Splicing Localization in Motion Blurred 3D Scenes

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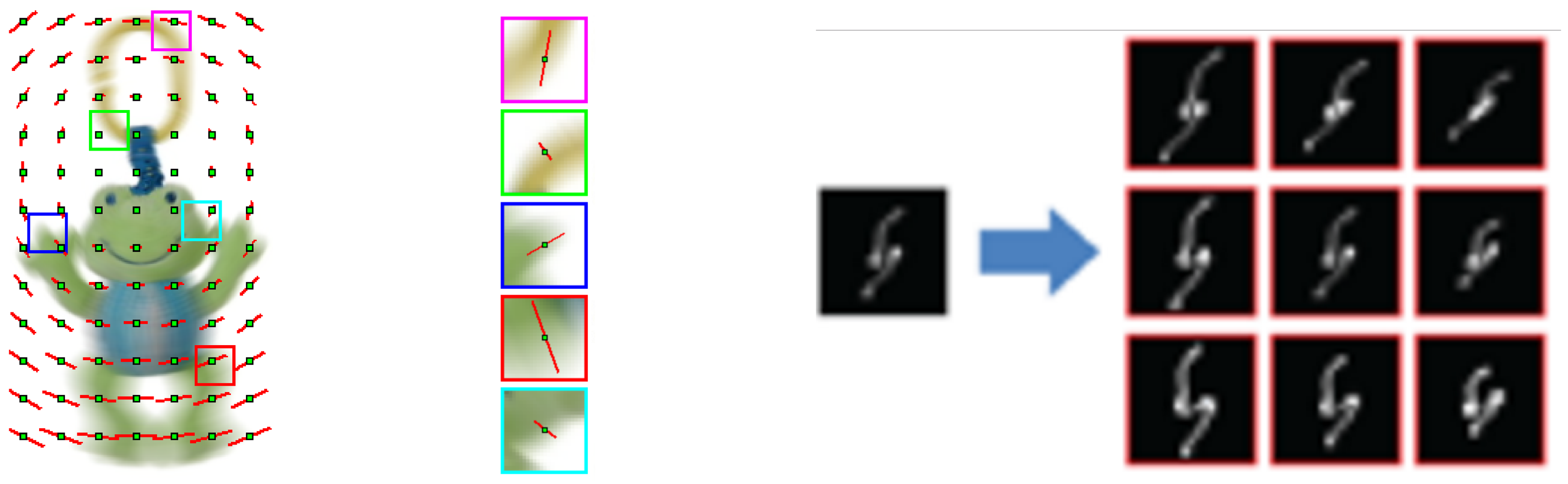
Introduction and motivation

- Given a single image of a static 3D scene, this work solves two tasks: a **Exposing Image Forgery** and a **Depth-based Scene Segmentation** by recovering camera motion that occurred during exposure.
- Necessary, since it is not possible to detect using naked eye. Previous techniques could not handle 3D scenes containing motion blur.
- **High level idea**: Scene Depth, camera trajectory and motion-blur kernels are inter-related.
- **Challenge**: Knowledge of one is required to estimate the other.
- **Solution**: Discovered a consistency between horizontal and vertical projections of spatially-varying blur kernels within an image.



Blurred Image   Kernels   Typical spatial variations

Blurring Model

- Pixel correspondences $\mathbf{x}$ and $\mathbf{x}_\lambda$ at depth Z, after a transformation $[\phi^\lambda, T^\lambda]$

$$\mathbf{x}_\lambda = KR_\lambda K^{-1}\mathbf{x} + \frac{KT_\lambda}{Z} \quad (1) \qquad \mathbf{x}_\lambda = P_{\phi^\lambda_z, \frac{T^\lambda}{Z}}(\mathbf{x}) = \begin{pmatrix} 1 & -\phi_z^\lambda & f\frac{t_x^\lambda}{Z} \\ \phi_z^\lambda & 1 & f\frac{t_y^\lambda}{Z} \\ 0 & 0 & 1 \end{pmatrix}\mathbf{x}$$

- If w_i denotes the fraction of time camera spent in position i, motion blurred image B can be derived from focussed image I as

$$B(\mathbf{x}) = \sum_{i=1}^{N} w_i I(P^{-1}_{\Phi_i,T_i}(\mathbf{x})) \qquad (2)$$

- Similarly, PSF at $\mathbf{x} = (x, y)$ can be derived from a single point:

$$p(x,y) = \sum_{i=1}^{N} w_i \delta(P^{-1}_{\Phi_i,T_i}(x,y)) \qquad (3)$$

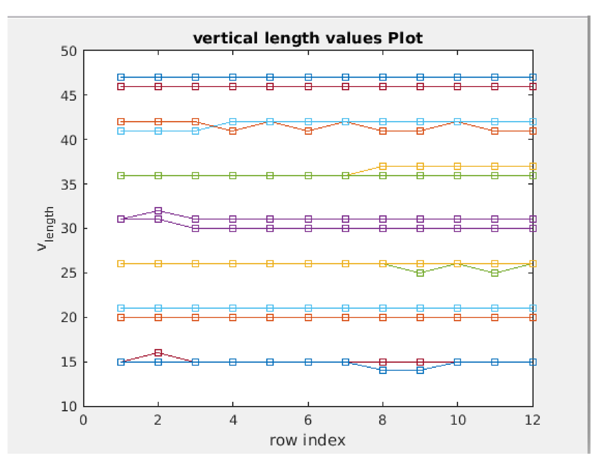
- In matrix form, it is equivalent to $p^{(x,y)} = M^{(x,y)}W_D$

Consistency of h_{length} and v_{length}

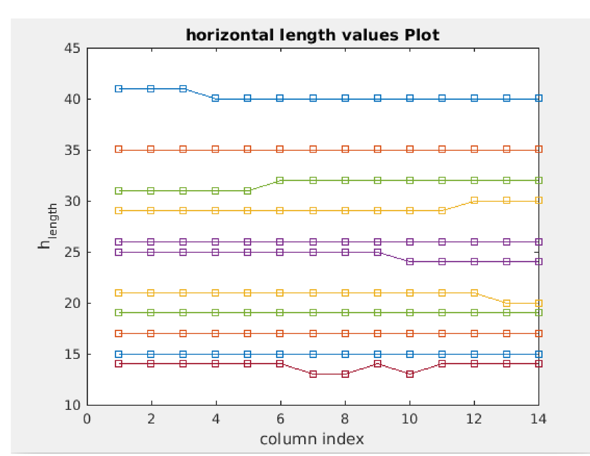
- **Assumption** Small angle of rotation ϕ.
- If we pick any two points: $\mathbf{x}_i$ and $\mathbf{x}_j$ on a PSF, the difference in their spatial locations can be expressed in terms of the PSF's pixel coordinate x and y:

$$\Delta x^l_{ij} = (x^l\ y^l\ 1)\begin{pmatrix} 0 \\ -(\phi^j - \phi^i) \\ \frac{(t_x^j - t_x^i)f}{Z^l} \end{pmatrix} = -y^l(\Delta\phi^{ij}) + \frac{(\Delta t_x^{ij})f}{Z^l} \qquad (4)$$

$$\Delta y^l_{ij} = (x^l\ y^l\ 1)\begin{pmatrix} (\phi^j - \phi^i) \\ 0 \\ \frac{(t_y^j - t_y^i)f}{Z^l} \end{pmatrix} = x^l(\Delta\phi^{ij}) + \frac{(\Delta t_y^{ij})f}{Z^l} \qquad (5)$$



(a) Vertical-lengths vs rows



(b) Horizontal-lengths vs columns

Figure 1: We can see that values Δx^l_{ij} and Δy^l_{ij} turn out to be constant for all the PSFs lying on same column index y and same row index x, respectively.

Camera Trajectory Estimation

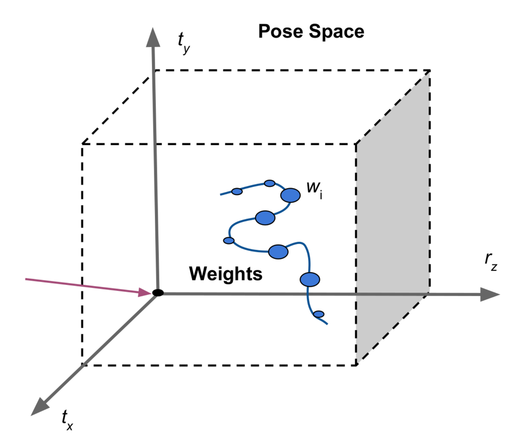


Figure 2: Camera Trajectory.

- Camera Trajectory estimation from local PSFs. Algorithm: [3].

$$p^{set} = M^{set}W_D \qquad (6)$$

- Minimize with sparsity constraint.

$$\| p^{set} - M^{set}W_D \|^2 + c \| W_D \|^1 \qquad (7)$$

Matching PSFs at various depths

Using depth and camera trajectory, we generate all possible PSFs at location $\mathbf{x}$. If the pixel $\mathbf{x}$ was actually situated at a different scene depth D_i , the PSF would be modified as follows

$$p^{D_i}(\mathbf{x},\mathbf{a}) = \sum_{\lambda=1}^{N} w_\lambda \delta(\mathbf{a} - (P_{\phi^\lambda, \frac{T^\lambda}{k_i D}}(\mathbf{x}) - \mathbf{x}))d\tau \qquad (8)$$

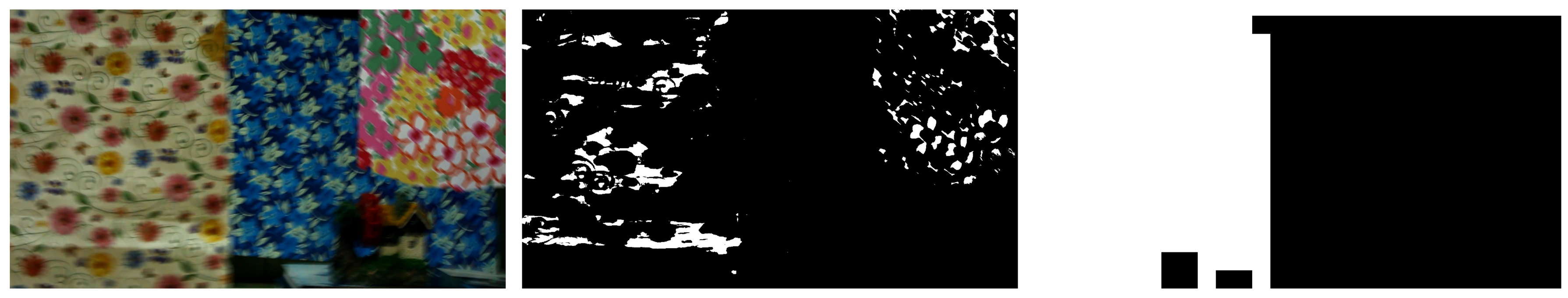
Low cross-correlation between actual PSF and estimated PSFs → Region Spliced!

Results

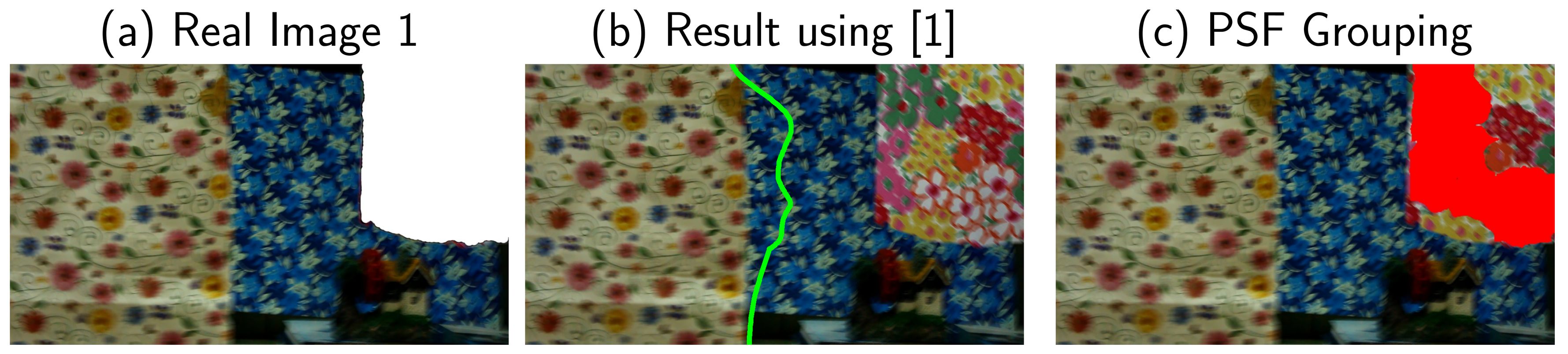
- Finally, we utilize natural image texture segmentation [Mobahi, IJCV 2011] of the input image to obtain meaningful region boundaries.

(a) (b) (c) (d) (e)

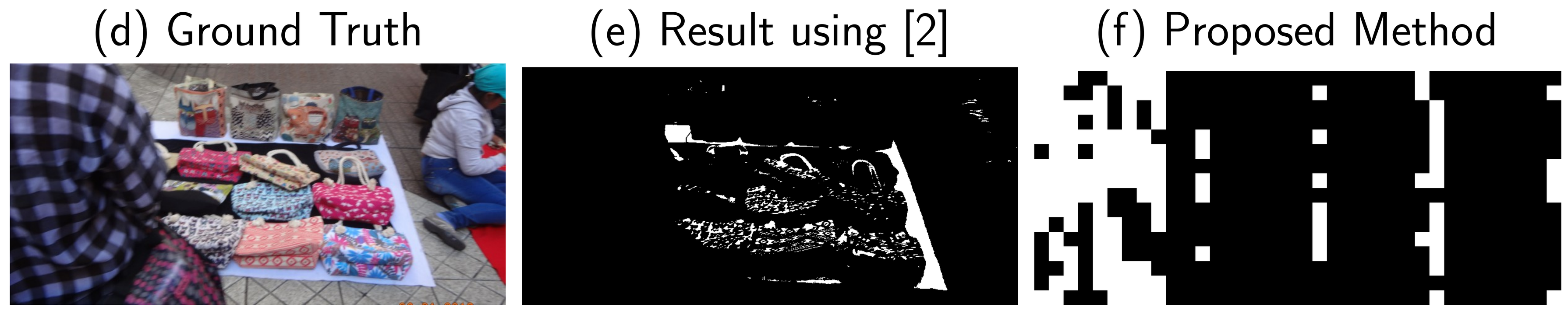
Table 1: Intermediate results after each step (a) Input spliced image (b) PSF grouping (all white pixels belong to single depth layer) (c) Patch-wise inconsistency between blur kernels (d) Texture based segmentation of the input image (e) Final result showing localized spliced region in red



(a) Real Image 1   (b) Result using [1]   (c) PSF Grouping



(d) Ground Truth   (e) Result using [2]   (f) Proposed Method



(g) Real Image 2   (h) Result using [1]   (i) PSF Grouping

(j) Ground Truth   (k) Result using [2]   (l) Proposed Method

References

[1] D.-Y. Hsiao and S.-C. Pei, "Detecting digital tampering by blur estimation," in *Systematic Approaches to Digital Forensic Engineering, 2005. First International Workshop on*. IEEE, 2005, pp. 264–278.

[2] M. P. Rao, A. N. Rajagopalan, and G. Seetharaman, "Harnessing motion blur to unveil splicing," vol. 9, no. 4. IEEE, 2014, pp. 583–595.

[3] C. Paramanand and A. Rajagopalan, "Shape from sharp and motion-blurred image pair," *International journal of computer vision*, vol. 107, no. 3, pp. 272–292, 2014.

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