

Rolling Shutter Motion Deblurring

Supplemental Material

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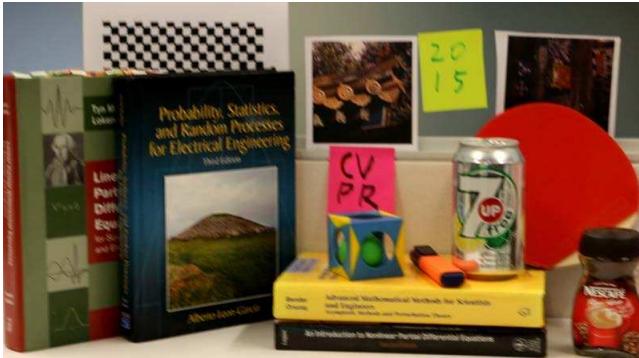
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Experiments Description

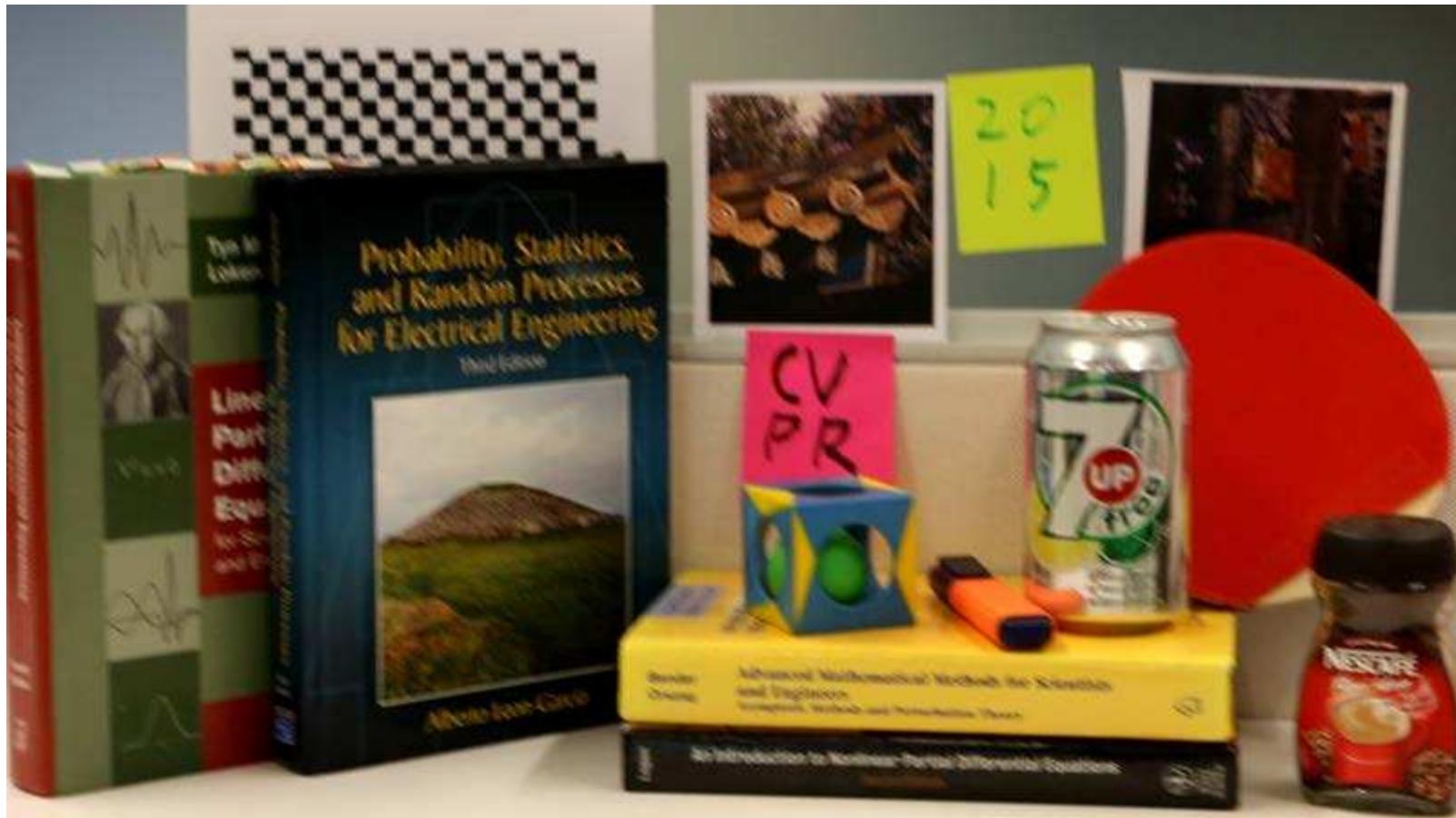
- Comparisons with other blind deblurring algorithms
 - **BD (Cho)**: Cho and Lee, Fast Motion Deblurring, Siggraph Asia 2009
 - **BD (Xu)**: Xu *et al.*, Unnatural L0 Sparse Representation for Natural Image Deblurring, CVPR 2013
- Comparisons with alternative approaches
 - **BD + Stitch**: Apply blind deblurring (Xu and Jia, ECCV 2010) to several overlapping blocks of rows in a RSMB image before stitching the deblurred blocks into a single image using the Photomerge feature in Adobe Photoshop CS6
 - **RS + BD**: Apply blind deblurring (Cho and Lee, Siggraph Asia 2009) to the rolling shutter rectified image obtained using the rolling shutter correction feature in Adobe After Effects CS6
- Results of the single image approach described in this paper
 - **RSMD**: The proposed blind deblurring approach that addresses the joint presence of rolling shutter and motion blur in a single image

Real-World RSMB Images

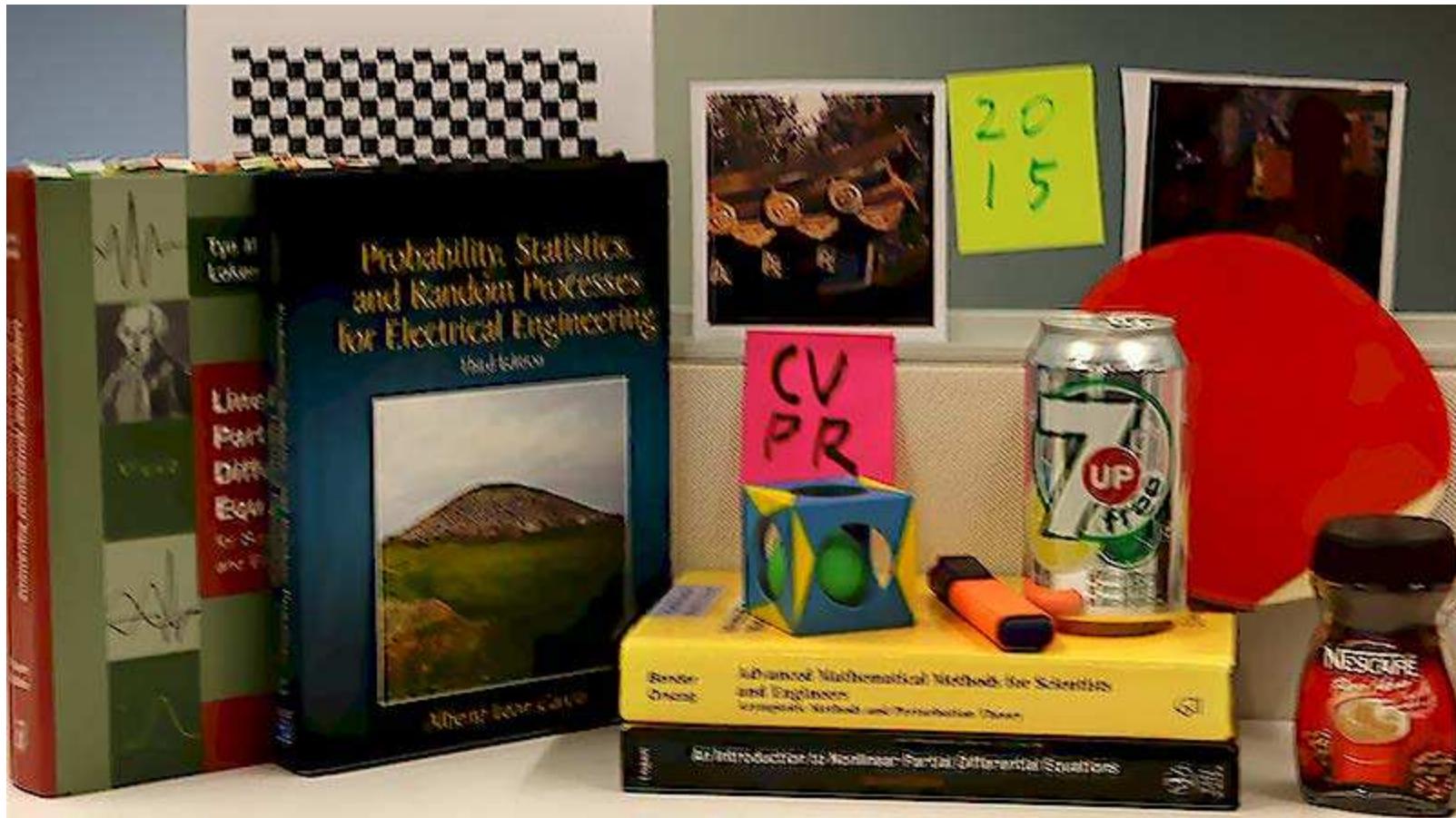
- Here we show full-size images of Fig. 8 from the paper with additional comparisons.



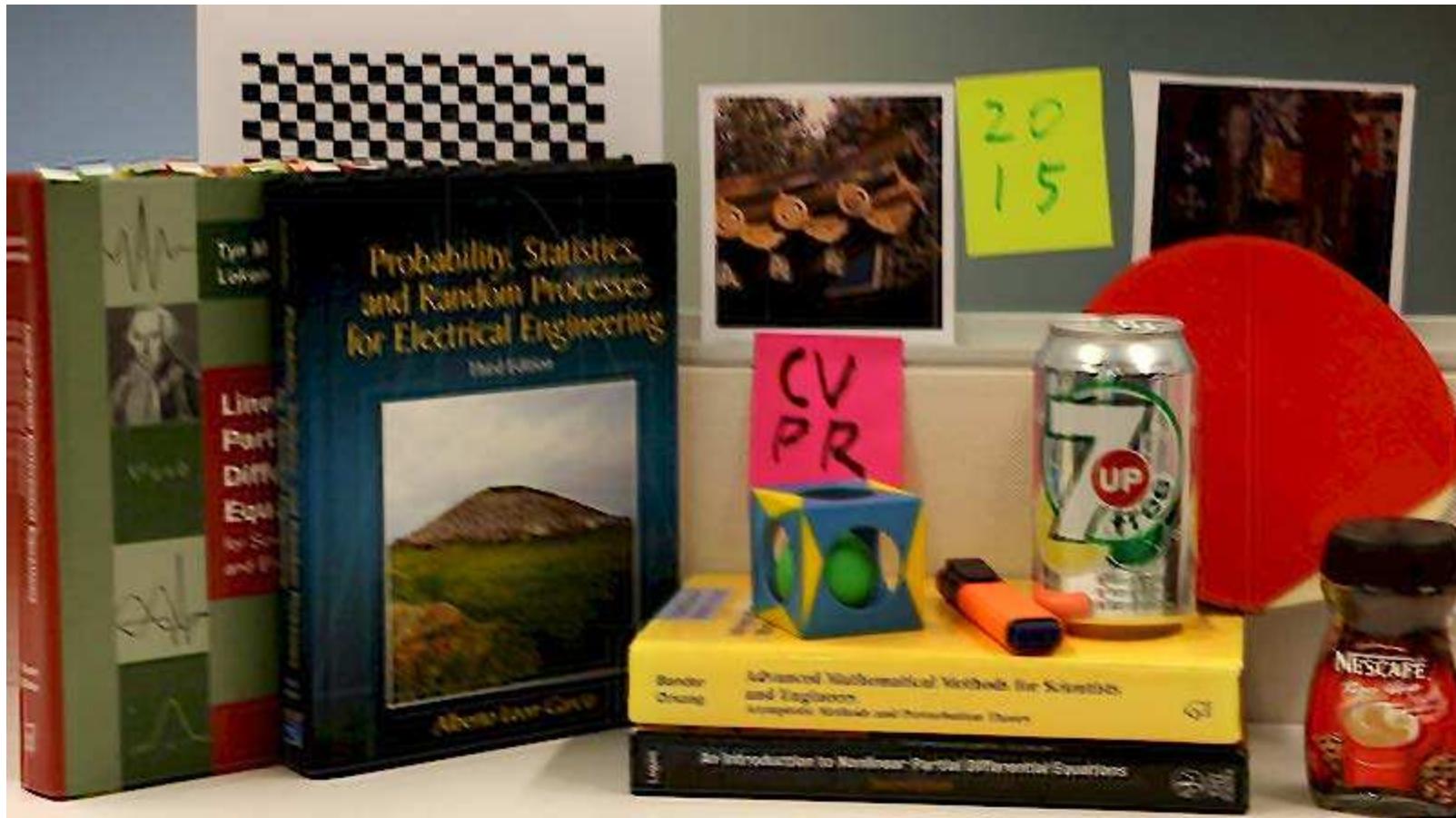
Real - Desk - Blurred



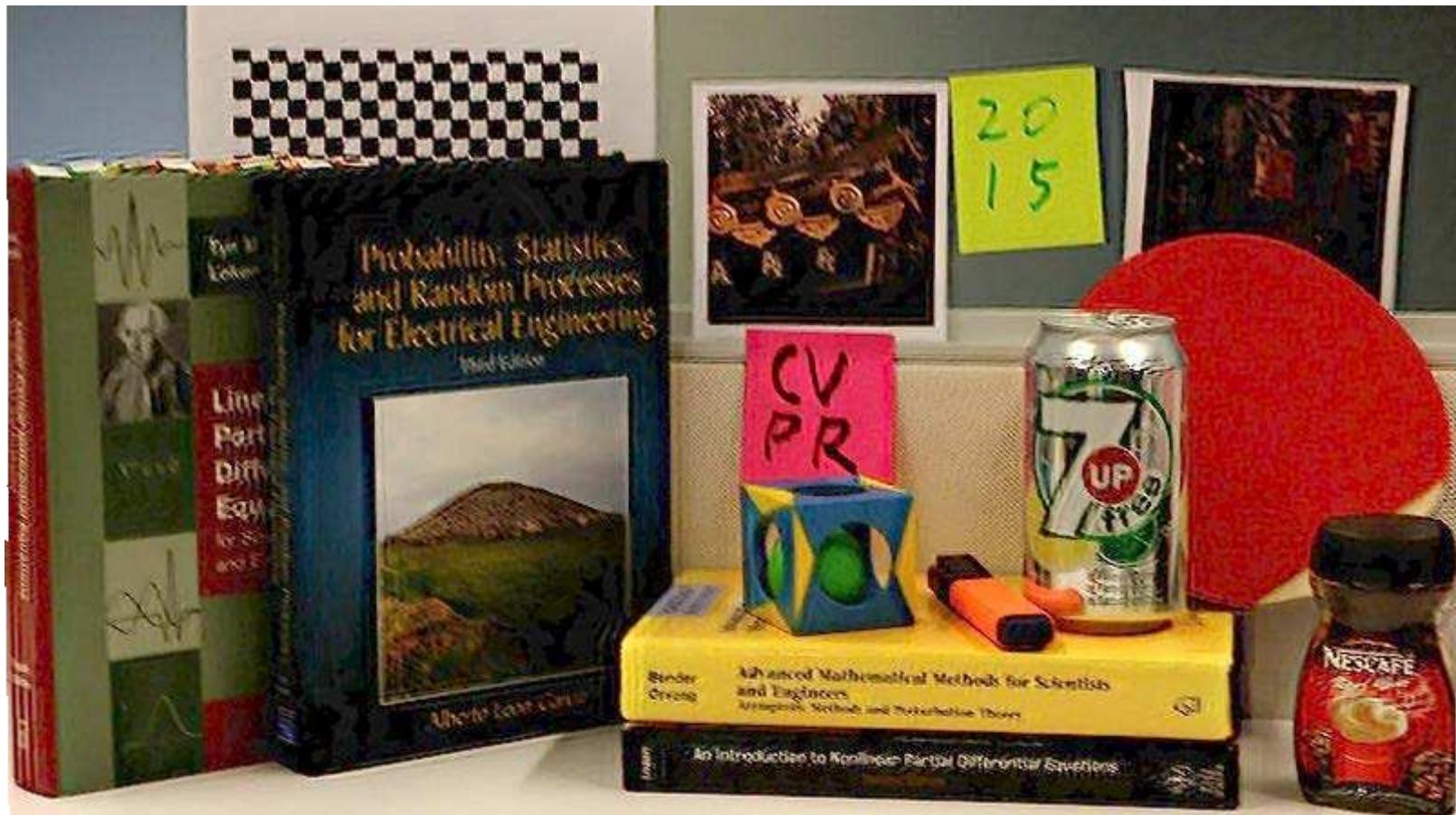
Real - Desk - BD (Cho)



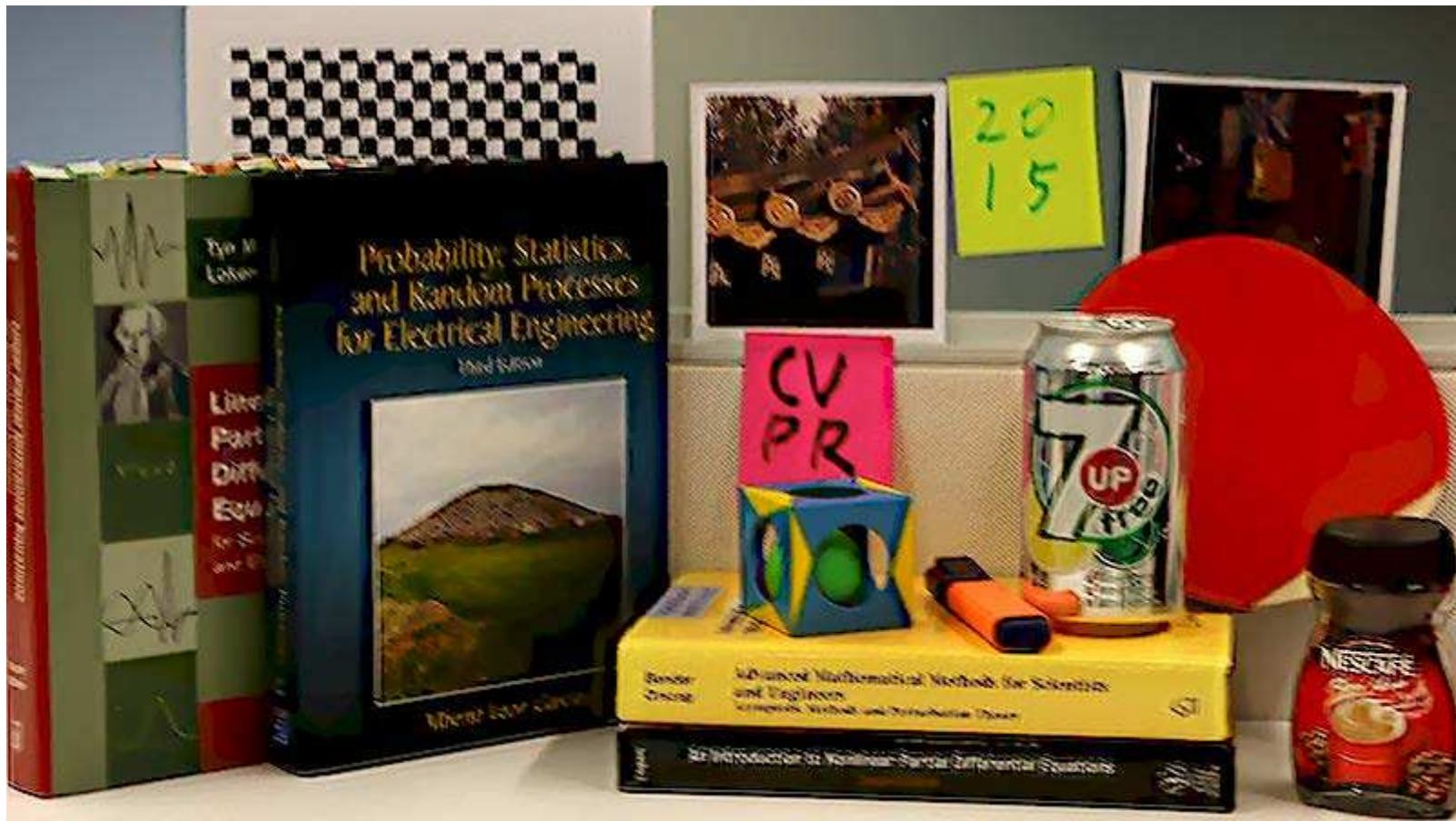
Real - Desk - BD (Xu)



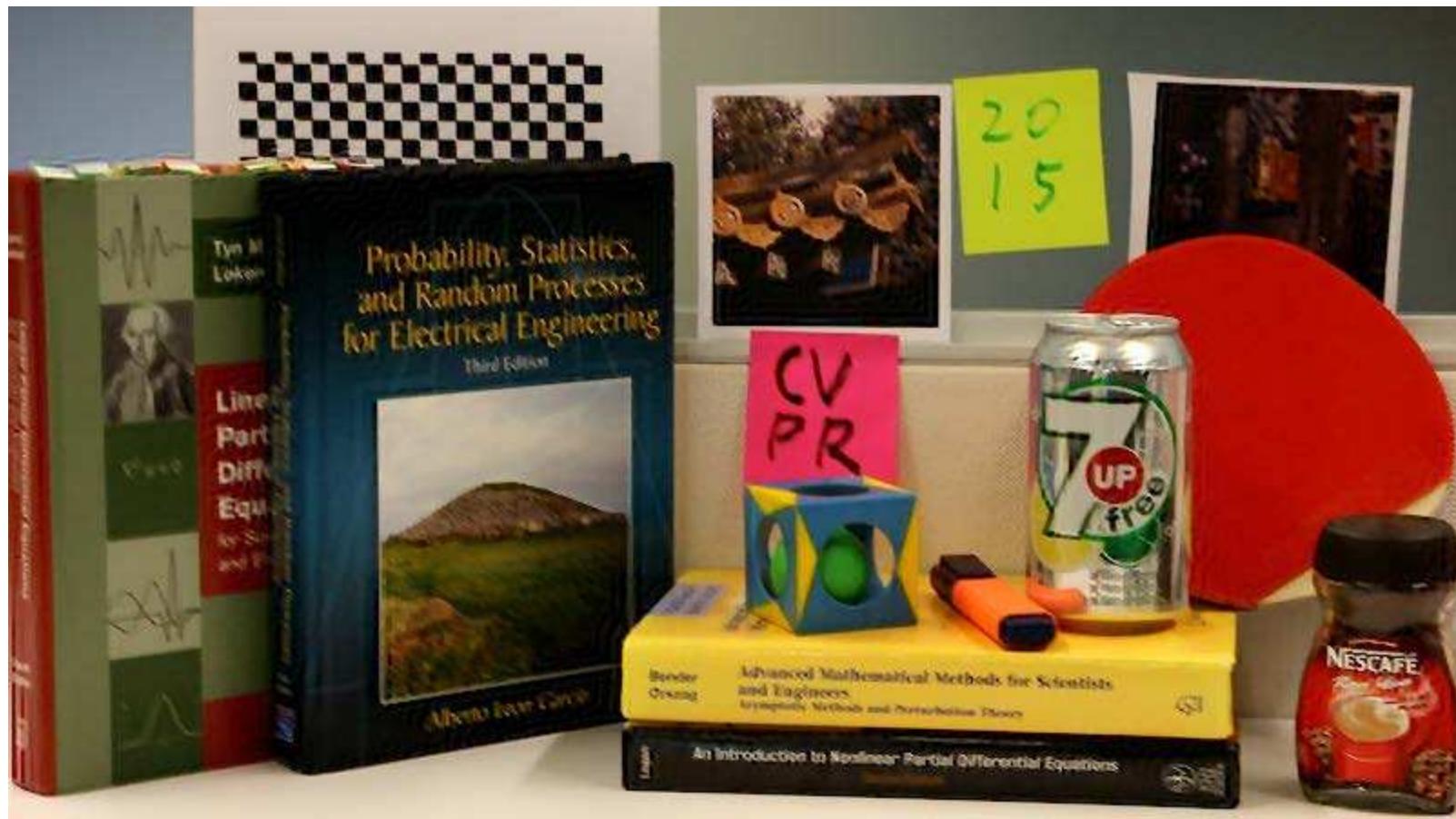
Real - Desk - BD + Stitch



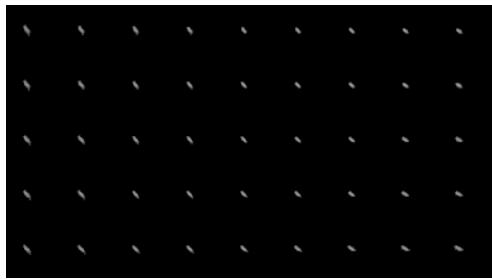
Real - Desk - RS + BD



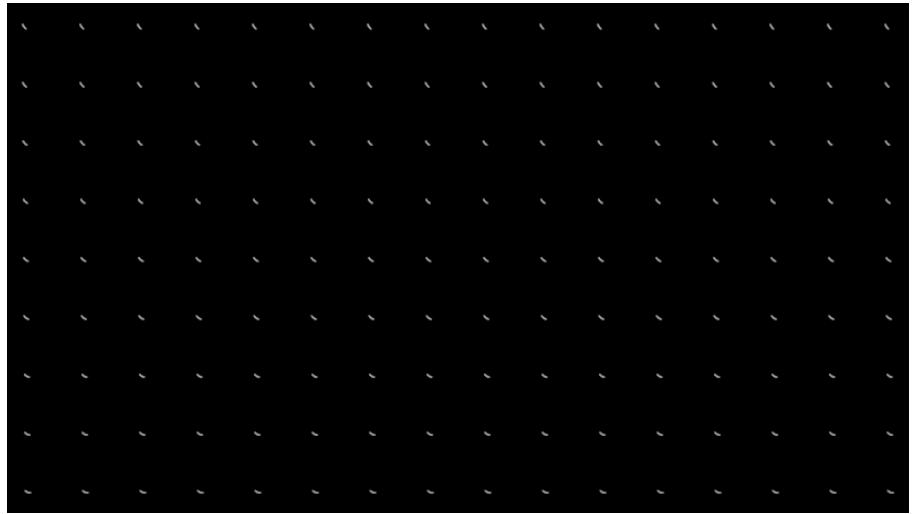
Real - Desk - RSMD



Real - Desk - Kernel Estimations



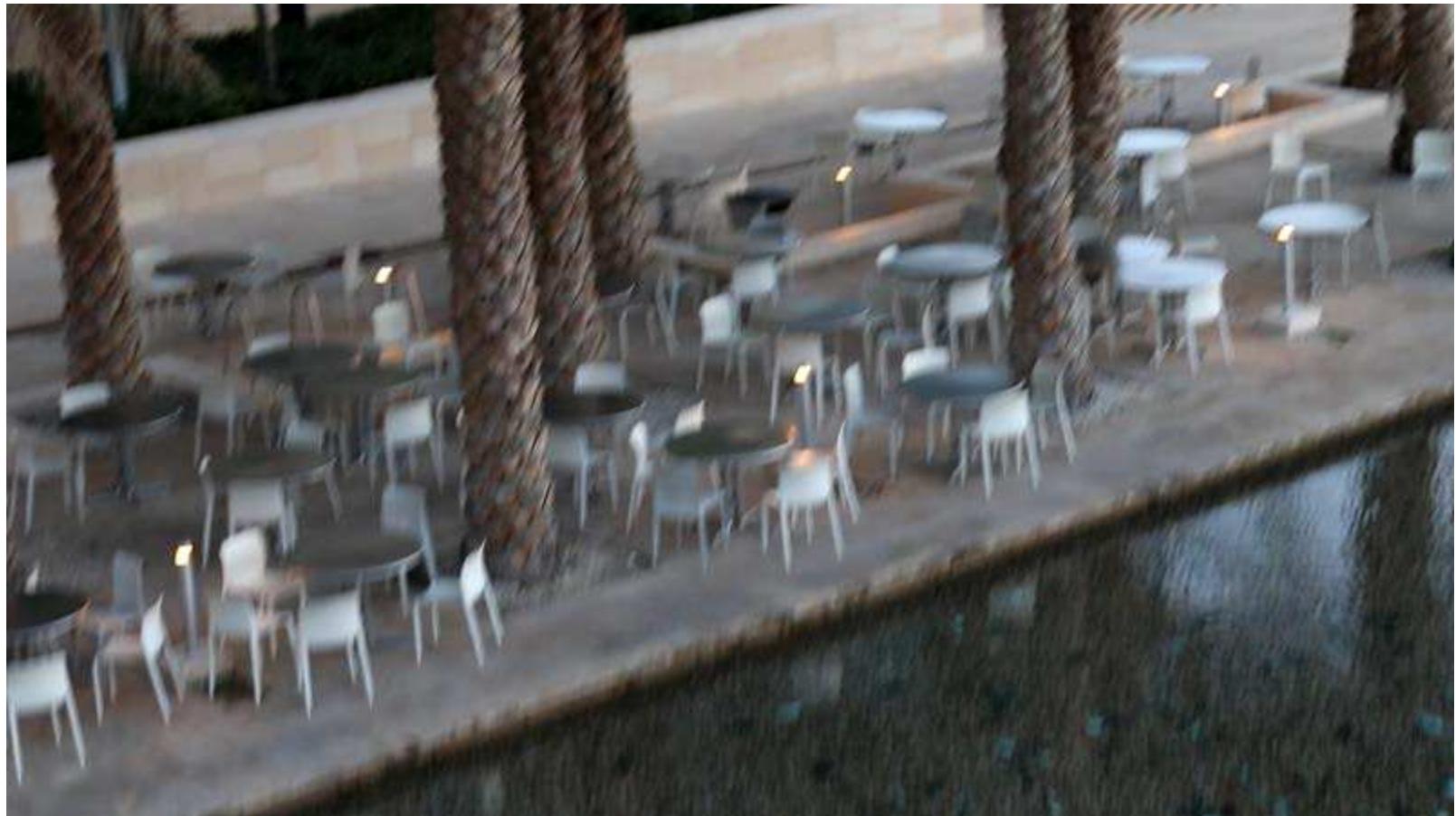
BD (Cho)



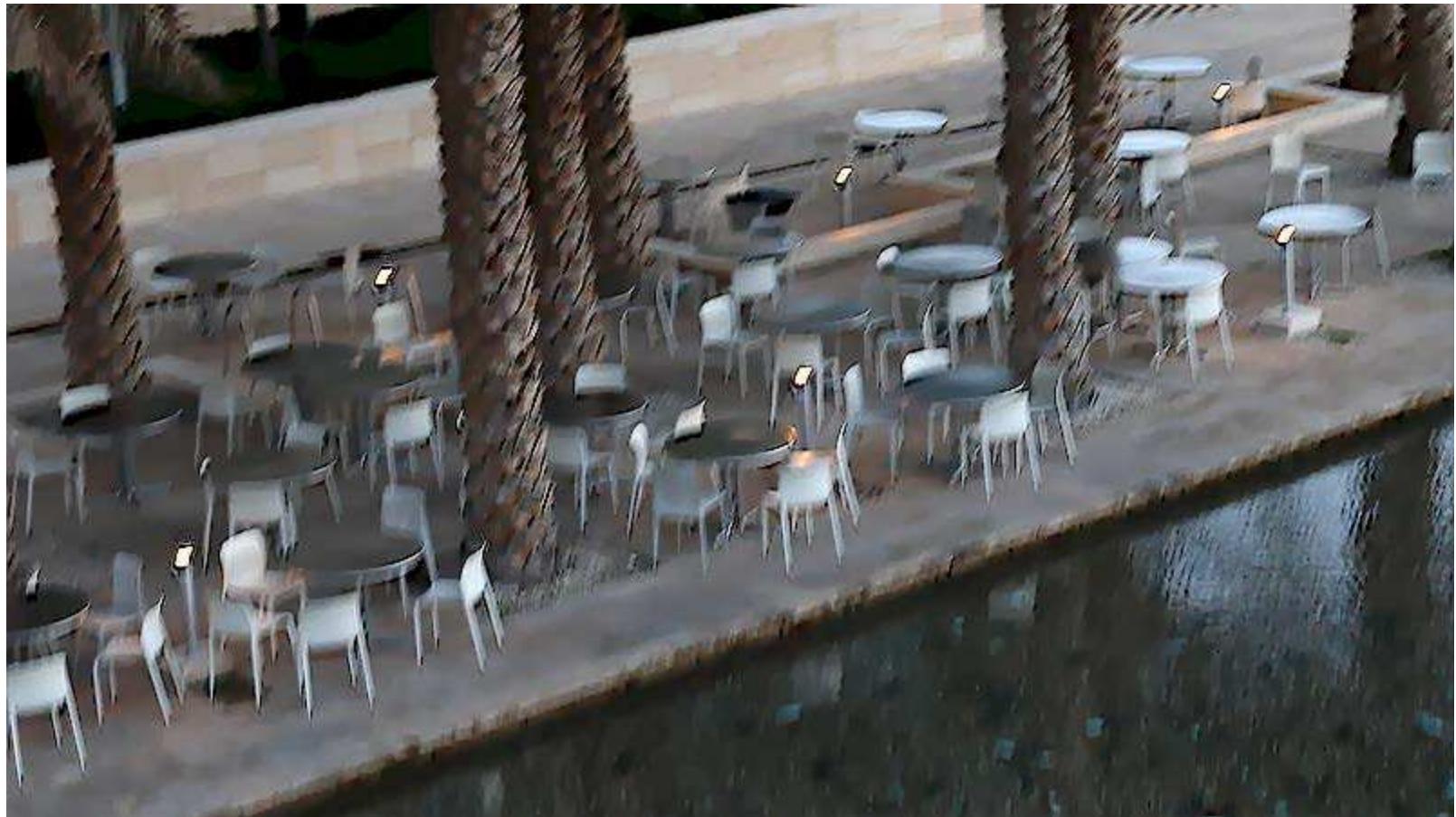
BD (Xu)*

RSMD

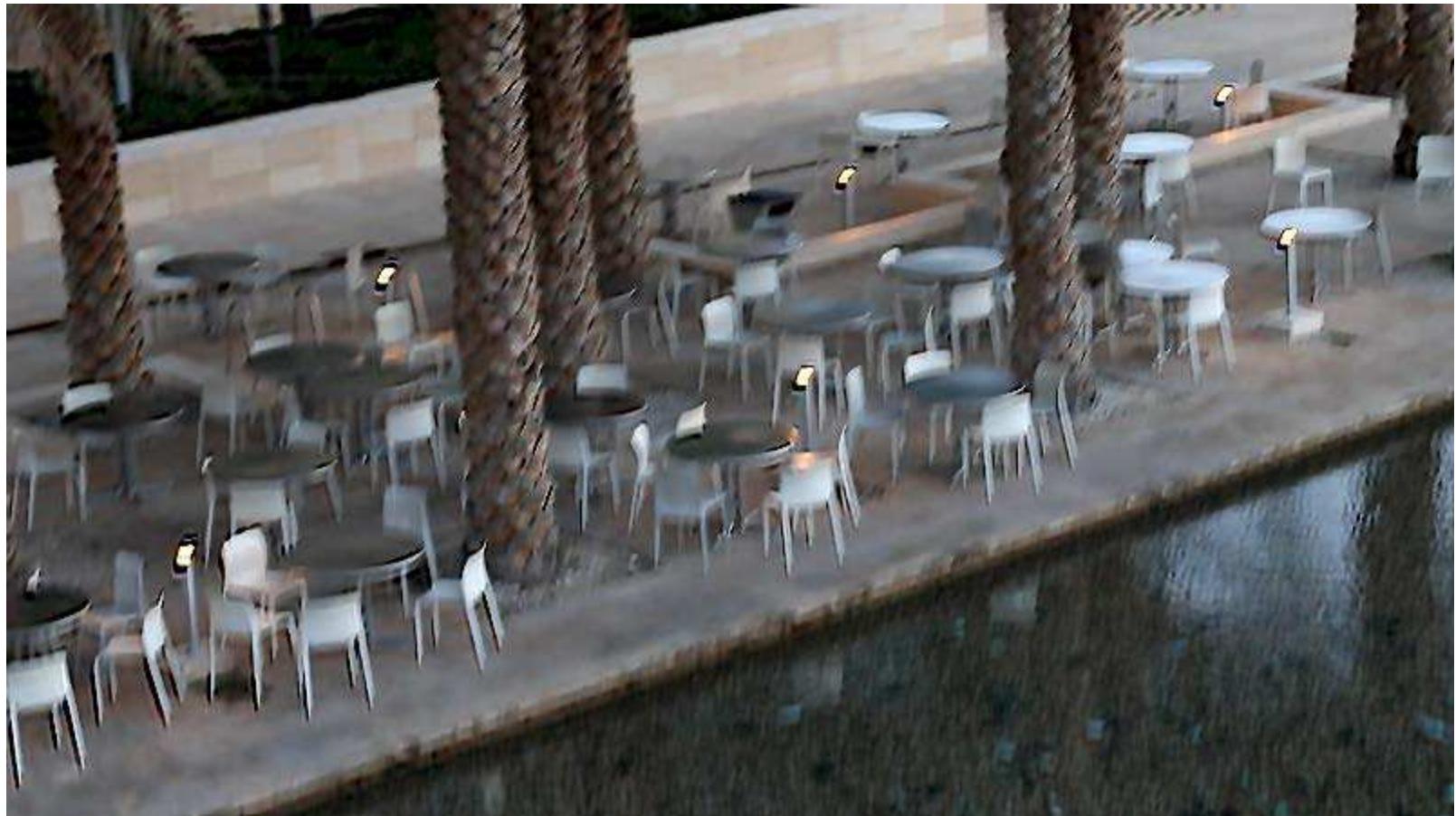
Real - Diner - Blurred



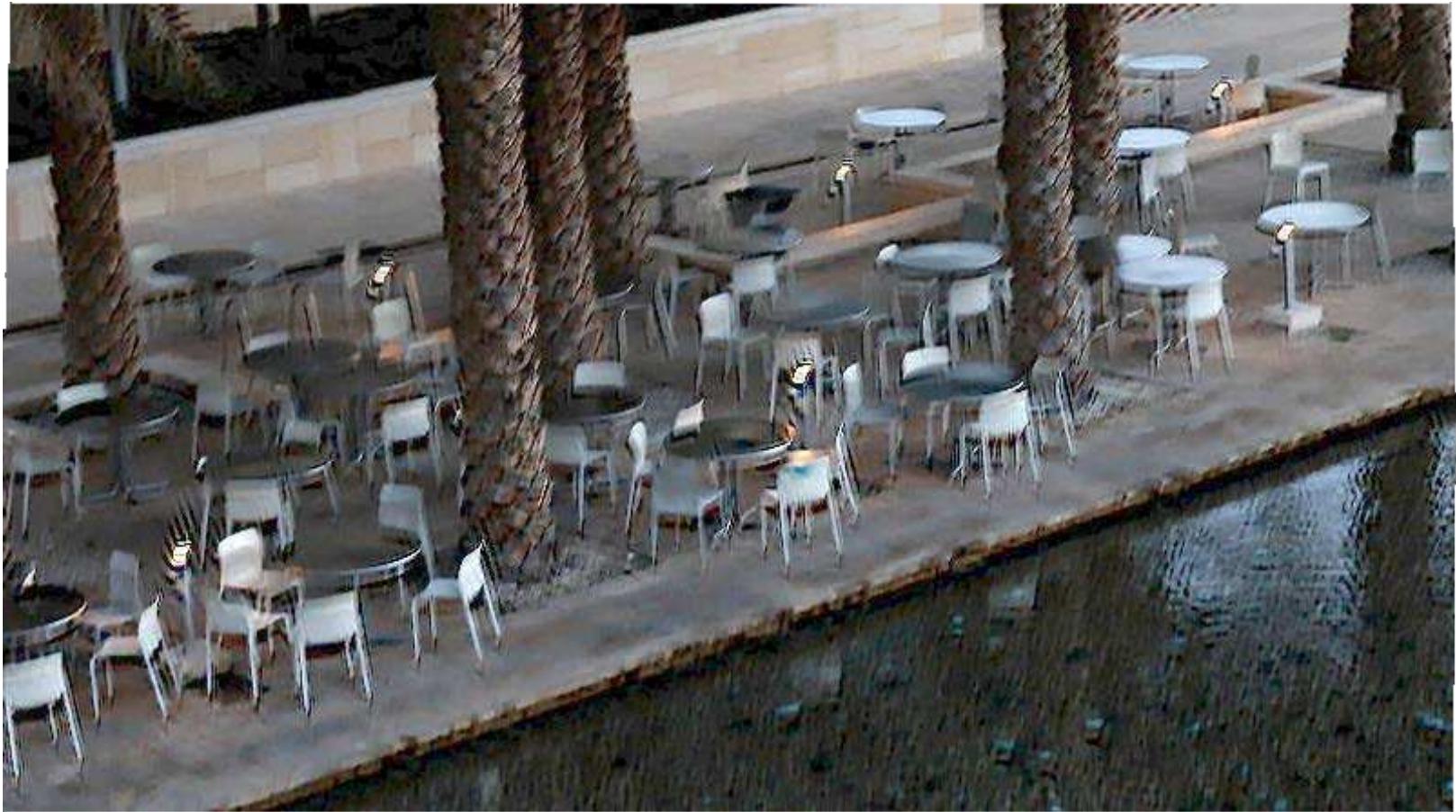
Real - Diner - BD (Cho)



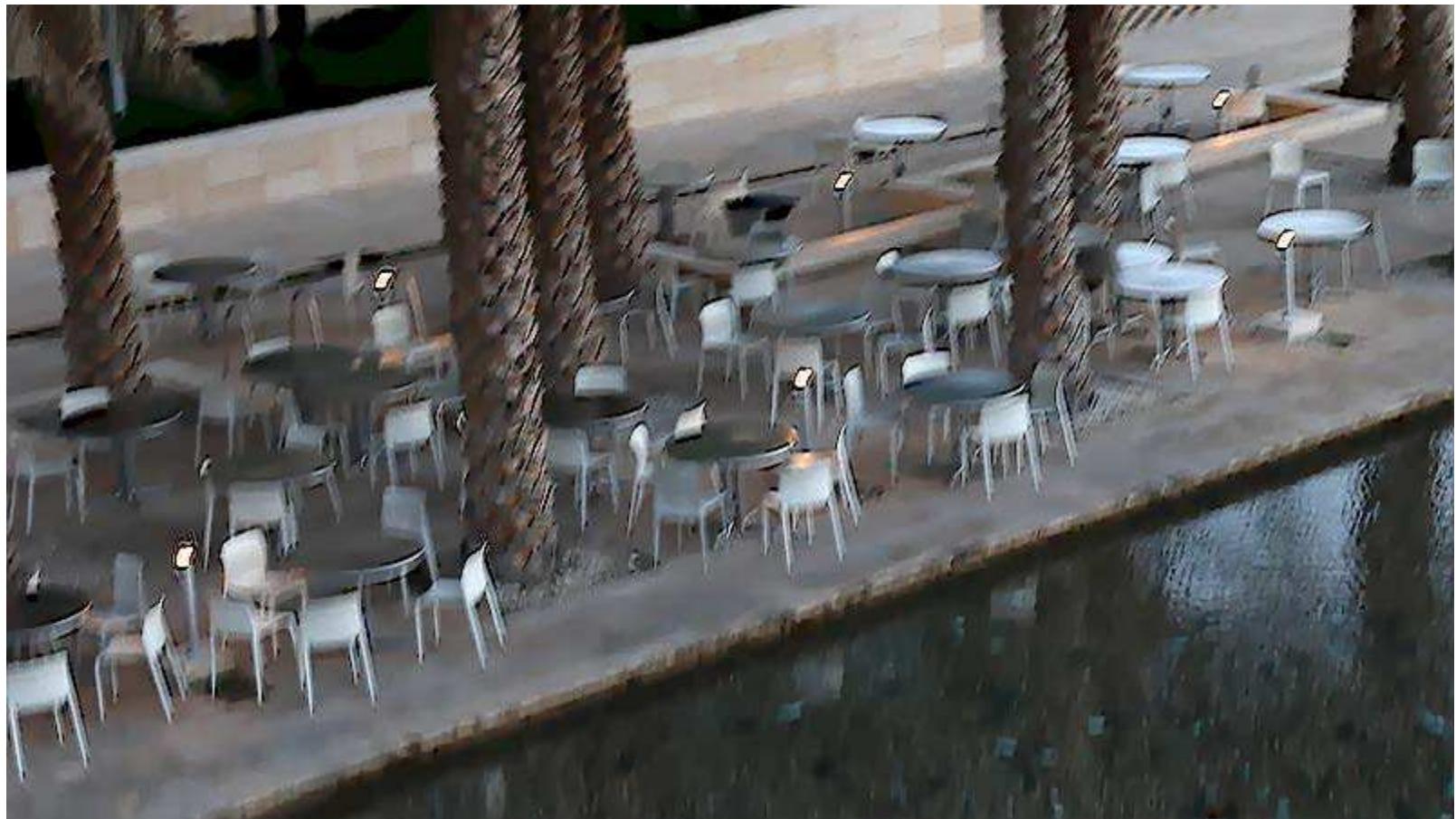
Real - Diner - BD (Xu)



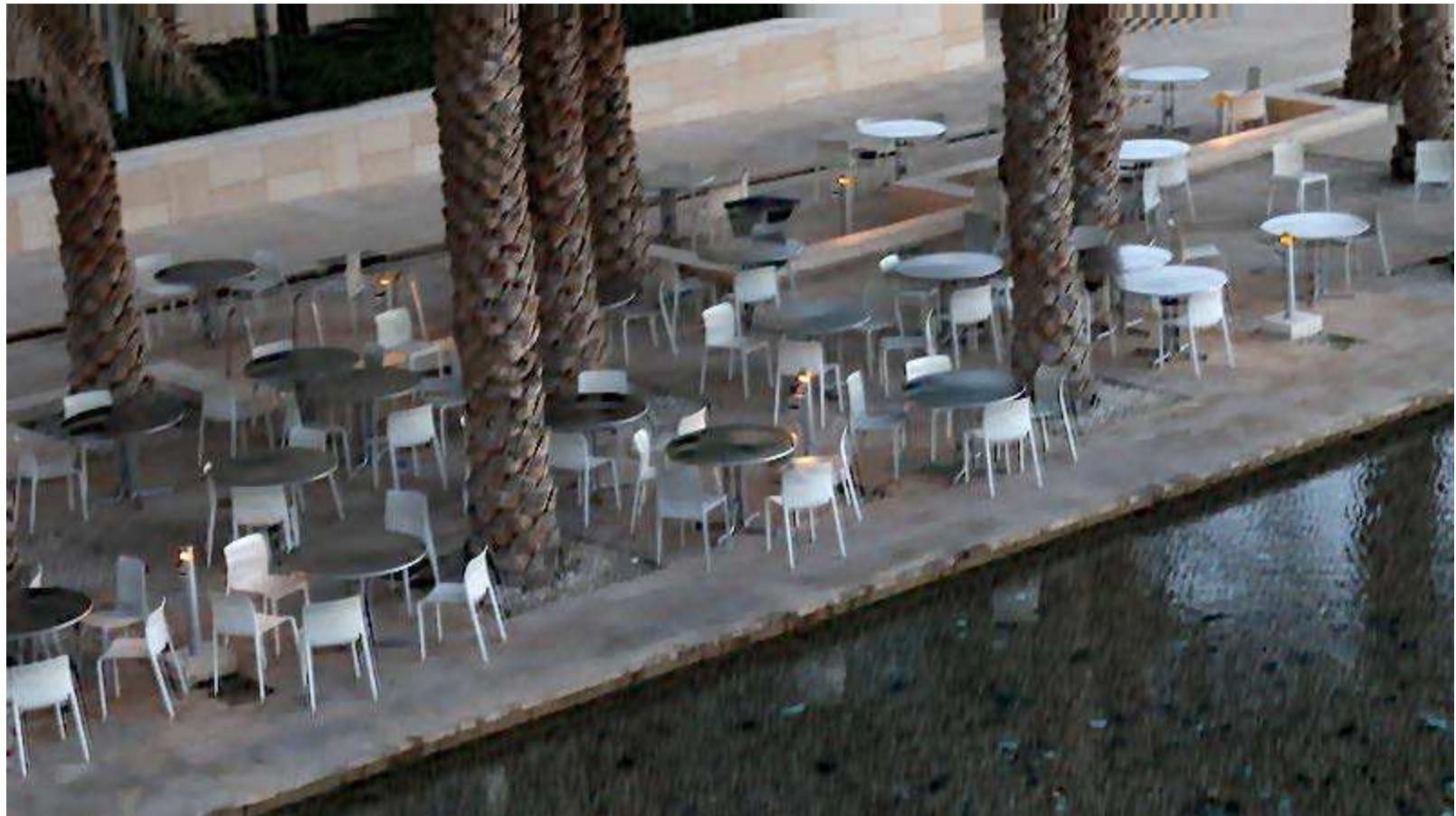
Real - Diner - BD + Stitch



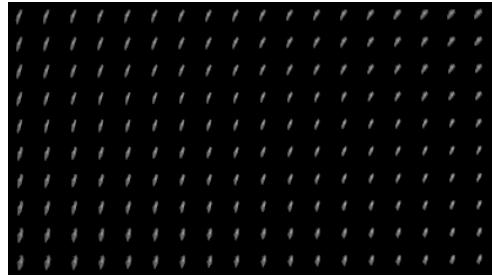
Real - Diner - RS + BD



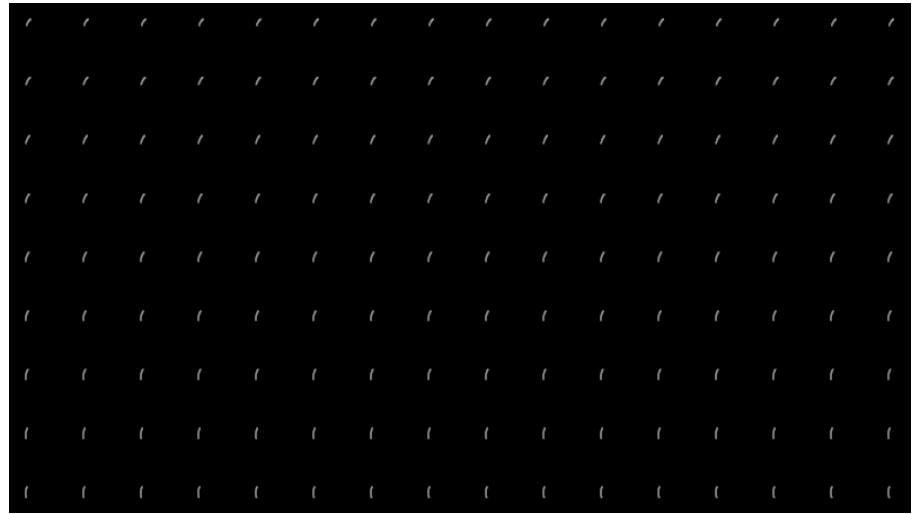
Real - Diner - RSMD



Real - Diner - Kernel Estimations



BD (Cho)



BD (Xu)*

RSMD

Real - Sofa - Blurred



Real - Sofa - BD (Cho)



Real - Sofa - BD (Xu)



Real - Sofa - BD + Stitch



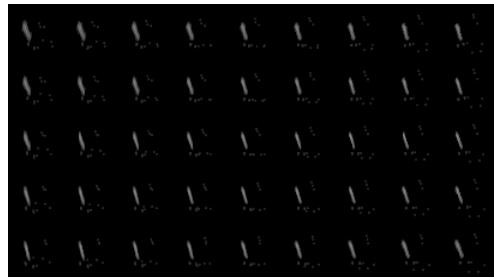
Real - Sofa - RS + BD



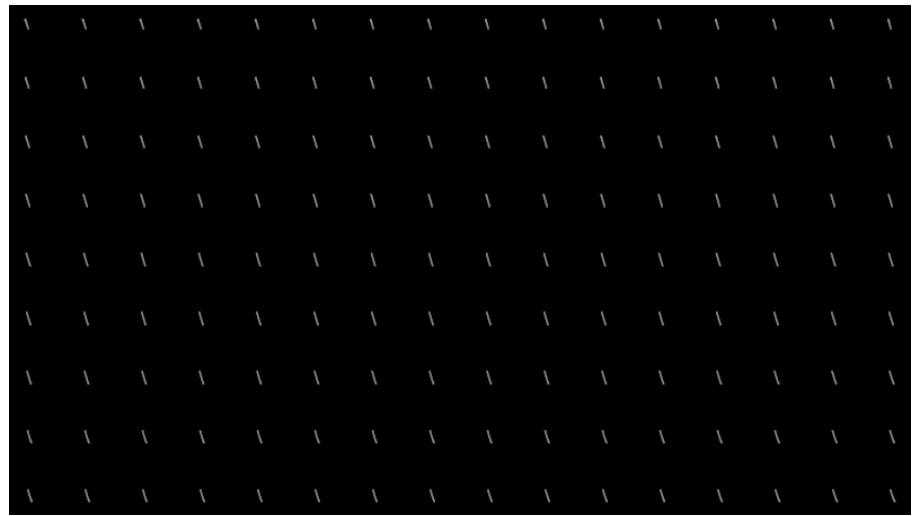
Real - Sofa - RSMD



Real - Sofa - Kernel Estimations



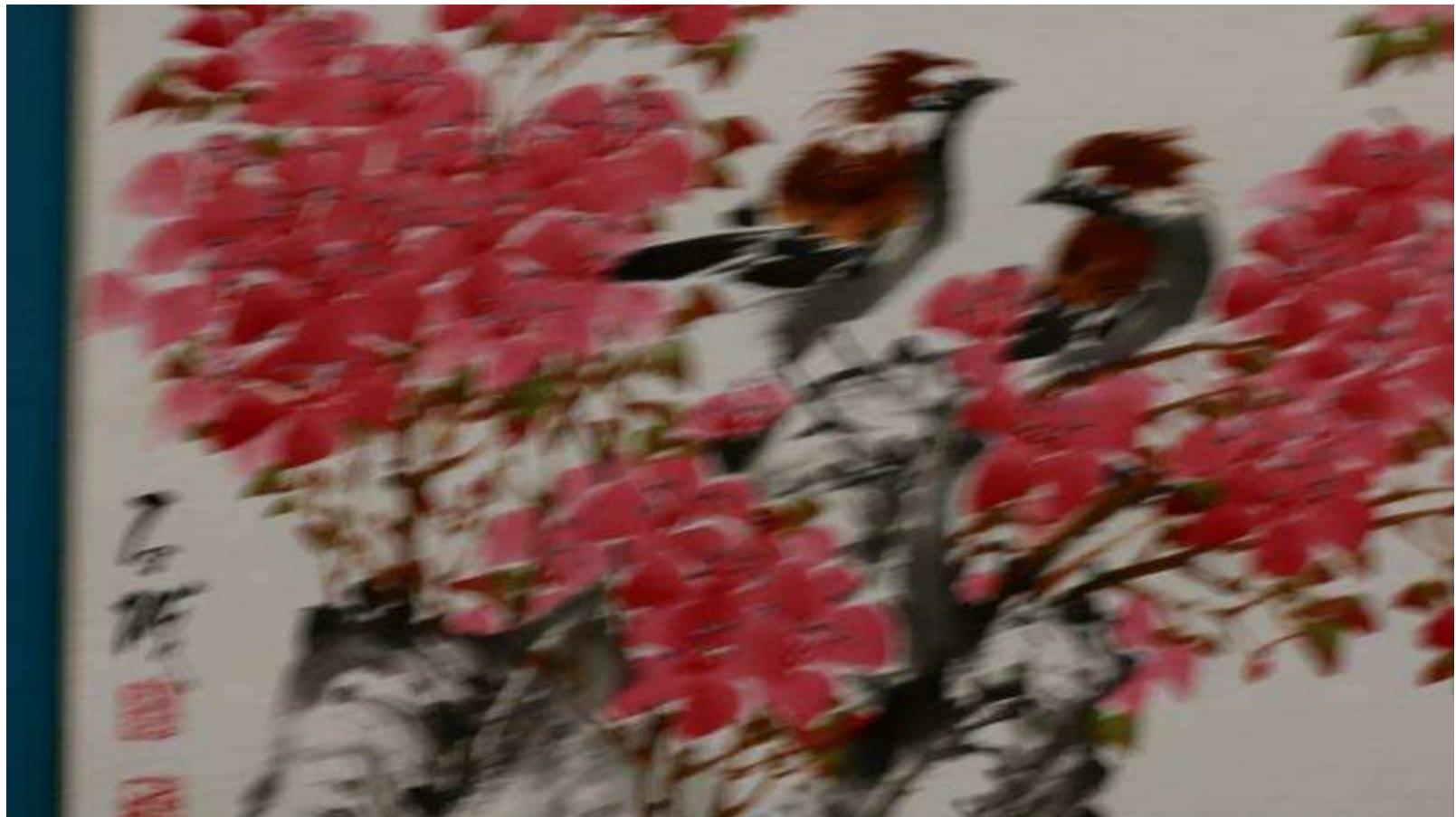
BD (Cho)



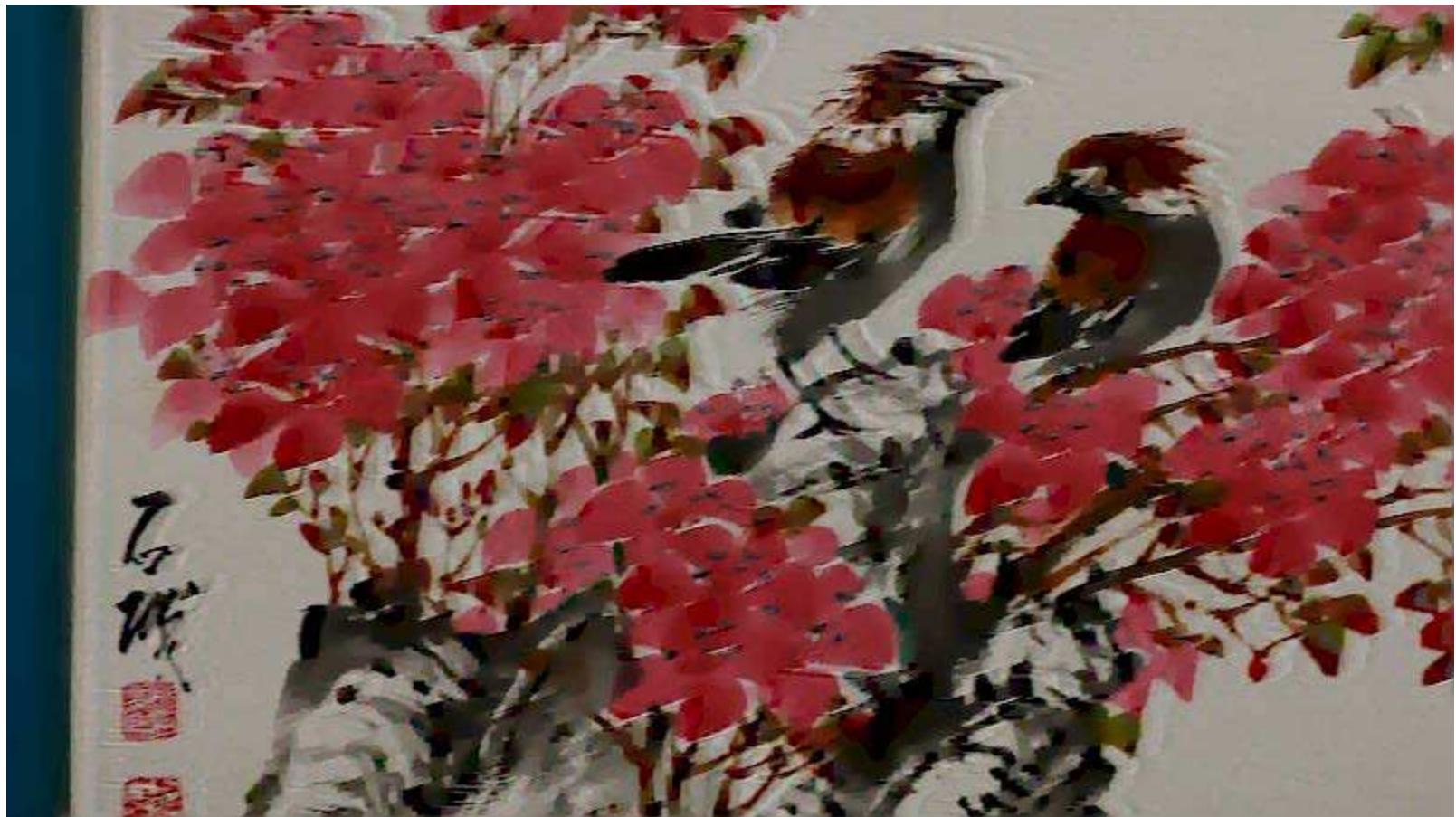
BD (Xu)*

RSMD

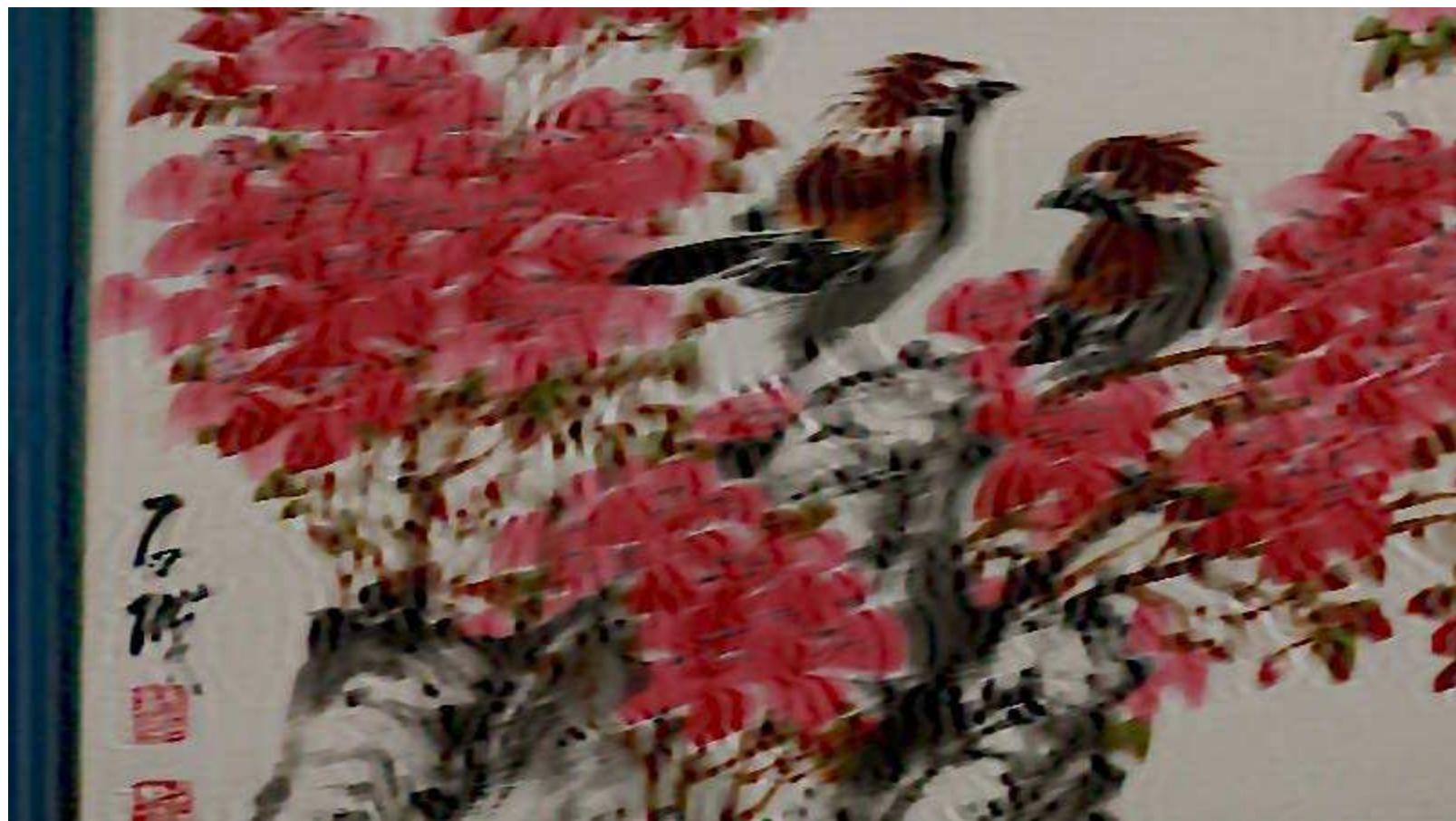
Real - Bird - Blurred



Real - Bird - BD (Cho)



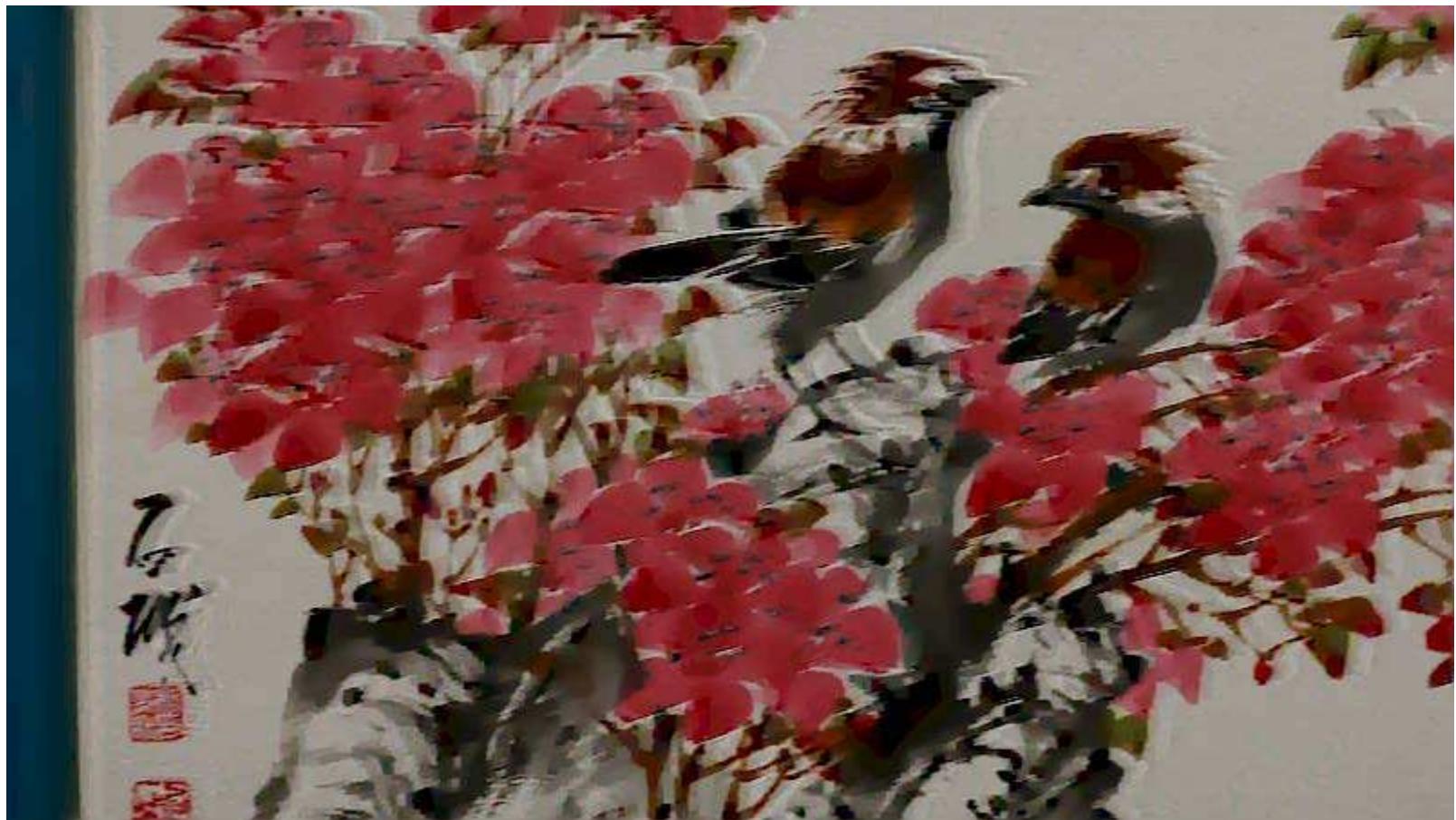
Real - Bird - BD (Xu)



Real - Bird - BD + Stitch



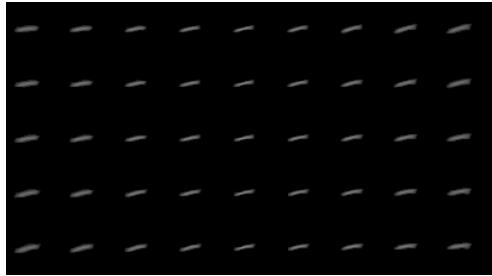
Real - Bird - RS + BD



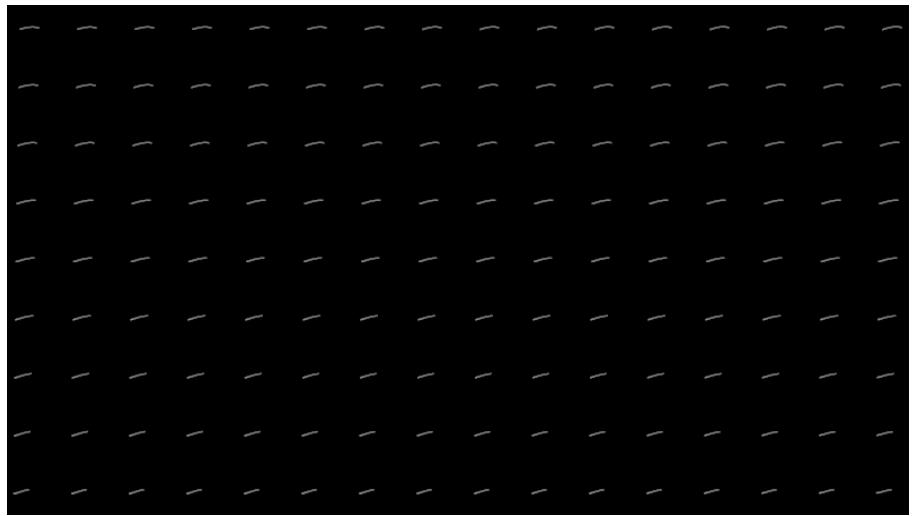
Real - Bird - RSMD



Real - Bird - Kernel Estimations



BD (Cho)



BD (Xu)*

RSMD

Synthetic RSMB Images

- Here we show full-size images of Fig. 6 from the paper with additional comparisons.



Synthetic - Clock (kernel 1) - Blurred



Synthetic - Clock (kernel 1) - Cho



Synthetic - Clock (kernel 1) - Xu



Synthetic - Clock (kernel 1) - BD + Stitch



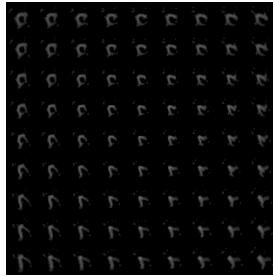
Synthetic - Clock (kernel 1) - RSMD



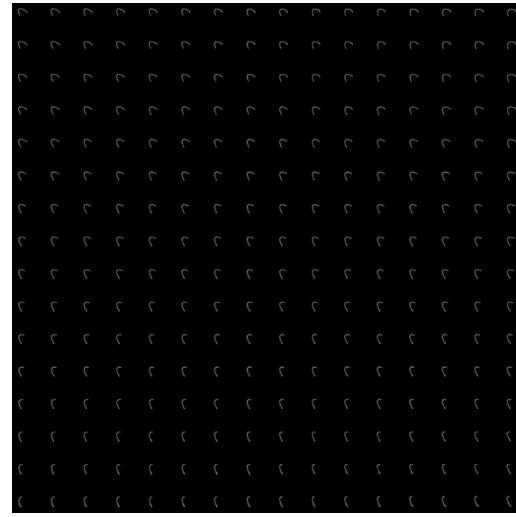
Synthetic - Clock (kernel 1) - Ground Truth



Synthetic - Clock (kernel 1) - Kernel Estimations

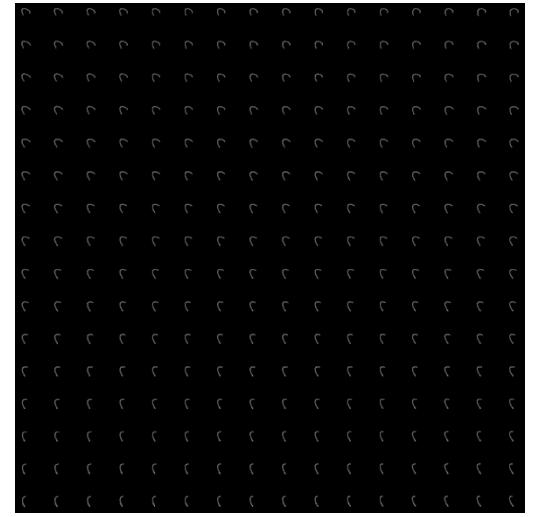


BD (Cho)



BD (Xu)*

RSMD

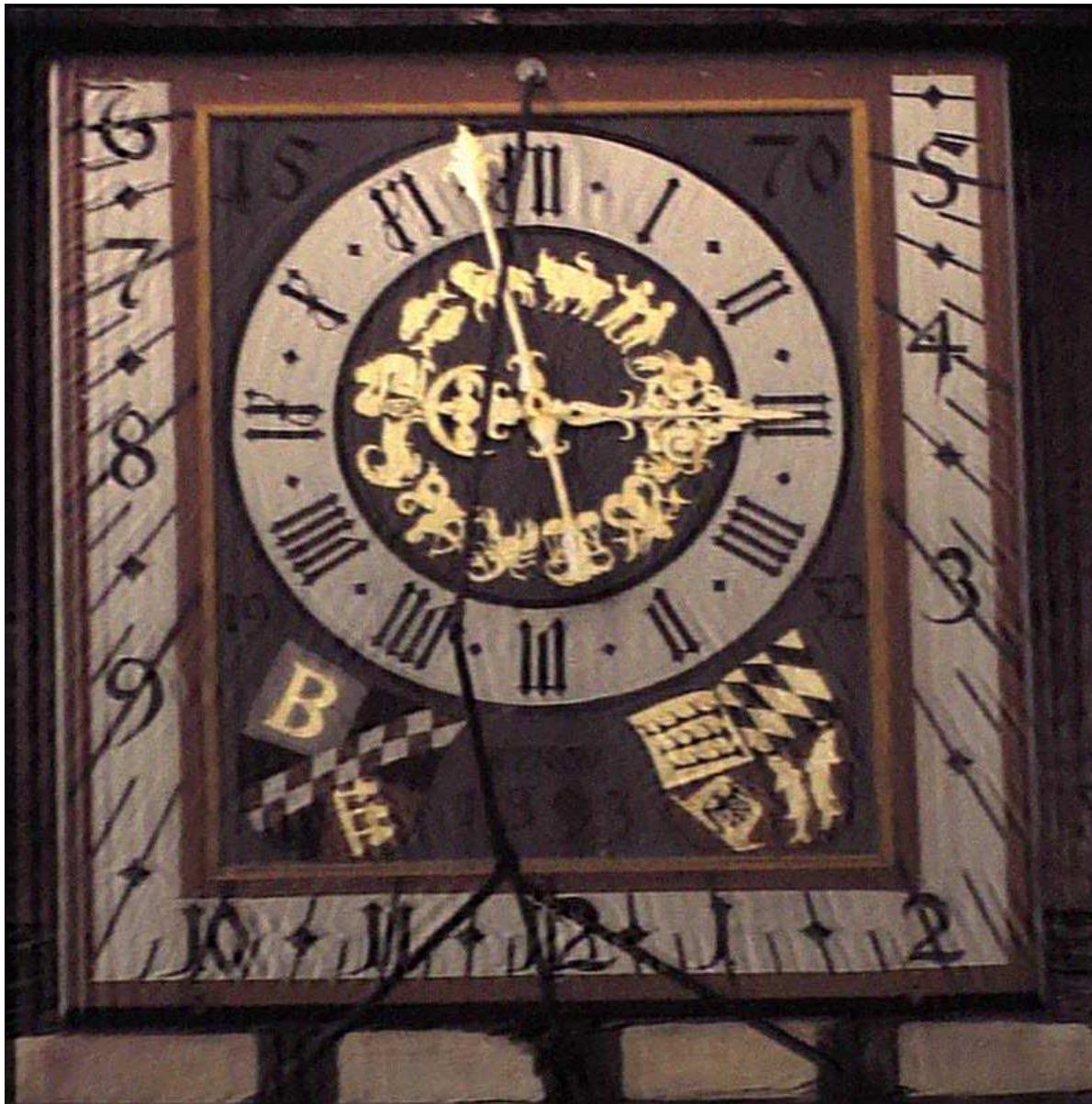


Ground Truth

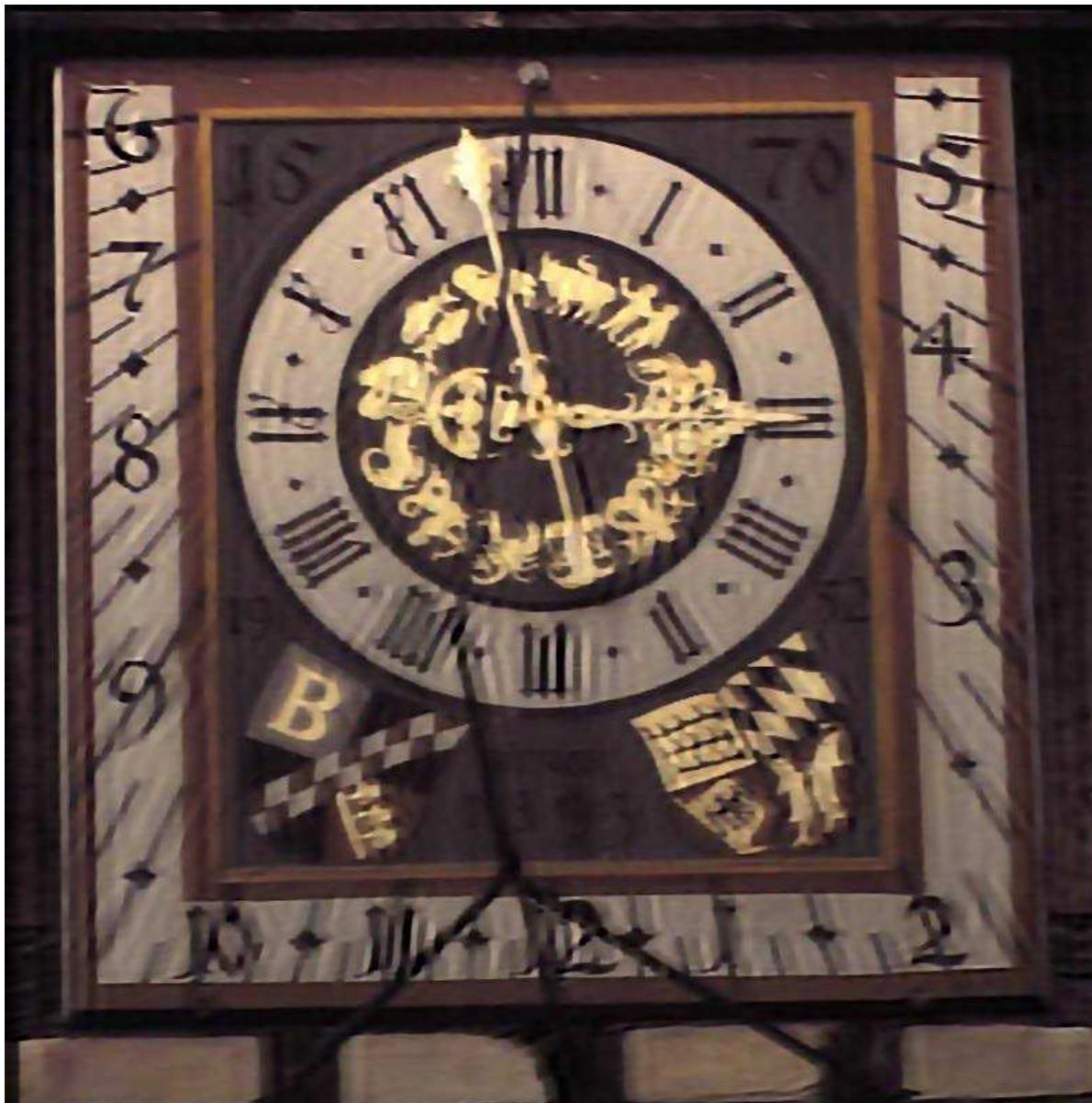
Synthetic - Clock (kernel 2) - Blurred



Synthetic - Clock (kernel 2) - Cho



Synthetic - Clock (kernel 2) - Xu



Synthetic - Clock (kernel 2) - BD + Stitch



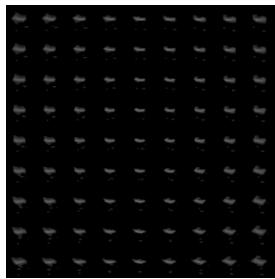
Synthetic - Clock (kernel 2) - RSMD



Synthetic - Clock (kernel 2) - Ground Truth

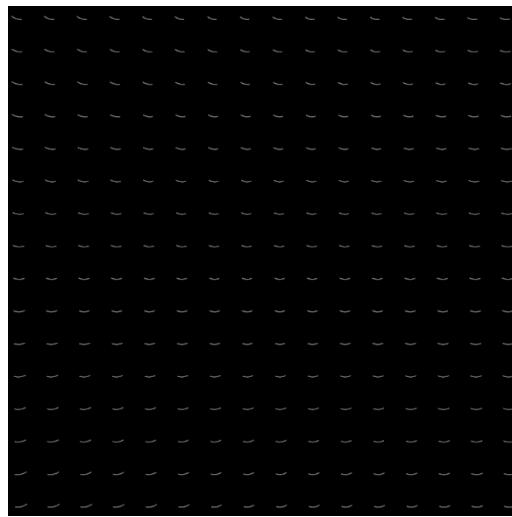


Synthetic - Clock (kernel 2) - Kernel Estimations

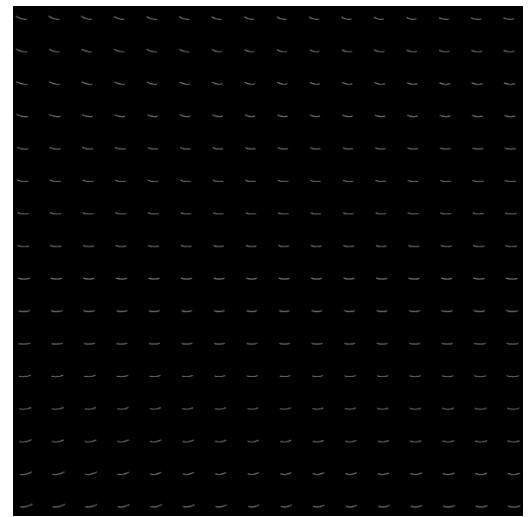


BD (Cho)

BD (Xu)*



RSMD



Ground Truth

* Scaled for visualization.

Synthetic - Fish (kernel 1) - Blurred



Synthetic - Fish (kernel 1) - Cho



Synthetic - Fish (kernel 1) - Xu



Synthetic - Fish (kernel 1) - BD + Stitch



Synthetic - Fish (kernel 1) - RSMD



Synthetic - Fish (kernel 1) - Ground Truth



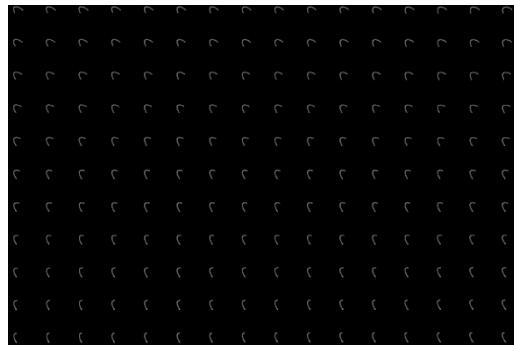
Synthetic - Fish (kernel 1) - Kernel Estimations



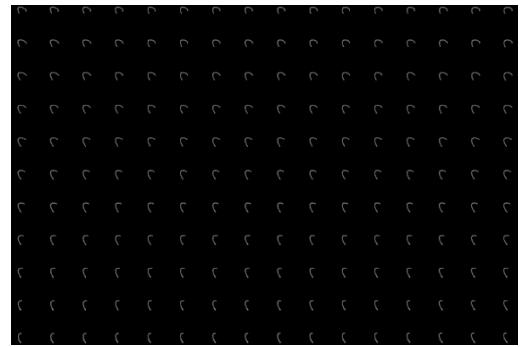
BD (Cho)



BD (Xu)*



RSMD



Ground Truth

* Scaled for visualization.

Synthetic - Fish (kernel 2) - Blurred



Synthetic - Fish (kernel 2) - Cho



Synthetic - Fish (kernel 2) - Xu



Synthetic - Fish (kernel 2) - BD + Stitch



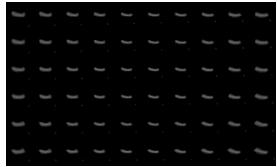
Synthetic - Fish (kernel 2) - RSMD



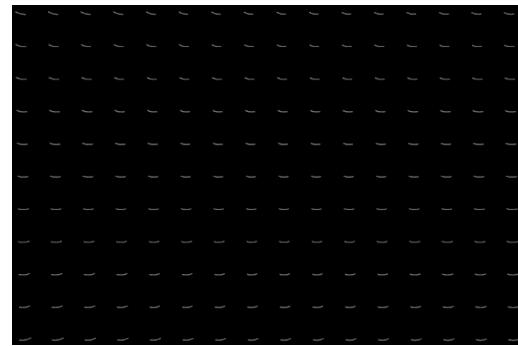
Synthetic - Fish (kernel 2) - Ground Truth



Synthetic - Fish (kernel 2) - Kernel Estimations

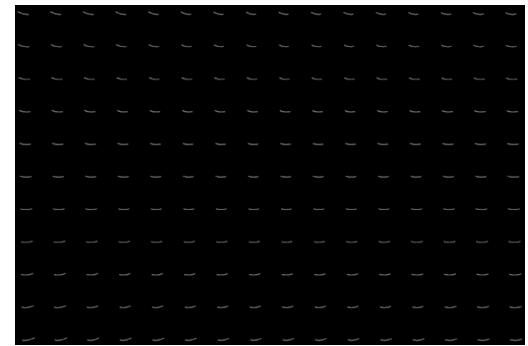


BD (Cho)



BD (Xu)*

RSMD

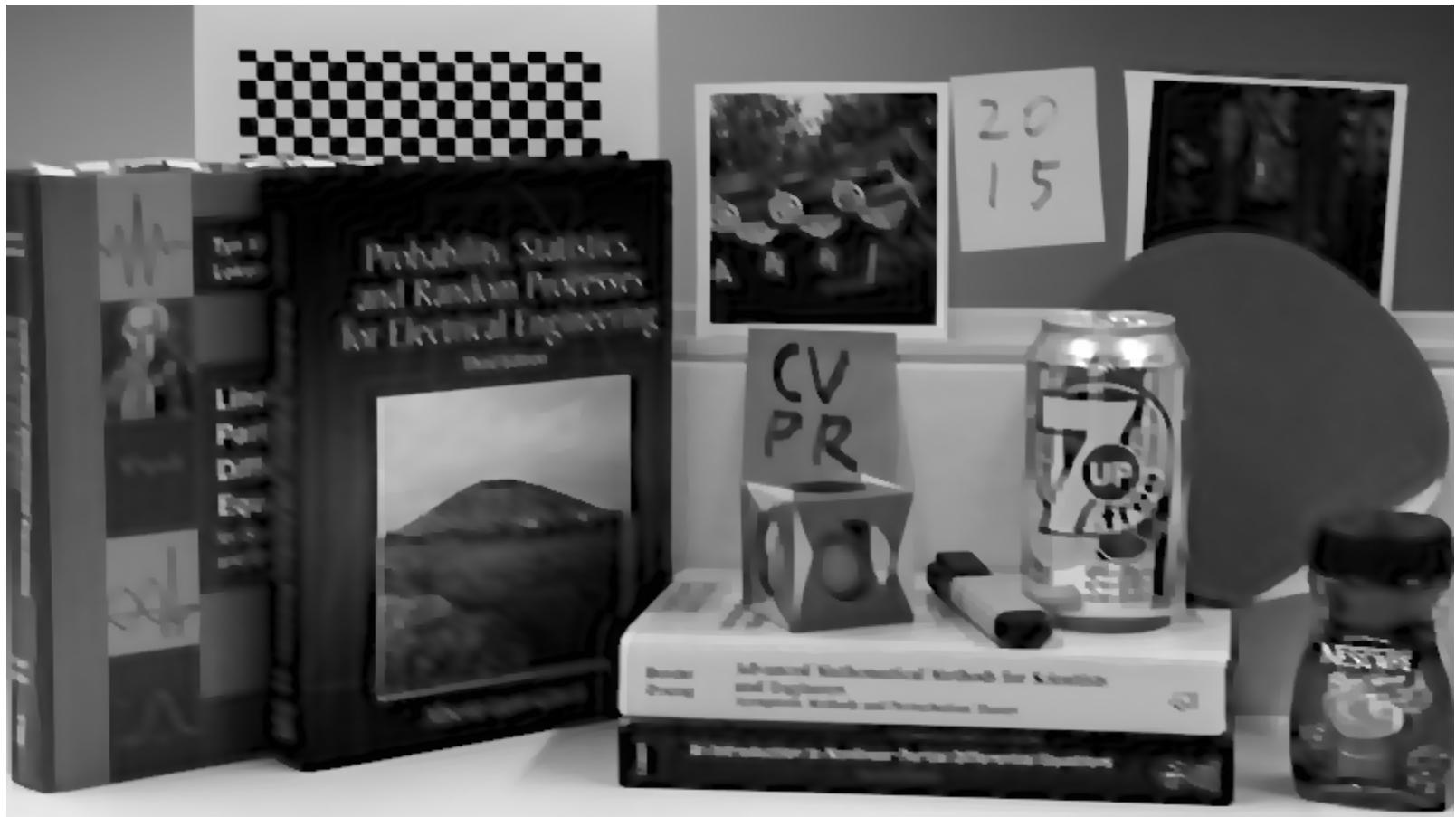


Ground Truth

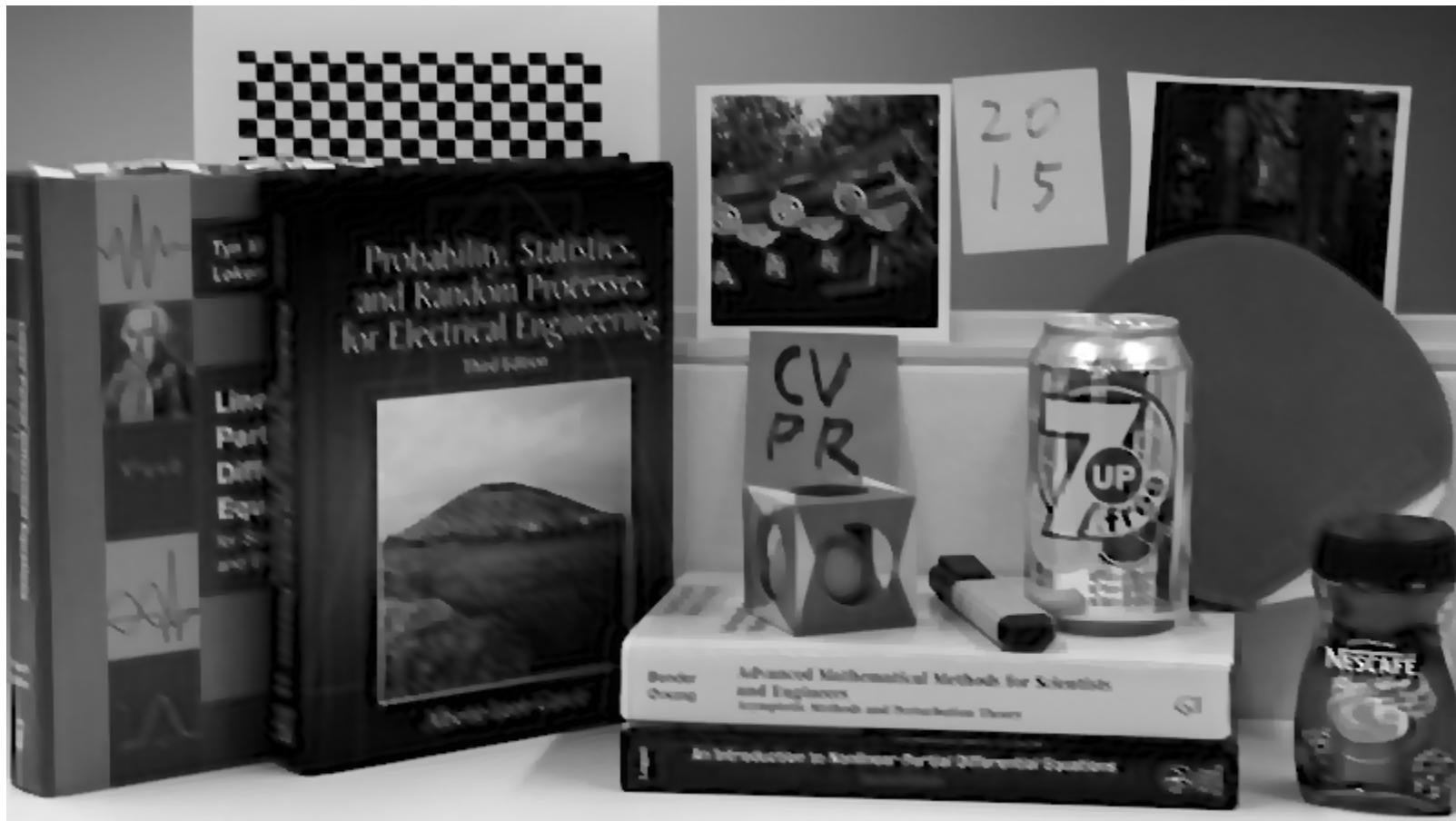
Intermediate Output

- Here we show additional examples of Fig. 5 from the paper, the intermediate output of *Desk*, to demonstrate the power of the proposed alternating optimization.

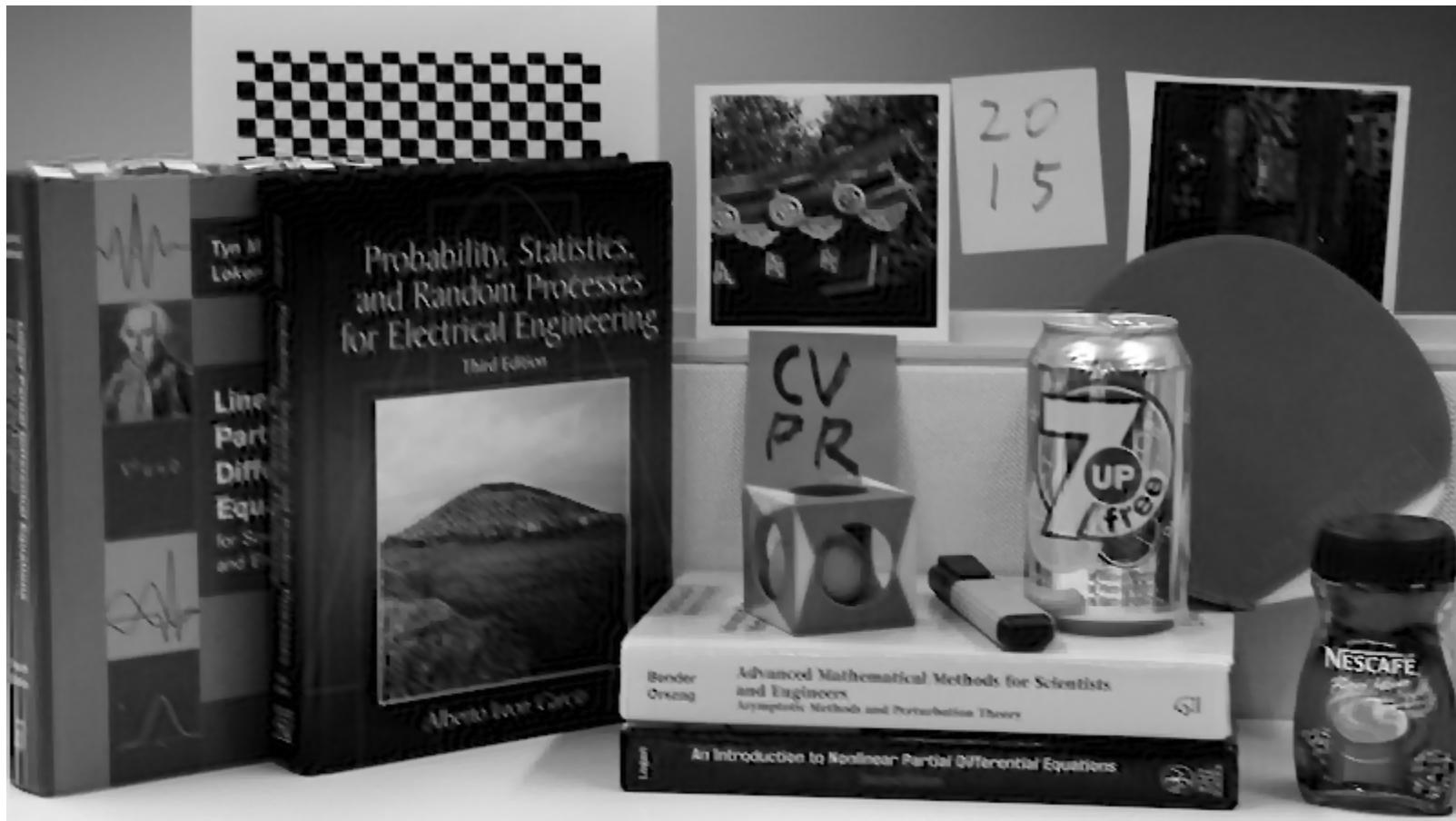
Latent image - First iteration



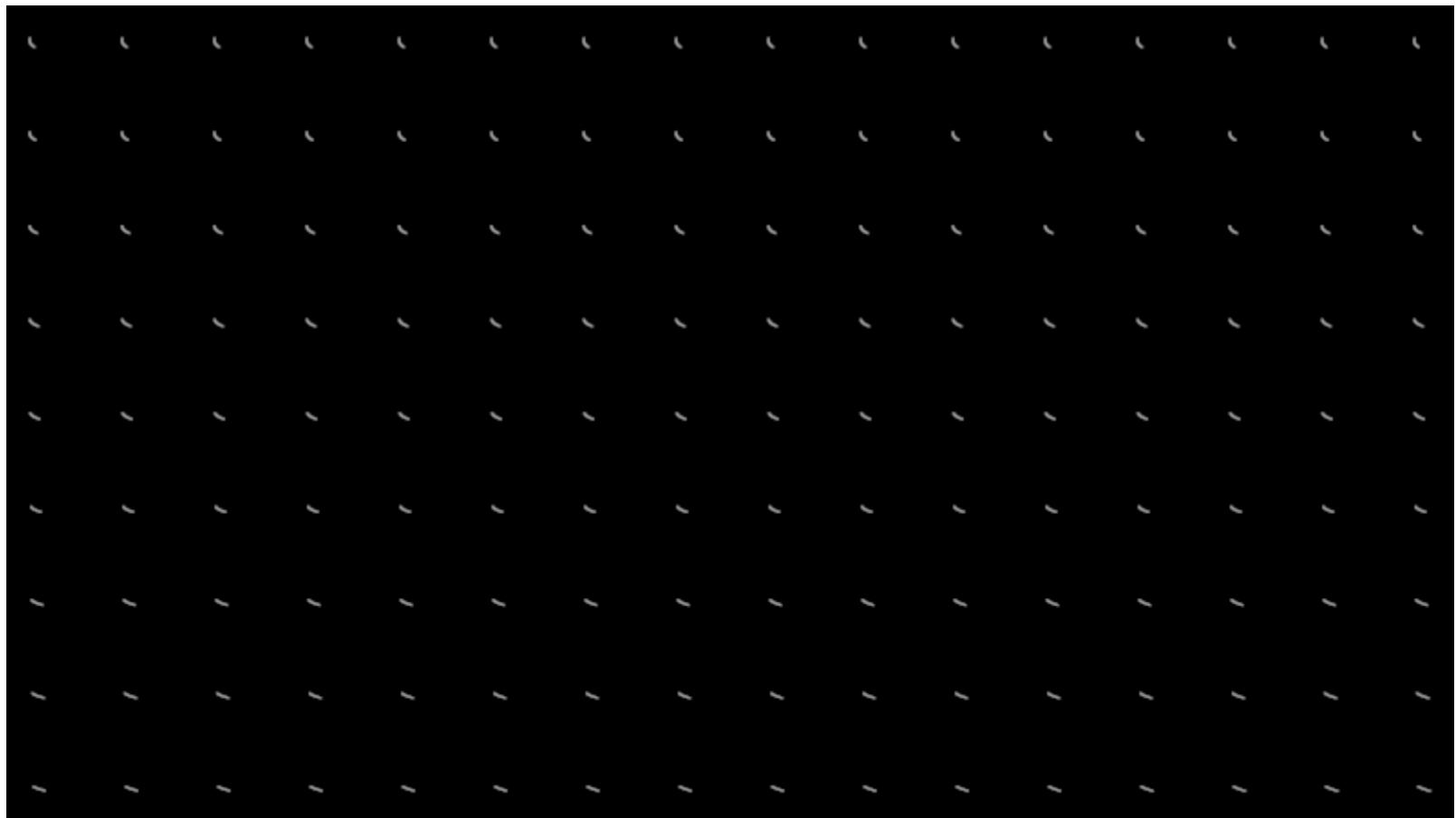
Latent image - Middle iteration



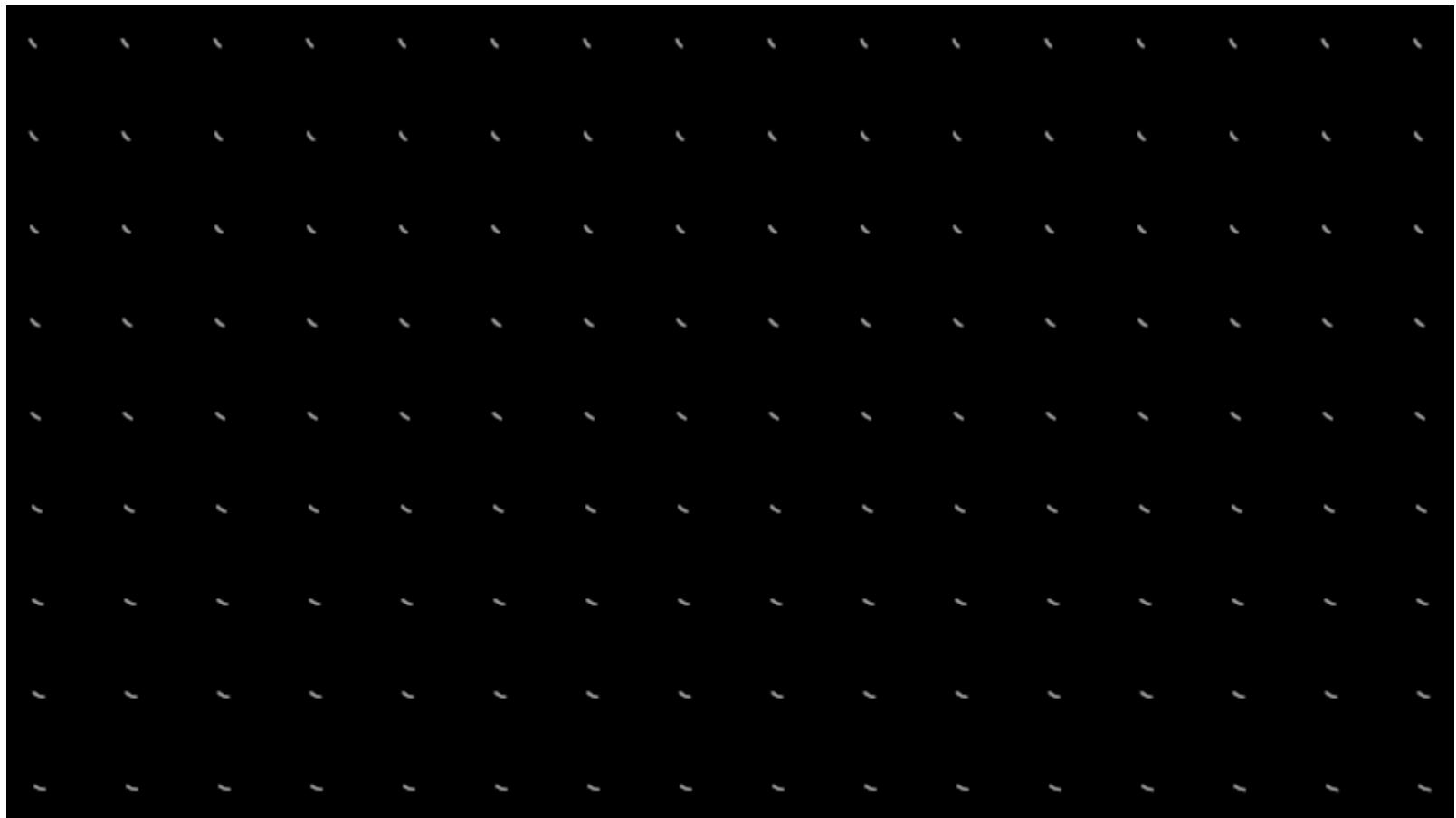
Latent image - Final iteration



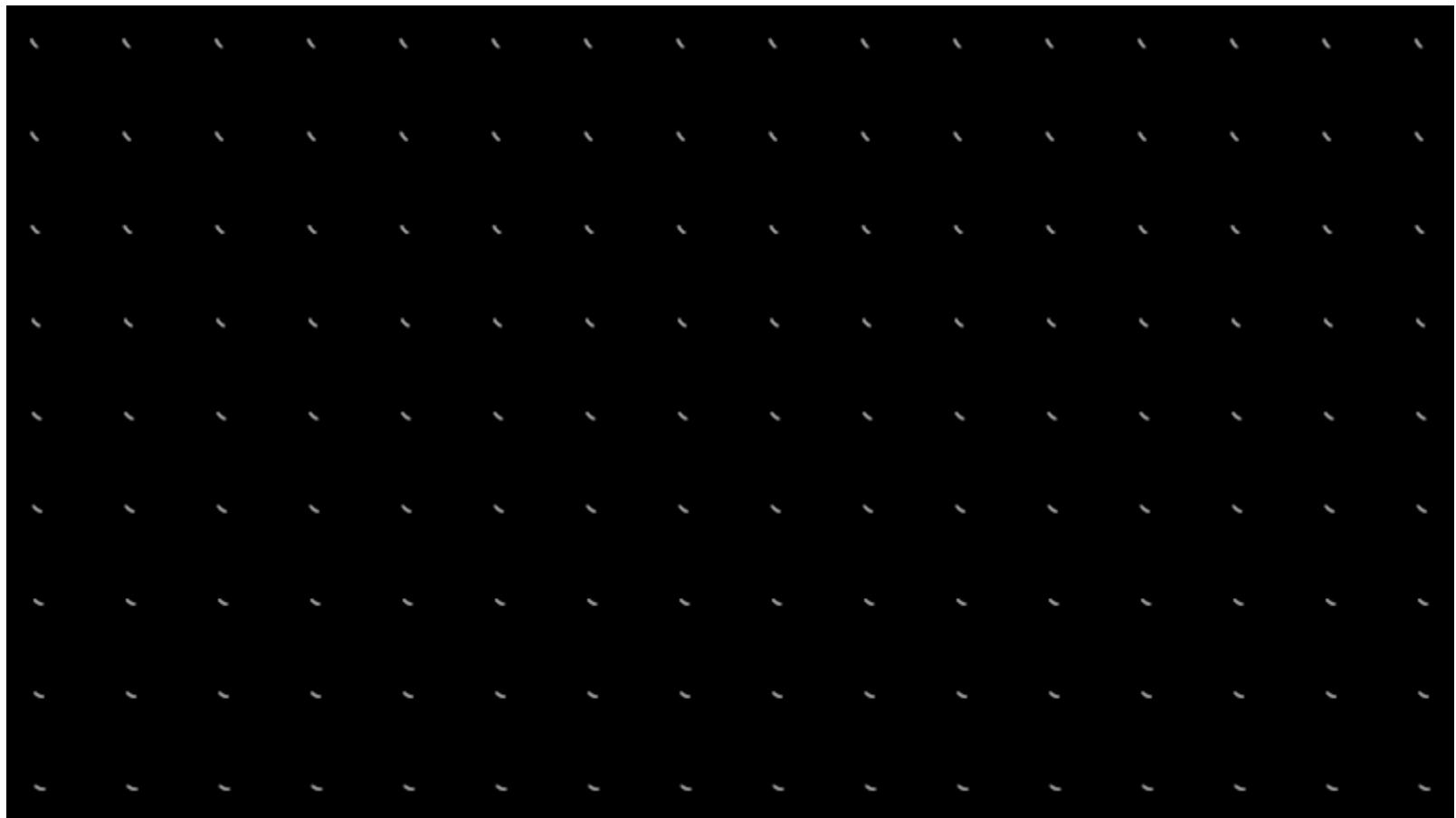
Trajectory coefficient (visualized as blur kernels) - First iteration



Trajectory coefficient (visualized as blur kernels) - Middle iteration

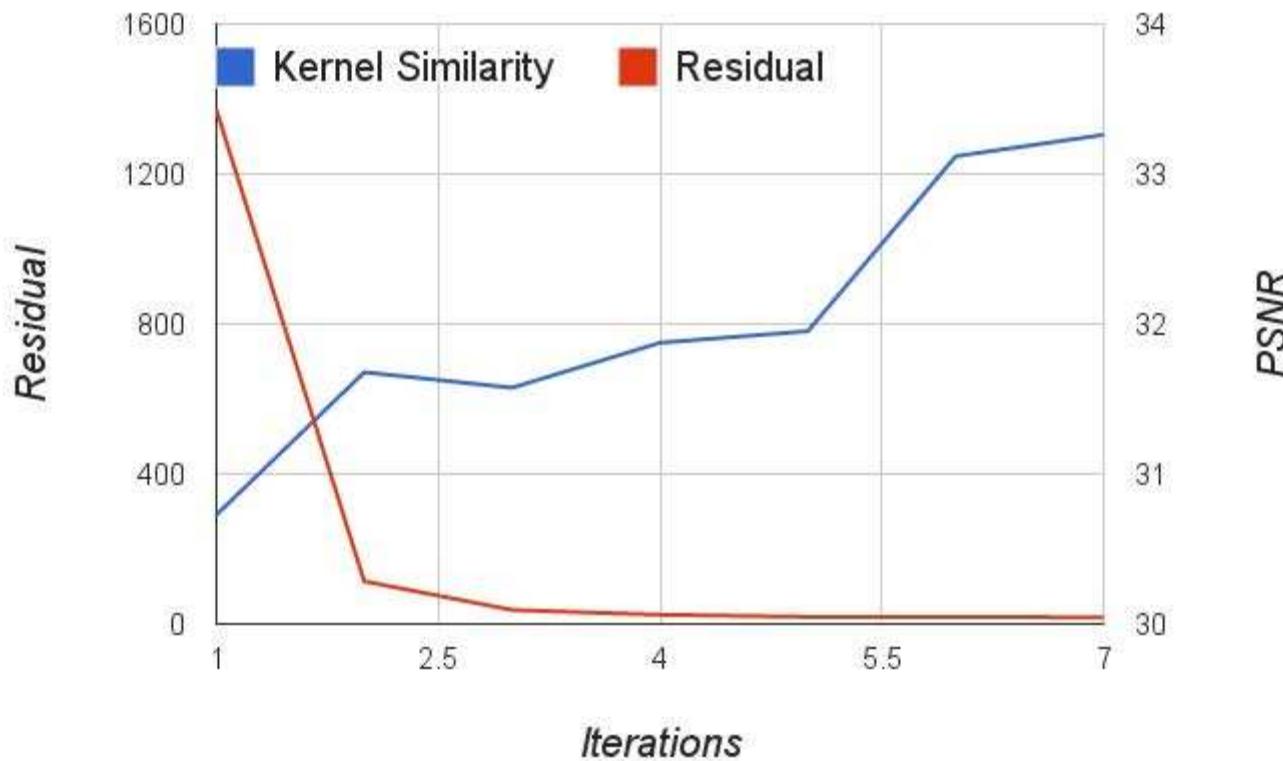


Trajectory coefficient (visualized as blur kernels) - Final iteration



Gauss-Newton Kernel Estimation

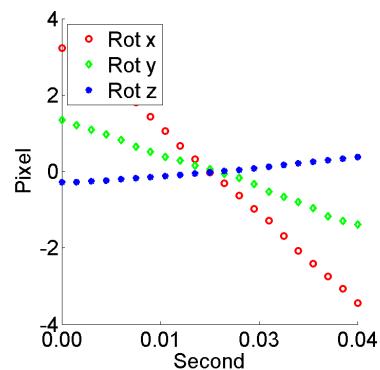
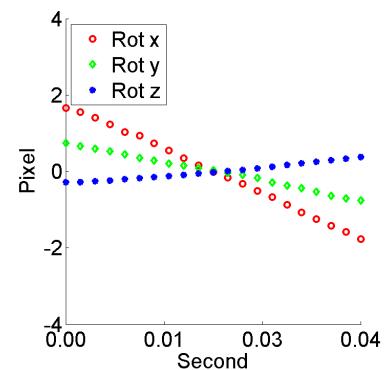
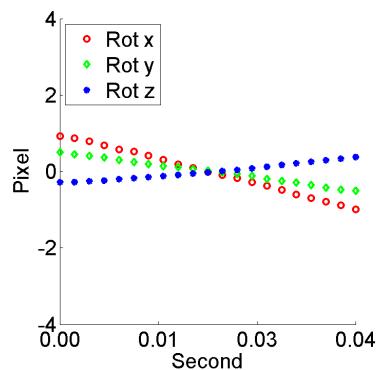
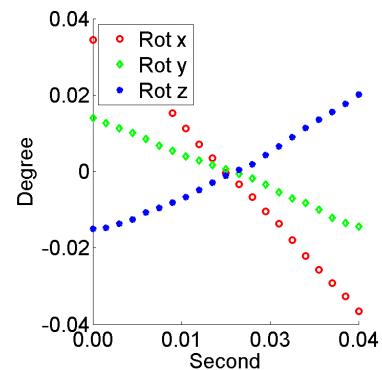
- Here we perform an analysis of the Gauss-Newton based kernel estimation algorithm on *Clock (kernel 1)*, to demonstrate the convergence of the residual (Eq. (9)) and kernel similarity to the ground truth in iterations.



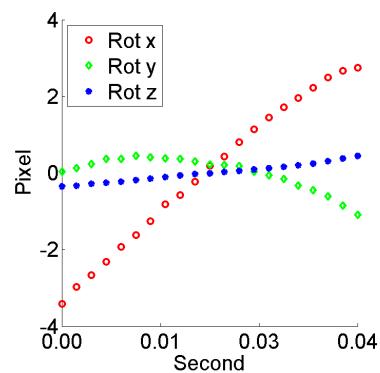
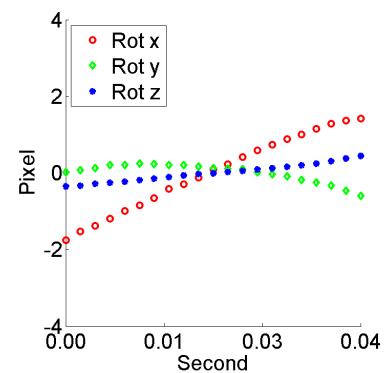
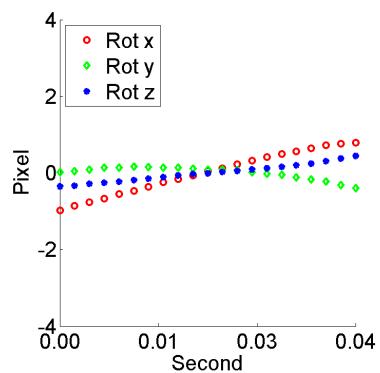
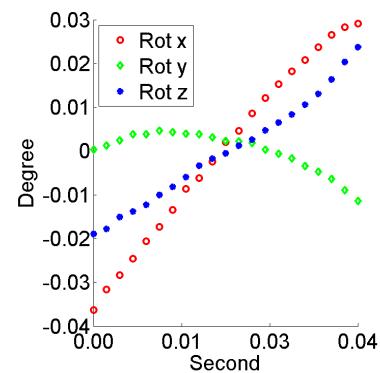
Negligibility of In-Plane Rotation

- Here we show additional examples of Fig. 3 from the paper
 - Three more camera motion trajectories from Kohler *et al.* and the resulting blur under different focal lengths.
 - Maximal blur of all the motions from Kohler *et al.*'s database, sorted by the in-plane rotation component.
- Conclusion
 - The blur caused by the in-plane rotation (Rot z) stays constant with varying focal length, while Rot x and Rot y cause larger blur as the focal length increases.
 - In-plane rotation is negligible except for very wide angle lenses. The spatial variance of the blur kernels in RSMB images is mainly caused by the rolling shutter as opposed to the in-plane rotation.

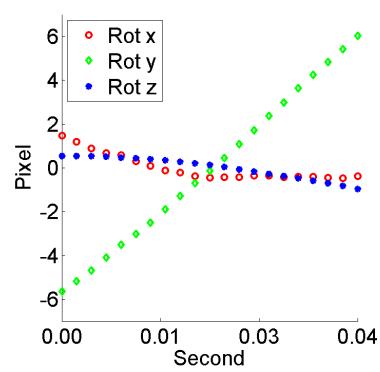
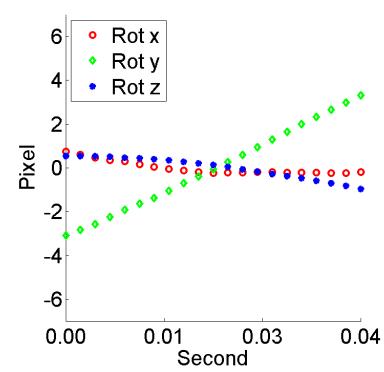
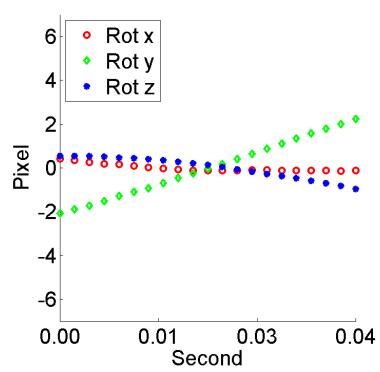
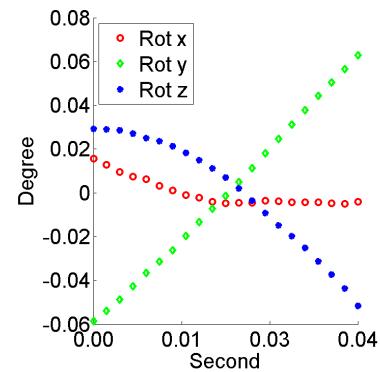
Motion 1



Motion 2



Motion 3

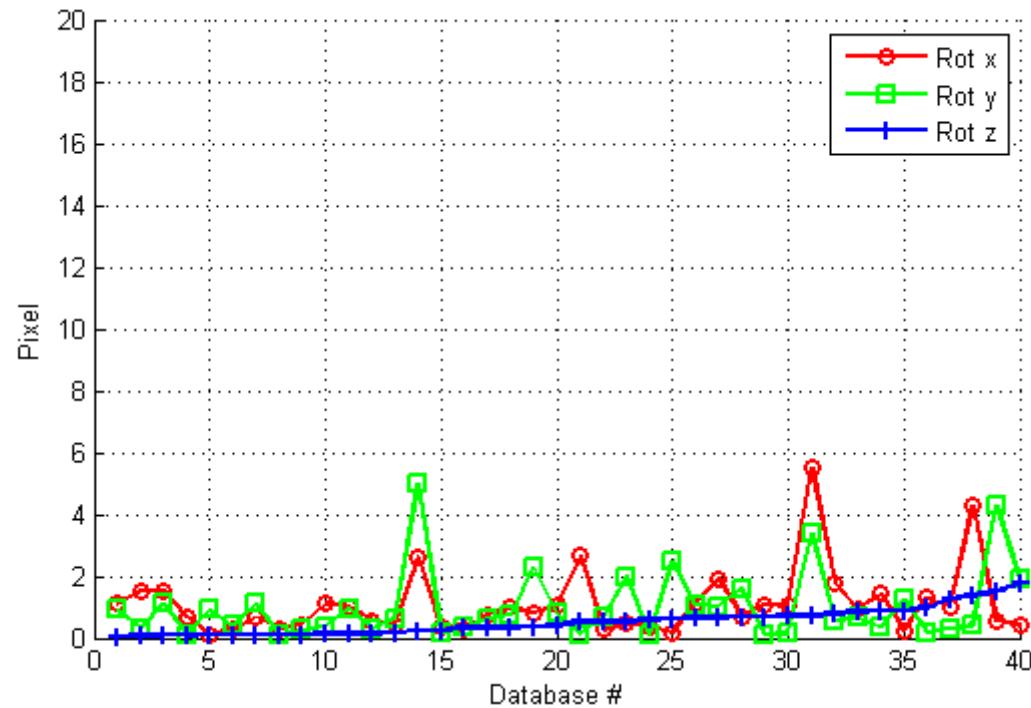


Pose space

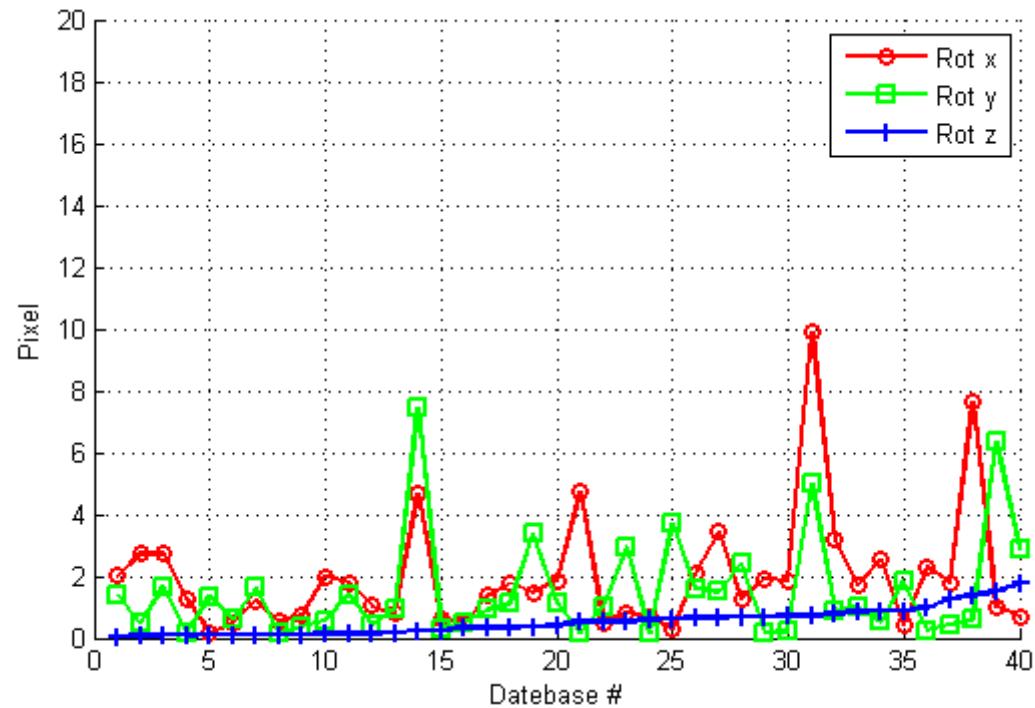
Pixel space (24mm)

Pixel space (50mm)

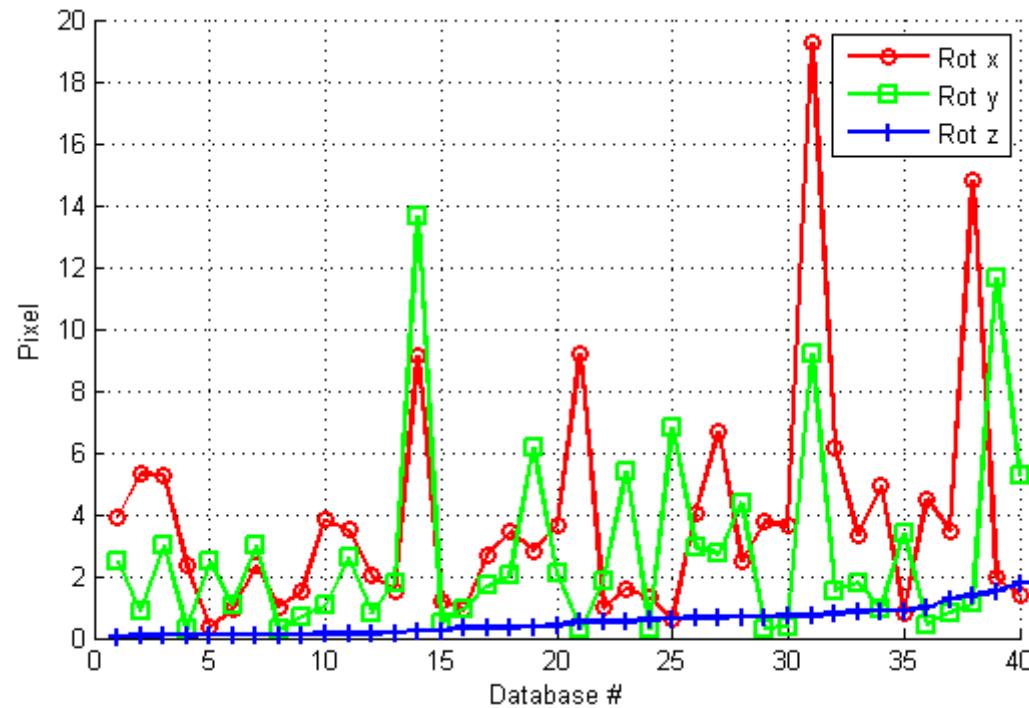
Pixel space (100mm)



Maximal blur (24mm)



Maximal blur (50mm)



Maximal blur (100mm)

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