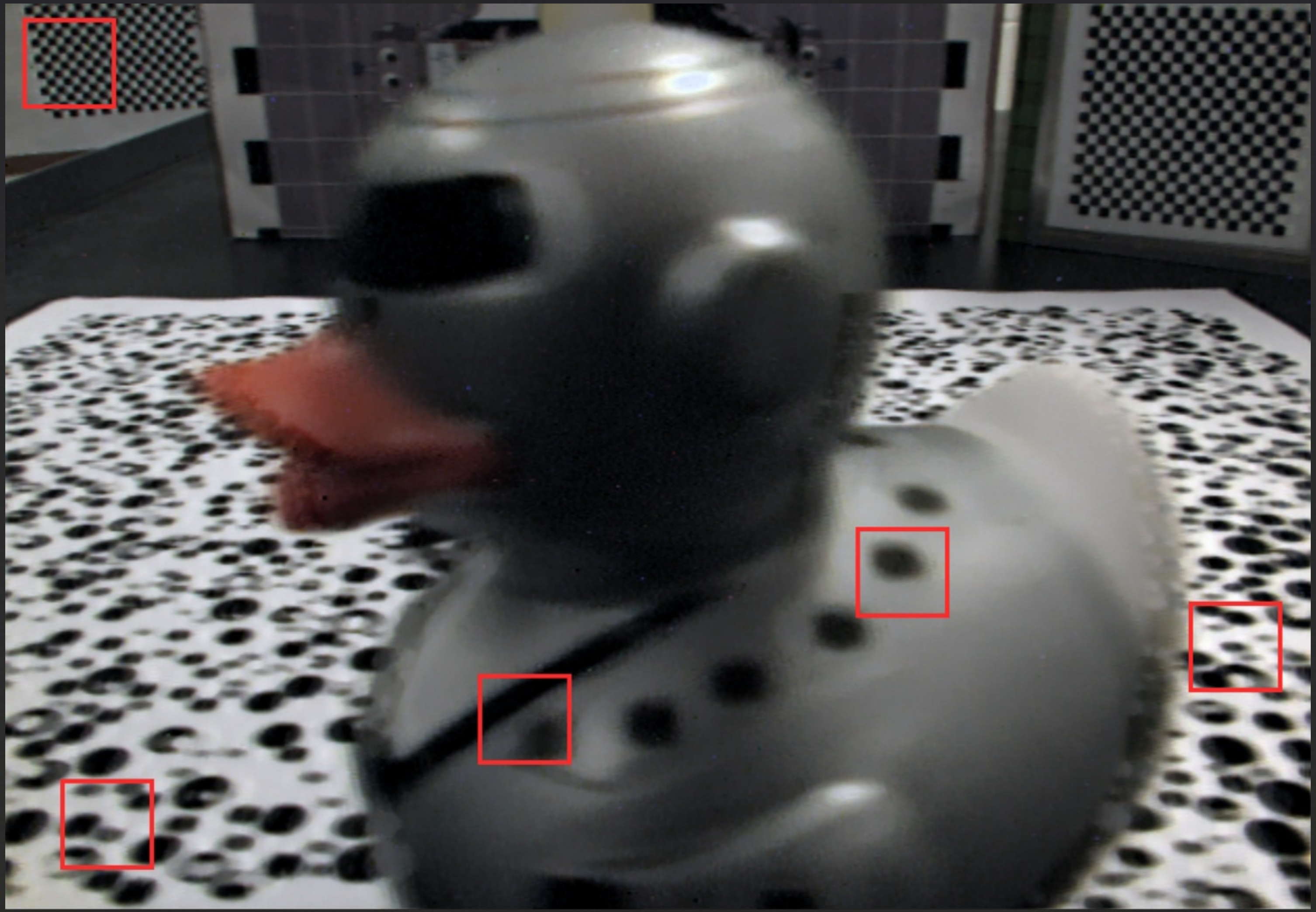
Results: Captured

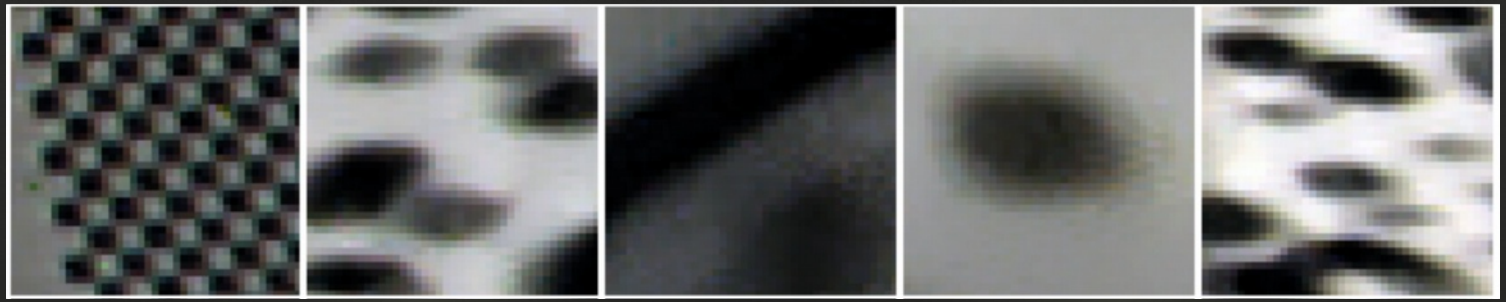


Results: Captured

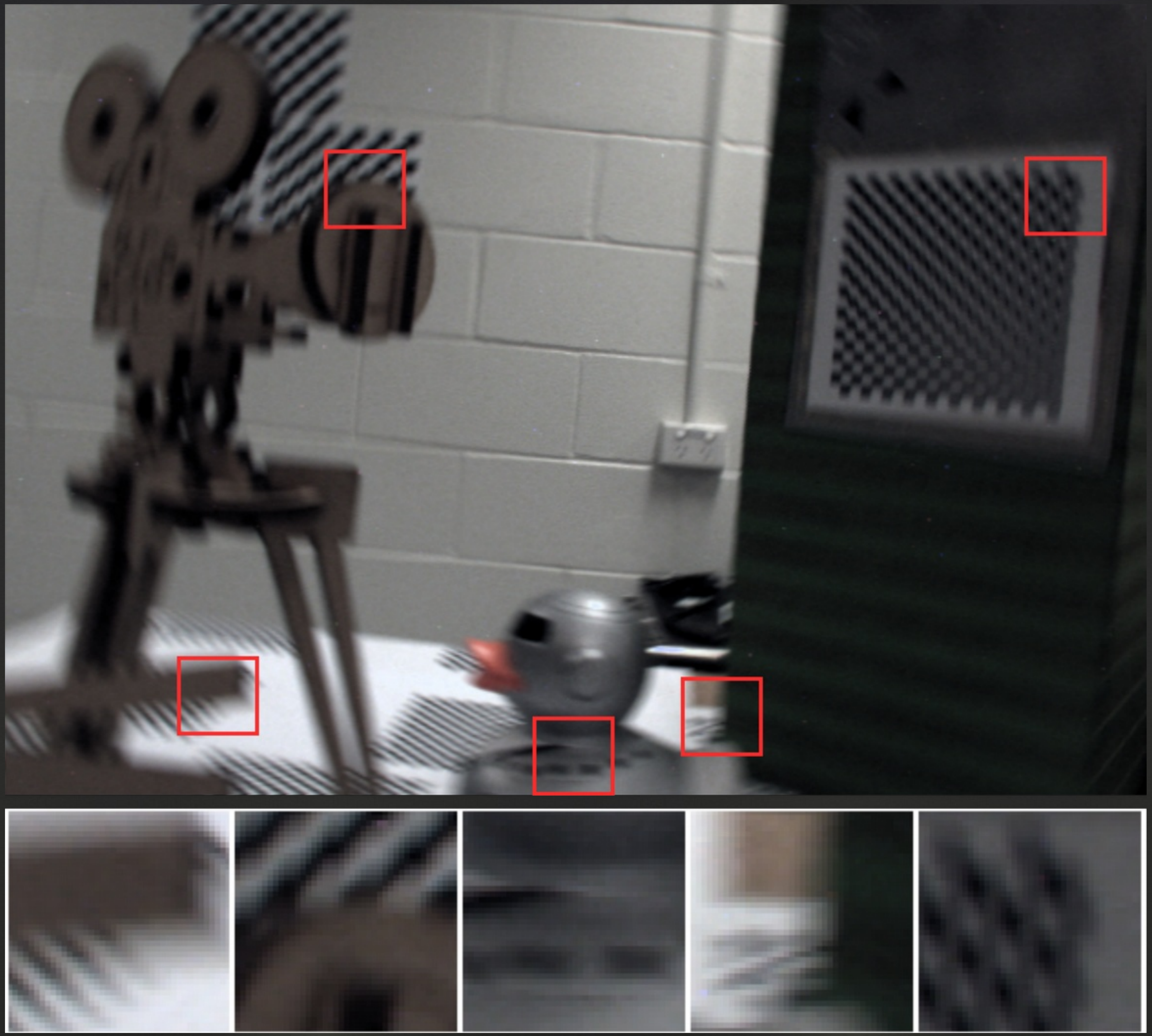


Results: Captured

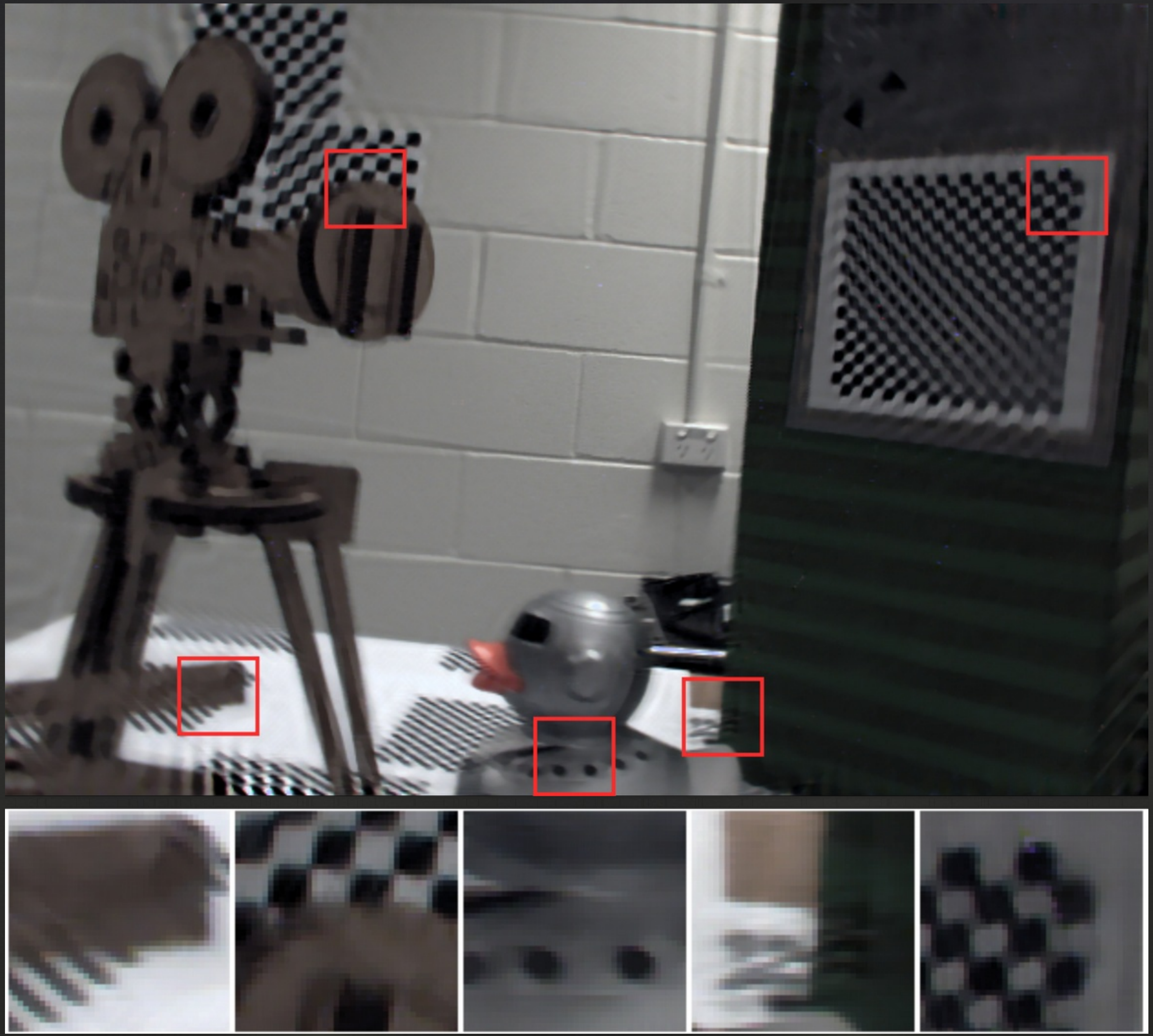




Results: Captured



Results: Captured



Summary & Future Work

Generalized convolutional blur using LF Rendering

Applied to RL deblurring

3D scenes, 6-DOF camera motion

Proof of convergence to ML estimate

Equiparallax regularization

Next:

Equiparallax regularization: applications

Beyond 6-DOF, defocus

Blind deblurring

Acknowledgments

Australian Government
Australian Research Council

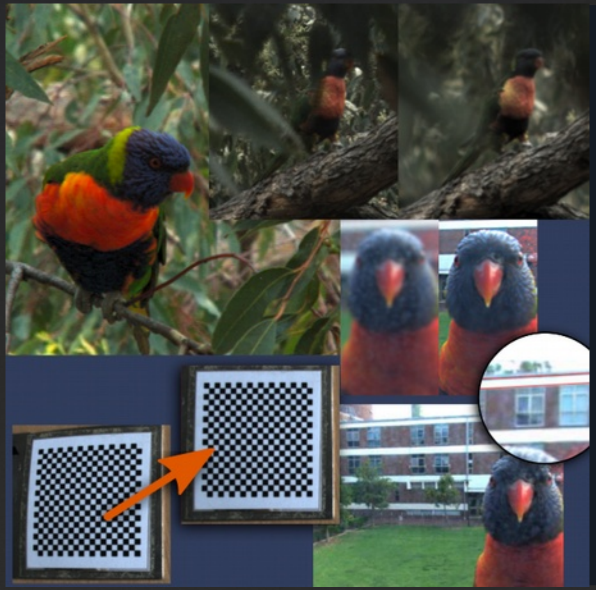
LELAND STANFORD JUNIOR UNIVERSITY
DIE LUFT DER FREIHEIT WEHT
1891

QUT

ACRV
AUSTRALIAN CENTRE
FOR ROBOTIC VISION

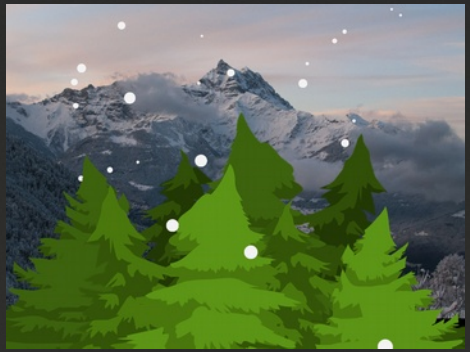
QUT HPC Group

George



Light Field Toolbox for MATLAB

- Load Gantry and Lytro imagery
- Calibrate and rectify Lytro imagery
- Linear depth, volume filters
- Denoising: low-light, fog, dust, murky water
- Occluder removal: rain, snow, silty water



LF Synth: Bare-Bones Rendering

dgd.vision