techvista PUNE 2011

IITB-Monash Research Academy — An Indian-Australian Research Partnership

Microsoft Research india

Adaptive Kernel Sampling for Projector Defocus Blur Correction with Indirect Illumination Compensation in Multiplanar Environments

Shamsuddin Ladha, Sharat Chandran, Kate Smith-Miles

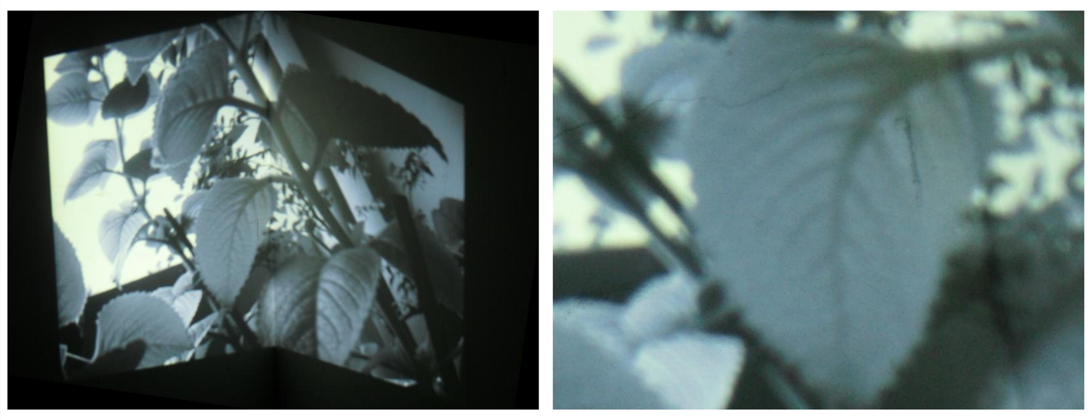
{sladha,sharat}@cse.iitb.ac.in | kate.smith-miles@monash.edu www.cse.iitb.ac.in/graphics

ViGIL

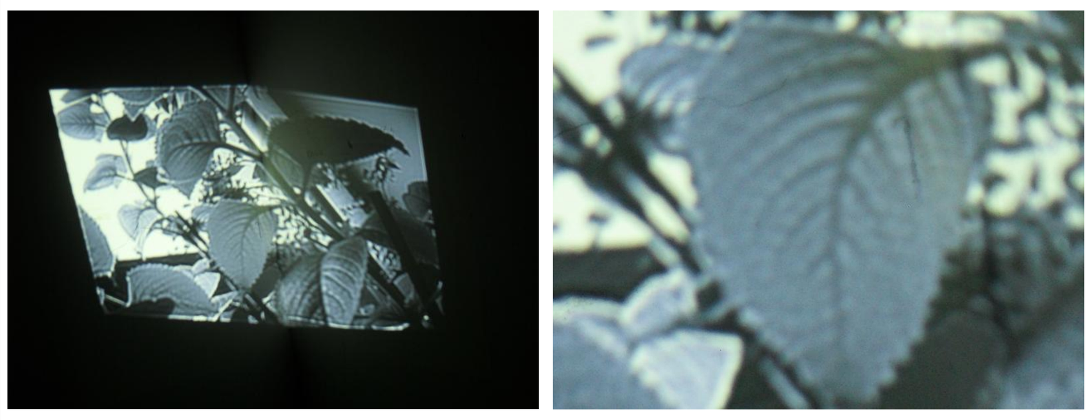
Problem Statement

Compensate for projector defocus blur and global illumination effects in multiplanar display environments

NOT a standard blur problem. The goal is to preserve image contents. Left: Input image to be shown. Right: A section of zoomed input image.



Left: When projected, the observed image (as captured by a camera) is geometrically distorted (horizontal lines are bent), blurred and has low contrast. Right: Zoomed output image depicting defocus blur.



Left: Corrected output (our method). Although smaller, the proportions are maintained; notice the horizontal line at the bottom. The resultant image is crisp and has better contrast. Right: Zoomed version of output.

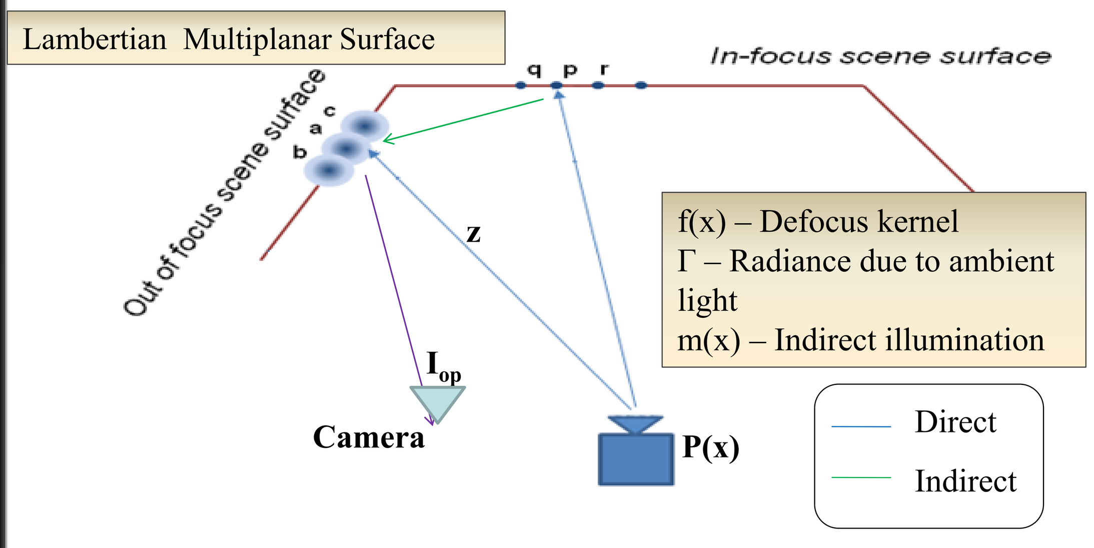
Motivation & Challenges

- Anywhere projection – Office of Future [4]
- More realistic virtual environments
- But what if surface is irregular or multiplanar?
- Limited dynamic range of projector: Focus only on a single fronto-parallel plane

Contributions

- Non-parametric blur estimation for multiplanar scene surface
- No assumption of existence of exemplar region
- Sparse sampling of scene surface for defocus kernel instead of [2]
- Compensation for indirect illumination effects due to oriented piece-wise planar display surface (Not considered in the literature before)

Problem Formulation



- Point a is out-of-focus and its irradiance equals sum of convolution of its defocus kernel with the light rays from projector and indirect illumination from neighbours

$$I_{op} = af(x)P(x) + bm(x)P(x) + \Gamma$$

Problem Formulation

- Project P',

$$P' = (af + bm)^{-1} * (I_{ip} - \Gamma)$$

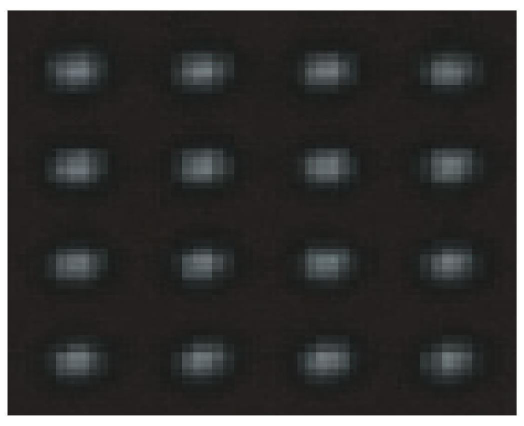
- Observed output (Iop) equals input (Iip)!
- Results in ringing artifacts and out of projector dynamic range pixel values

$$P' = \arg\min \{d(afP + bmP + \Gamma; I_{ip}); P(x) \in [0, 255]\}$$

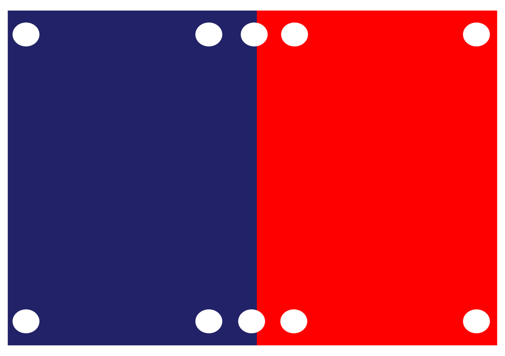
- Compute P' within dynamic range of projector by solving the minimization equation

Kernel Estimation

- Incorrect kernel estimates happen in [2] near the edge where two planar surfaces meet
- We observe, as distance of planar surface increases from projector, blur kernel can be linearly approximated
- Measure kernel at few key points on the display scene surface and then interpolate
- Key point identification requires knowledge of surface geometry
- Use surface geometry in image space



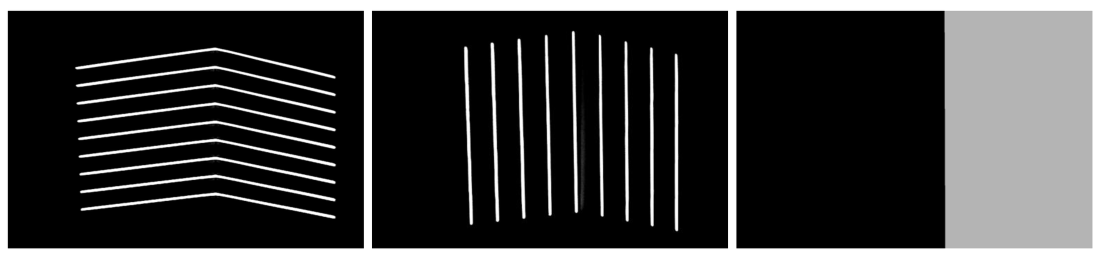
(a) Dense kernel sampling [2]



(b) Our approach – Adaptive kernel sampling

Geometric Correction

- Multiplanar environments result in defocus blur as well as geometric distortion
- Based on earlier work we compute edge **"kink"** where 2 planar surfaces meet in image plane by projecting various patterns
- Compute homography between projector and camera pixels for each planar surface
- Pre-warp pixels in each planar surface with inverse homography before projecting to correct for geometry



(a),(b) Horizontal & vertical projected patterns; (c) 2 planar surfaces identified in image space

Global Illumination Compensation

- Oriented planar scene surface results in indirect illumination
- [2] computes sum of squared pixel difference for image distance metric
- Each pixel in each channel (R, G, B) is solved independently

Our Approach

- Measure indirect illumination (M) between scene points by adapting radiosity concepts in image domain
- Don't address a pixel in isolation, take into account neighborhood of that pixel
- Correct for chrominance and luminance separately

- Convert from RGB to YCbCr to separate luminance and chrominance
- Modify the distance function based on [3] to reduce indirect illumination effect by minimizing

Global Illumination Compensation

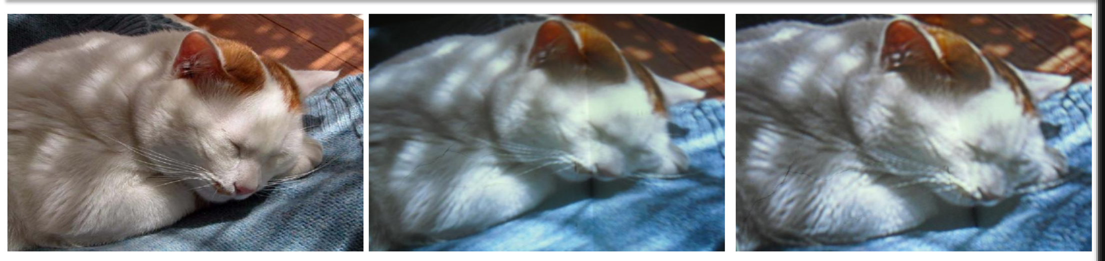
- Absolute luminance and chrominance error per pixel
- Spatial luminance and chrominance error in the neighborhood of a pixel

$$d(afP + bmP + \Gamma; I_{ip}) = ((F+M)P + \Gamma - I_{ip})^T W ((F+M)P + \Gamma - I_{ip})$$

$$W = aW_0 + bW_1 + cW_2 + dW_3$$

- **W0** and **W1** minimizes absolute luminance and chrominance error
- **W2** and **W3** minimizes spatial luminance and chrominance discontinuities error

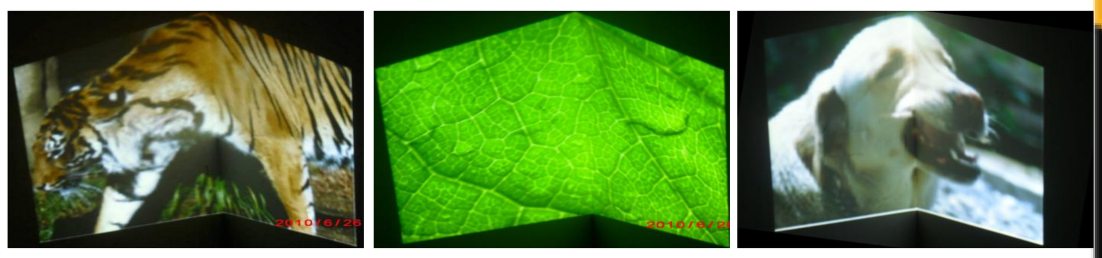
Results



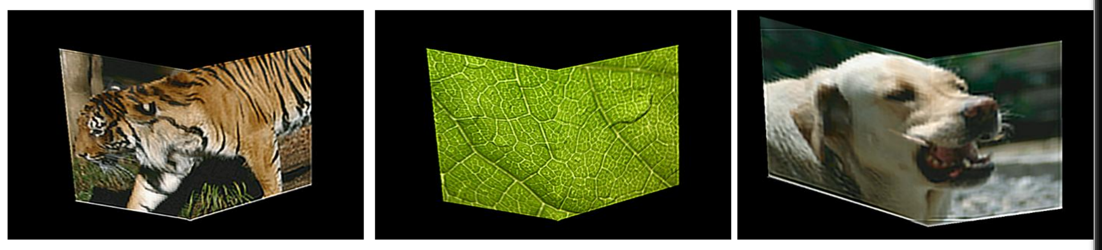
Left to right: Projected image; observed image with geometric distortion , defocus blur and low contrast; corrected image with our approach

Edge Pixels	Input Image	Corrected Input Image	Output Image	Corrected Output Image
Cat	181081	240577	167383	218688
Plant	109595	182400	92347	118577
Dog	68119	115329	67512	78905

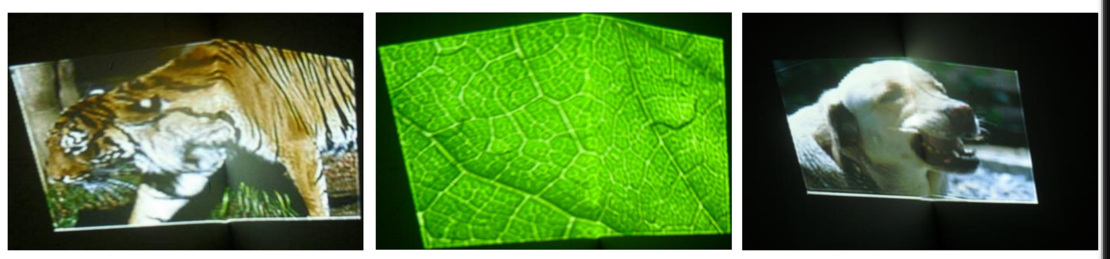
Projected image (Original)



Uncorrected observed image



Corrected projected image



Corrected observed image

References

1. K. Paidimarri and S. Chandran. Computer Vision, Graphics and Image Processing, pages 289-298. Lecture Notes in Computer Science, Springer 2006.
2. L. Zhang and S. Nayar. Projection defocus analysis for scene capture and image display. ACM Transactions on Graphics, 25(3):907-915, 2006.
3. Y. Sheng, T. Yapo, and B. Cutler. Global illumination compensation for spatially augmented reality. In Computer Graphics Forum:387-396,2010.
4. R. Raskar, G. Welch, M. Cutts, A. Lake, L. Stesin, and H. Fuchs. The office of the future: A unified approach to image-based modeling and spatially immersive displays. ACM SIGGRAPH, 32(Annual Conference Series):179-188, 1998.