# TAPPING MOTION BLUR FOR ROBUST NORMAL ESTIMATION OF PLANAR SCENES


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## 1 Introduction

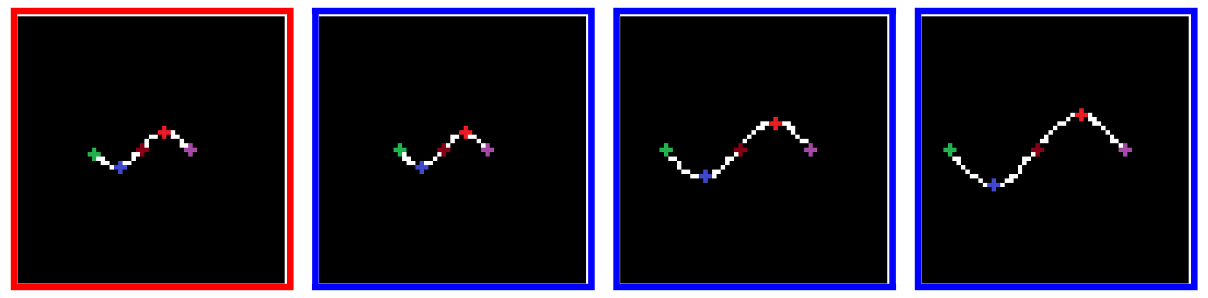
- We propose a framework for robust estimation of surface normal of a planar scene from a single motion-blurred image.
- Assumption: The scene is static and the blur is due to in-plane translations of camera.
- Applications: High-level scene description, classification etc.

## 2 Blur kernels and correspondences

- The blur kernel at any location x can be expressed as a function of the set of homographies induced by camera motion during the exposure time $T_e$

$$h(\mathbf{x},\mathbf{s}) = \frac{1}{T_e}\int_0^{T_e} \delta\left(\mathbf{s} - (H_\nu(\mathbf{x}) - \mathbf{x})\right) d\nu \tag{1}$$

- In the assumed scenario the homography at time $\nu$ is given by, $H_\nu = K\left(I + t_\nu \frac{n^T}{d}\right)K^{-1}$
- If the scene is not fronto-parallel, blur kernel varies as a function of the spatial location in the image.



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

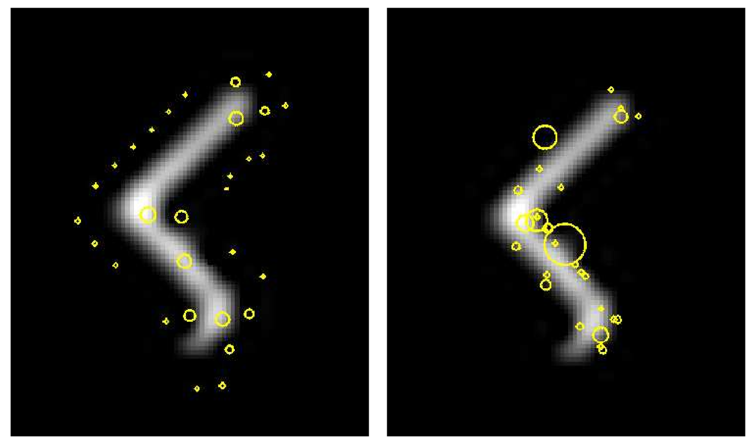
Figure 1: Blur kernel for (a) fronto-parallel scene, and (b-d) inclined plane for different positions on the blurred image

## 3 Normal estimation and feature detection on blur

- Difference in spatial location along $x$, $\triangle x_{p_i}$ of a pair of points on the $i^{th}$ kernel can be related to desired normal $(N_X,\ N_Y,\ N_Z)$ as

$$\begin{bmatrix} \triangle x_{p_1} \\ \triangle x_{p_2} \\ . \\ . \\ \triangle x_{p_\beta} \end{bmatrix} = \begin{bmatrix} x_1 & y_1 & 1 \\ x_2 & y_2 & 1 \\ . & . & . \\ . & . & . \\ x_\beta & y_\beta & 1 \end{bmatrix} \begin{bmatrix} N_X \frac{\triangle T_{X_\nu}}{d} \\ N_Y \frac{\triangle T_{X_\nu}}{d} \\ f N_Z \frac{\triangle T_{X_\nu}}{d} \end{bmatrix} \tag{2}$$

where $(x_i, y_i)$ is the location of blur kernel on the blurred image, $\beta$ indicates number of blur kernels, $\triangle T_{X_\nu}$ is the difference between corresponding translational motions of camera along $x$.



(a) (b)

Figure 2: Feature points detected by (a) SIFT and (b) HL .

- Harris Laplace (HL) detector was observed to give reliable points i.e. points with in the blur kernel, as compared to other feature detectors.
- We use HL detector and SIFT descriptor to find feature points and its correspondences across blur kernels.
- Each pair of points and their correspondences can give a single estimate of normal using equation (2).

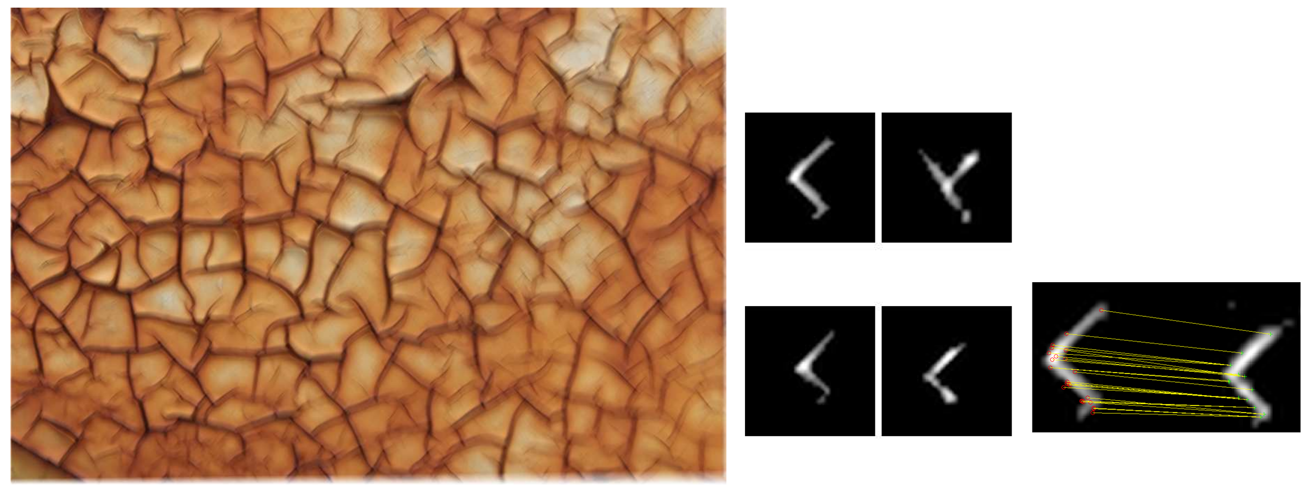
## 4 Robust normal estimation

- Existing work by Purna et al. (say method 1) uses extreme points of blur kernel as the pair of points to yield the desired normal.
- Although the each pair of points are governed by different homographies we exploit the fact that they all conform to the same normal.
- We use every possible pair of feature points to yield ${}^{N}C_2$ normal estimates, where N is the total number of feature points.
- Since some of these estimates could be wrong, we employ hierarchical clustering to group the normals into a number of clusters.

  **Claim**: *The set of all homographies of a planar scene induced by in-plane translational motion of the camera lies in a 3-dimensional space.*
- Compute the residual error for 3-rank approximation of the homographies corresponding to normals in each cluster.
- The mean of the cluster with the lowest residual error yields robust estimate of the desired normal.

## 5 Experimental Results

- Synthetic example

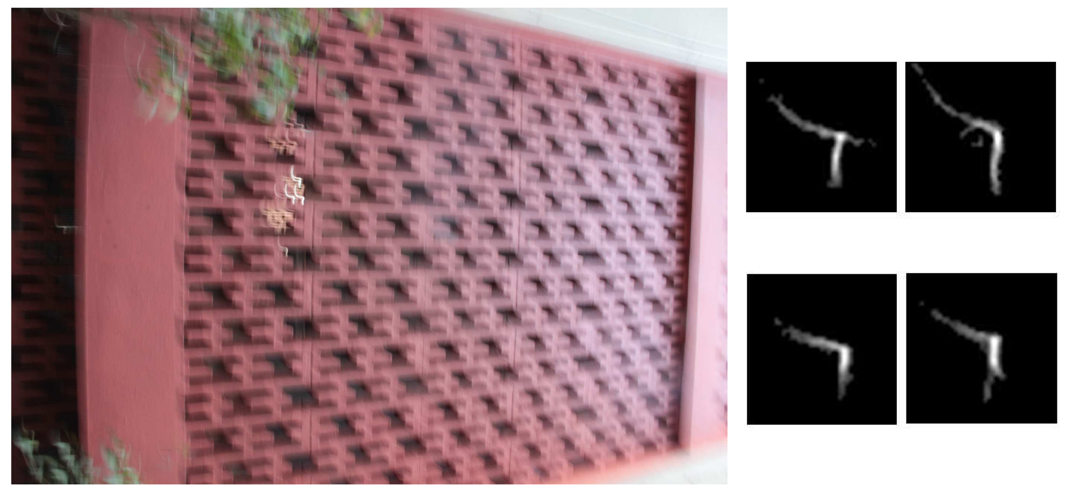


(a) (b) (c)

Figure 3: (a) Motion blurred image. (b) Blur kernels (PSFs) at different locations of (a). (c) Depiction of matches between two kernels.

For this example, error in the normal estimate using proposed method was found to be 5.2 degrees as compared to 15 degrees of method 1.

- Real example
- We compute the average angular deviation from mean (AADM) of 10 independent estimates of normal, to asses the accuracy of the estimated normal in real experiments.



(a) (b)

Figure 4: (a) Inclined wall with normal oriented towards $X$-axis. (b) Extracted PSFs.

In this case, AADM for the proposed method was found to be 4.3 degrees as compared to 8.5 degrees of method 1.

## 6 Conclusions

- We proposed a scheme for robust estimation of planar orientation from a single motion blurred image.
- Employ a rank-3 constraint within a hierarchical clustering framework, to make use of multiple feature correspondences across blur kernels.
- We plan to extend the scope to multiple planes.