WARP-BASED NEAR-REGULAR TEXTURE ANALYSIS FOR IMAGE-BASED TEXTURE OVERLAY

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Computer Vision & Graphics

Visual Computing Group
Department of Computer Science

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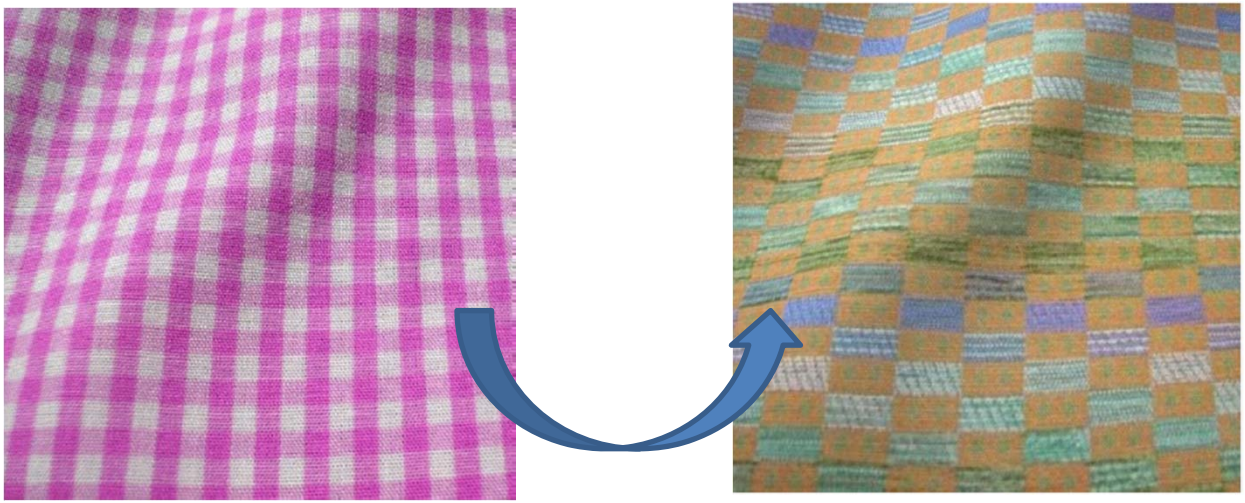
Image-based Texture Overlay



Original *Synthesized*

Preservation of

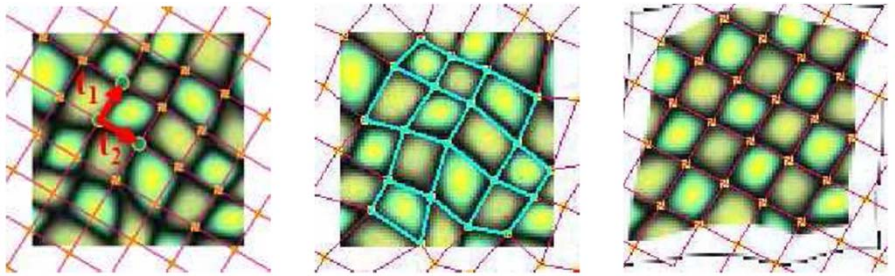
- texture distortion
- shading and reflection properties

Modification of

- texture albedo only

Related Work – Texture Overlay

Videos	Pilet2005 Scholz2006 Hilsmann2010	Estimation of texture distortion and shading properties in relation to a reference
Single Views using Shading Information	Fang2004 Guo2008 Yan2010	• No reference given • Texture-less surfaces • Estimation of texture distortion from shading
Single Views using Texture Information	Liu2004	• No reference given • Near regular textures • Interactive texture analysis



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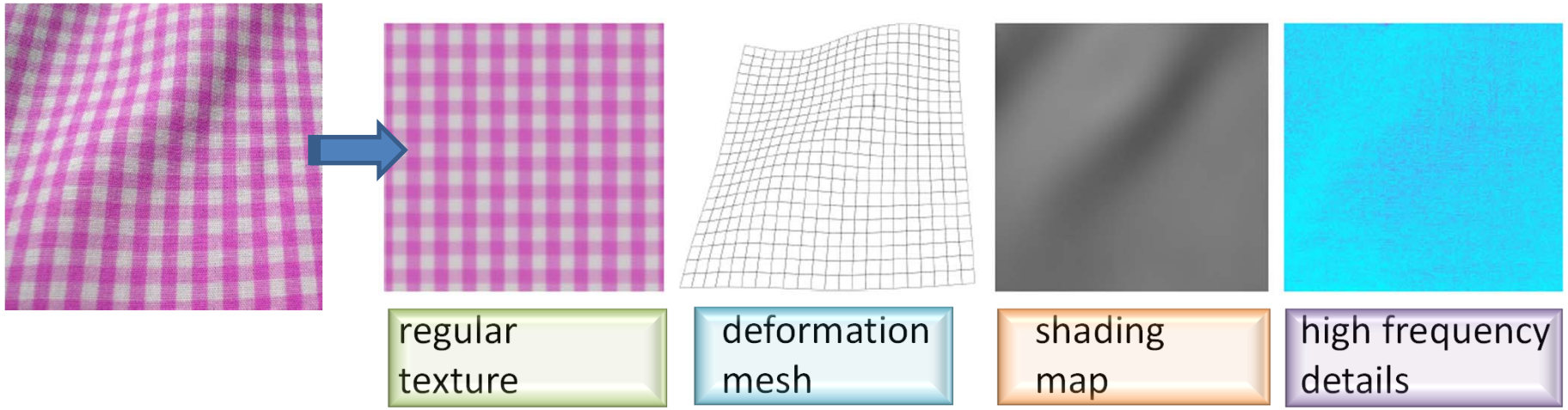
Single Views using Shading Information	Fang2004 Guo2008 Yan2010	• No reference given • Texture-less surfaces • Estimation of texture distortion from shading
Single Views using Texture Information	Liu2004 **our method**	• No reference given • Near regular textures • ~~Interactive texture analysis~~ • **automatic warp-based geometric and photometric texture analysis**

Near-Regular Textures

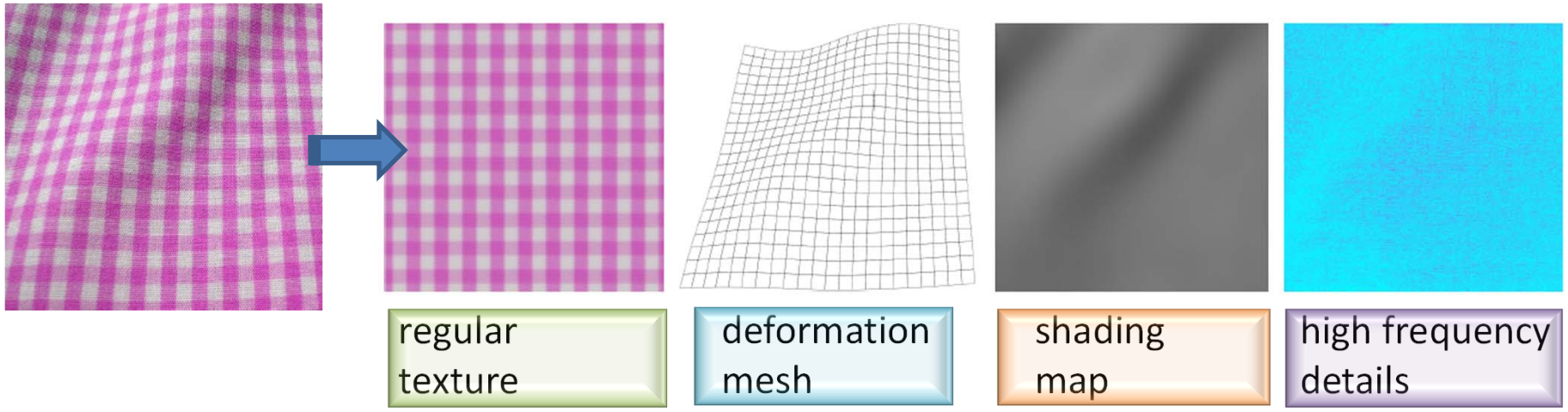
- Regular textures: constructed by regularly tiling the texture space with the same texture element
- Near-regular textures (Liu 2004):
  - Geometric and photometric deviation from regularity
  - Same topological regularities and relations

Texture Decomposition- Image Model



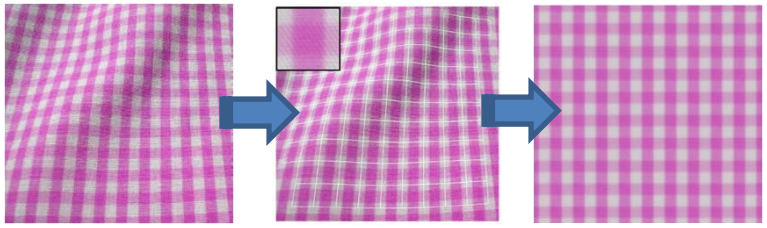
$$\mathcal{I}(\mathbf{x}) = \mathcal{W}_p(\mathbf{x}) \cdot \mathcal{T}(\mathcal{W}_g(\mathbf{x})) + \alpha \cdot \mathcal{HF}(\mathbf{x})$$

Texture Decomposition- Image Model

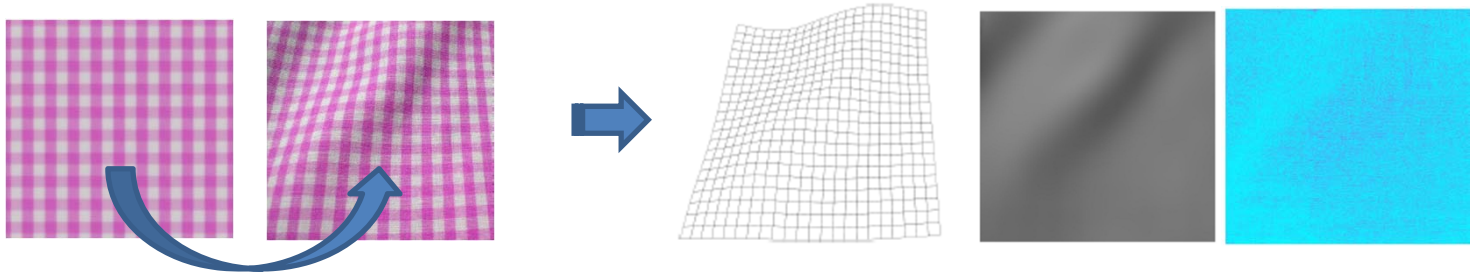


Overview

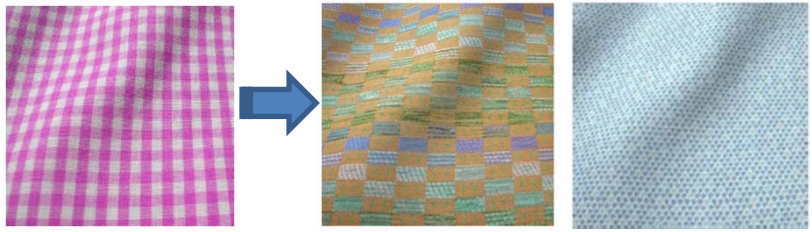
- Mean texel appearance and lattice estimation



- Texture decomposition through joint geometric and photometric registration



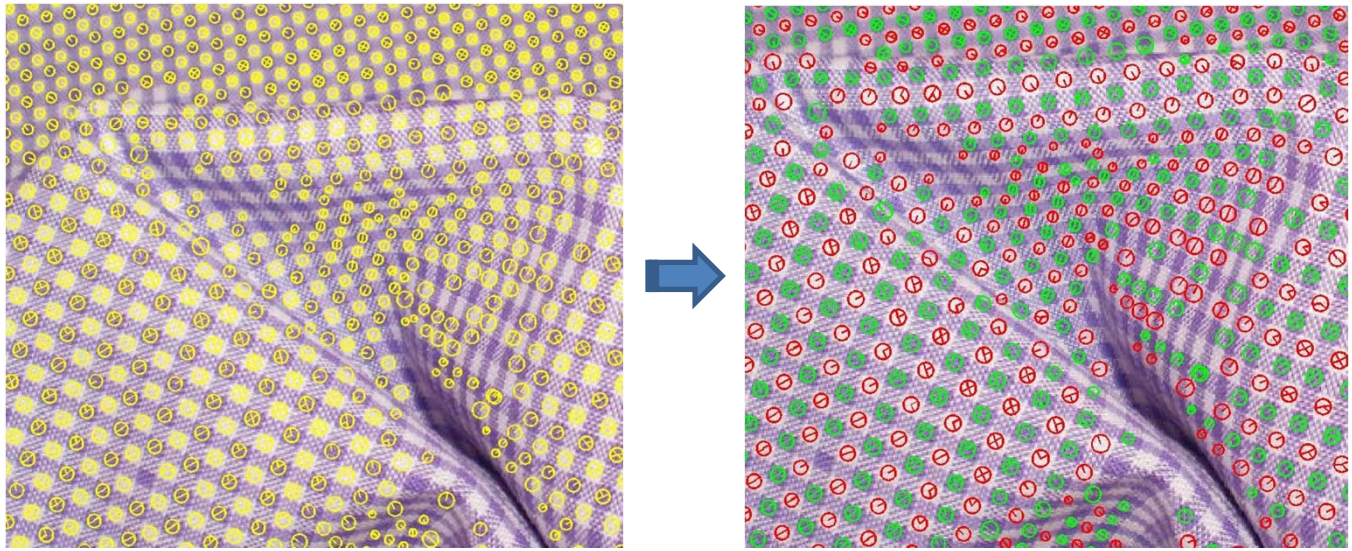
- Texture replacement



Mean Texel Appearance and Lattice Estimation

- Texels appear geometrically and photomatrically distorted
- Nevertheless, they are still *similar*

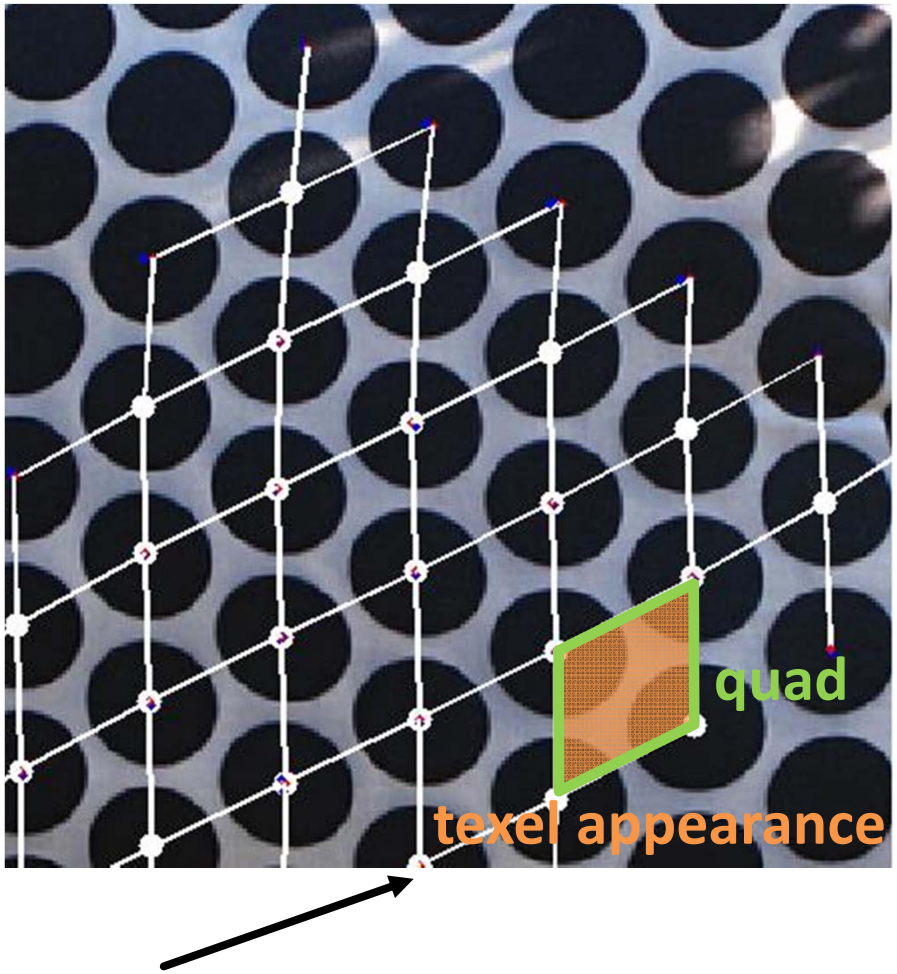
Idea: unsupervised clustering of feature descriptors (e.g. SIFT)



Lattice Generation

- Each cluster consists of image points with similar SIFT descriptors
- Goal: generate degree-4-**lattice** that relates the points of each cluster by the same **topological relations** as in the undeformed texture (Liu et al 2004)

! there is more than one valid texel and tiling pattern



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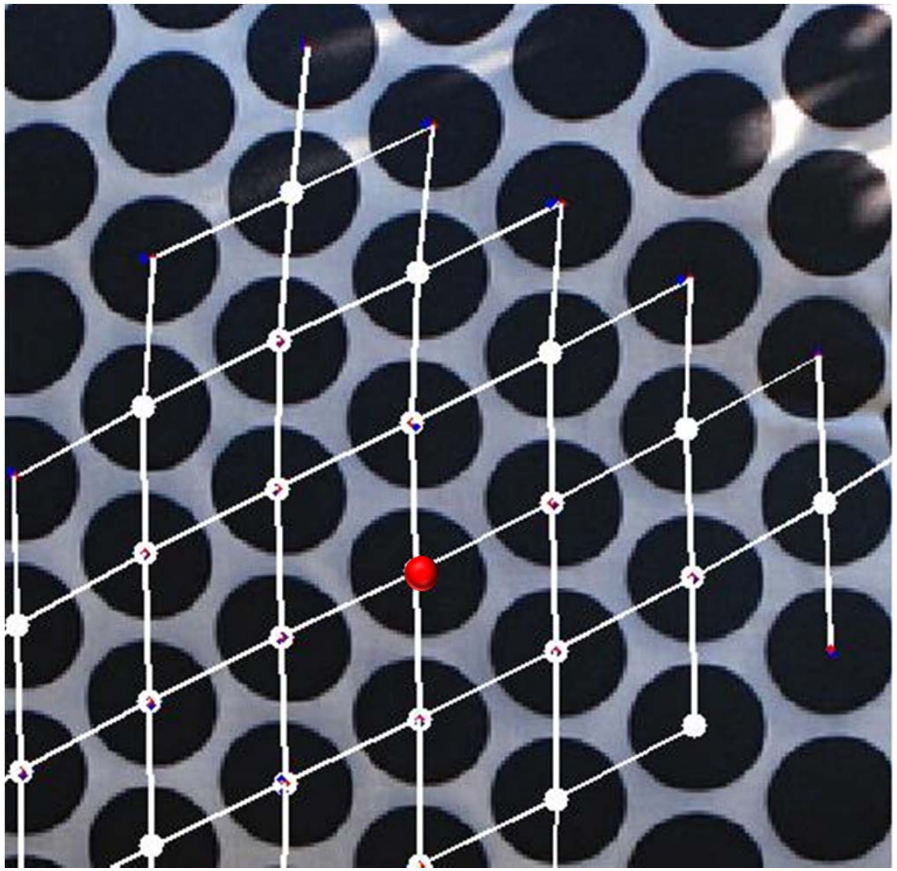

seed point $\mathbf{p}_S$

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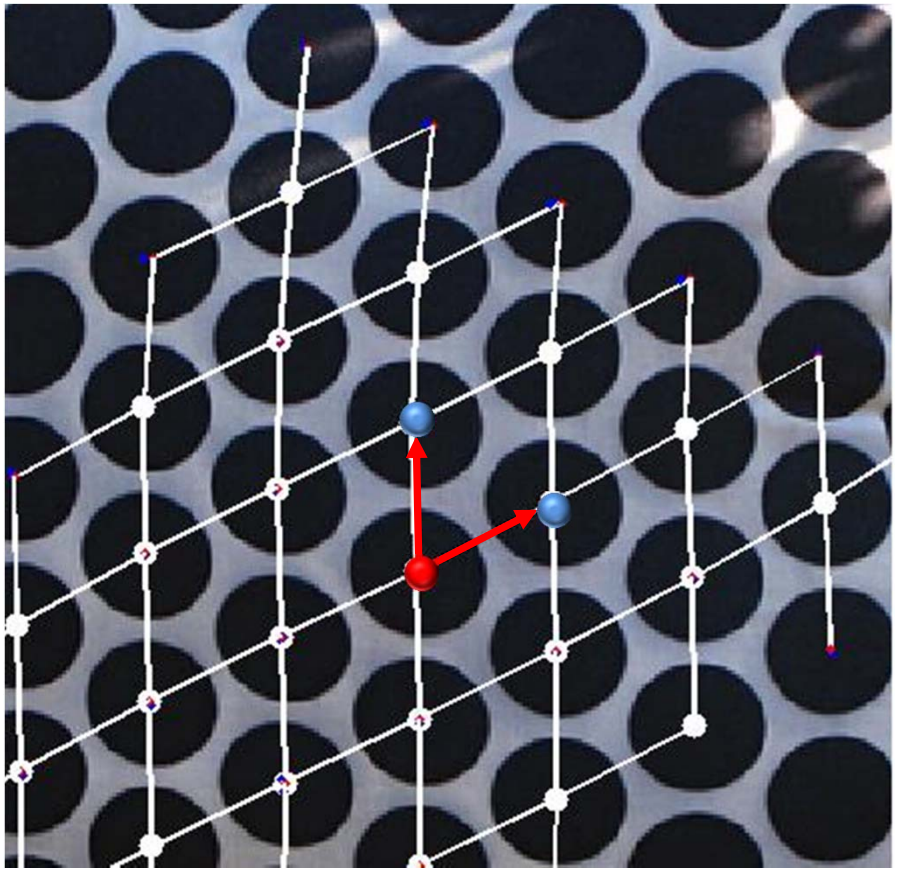

proposing vectors $\mathbf{v}_1$, $\mathbf{v}_2$

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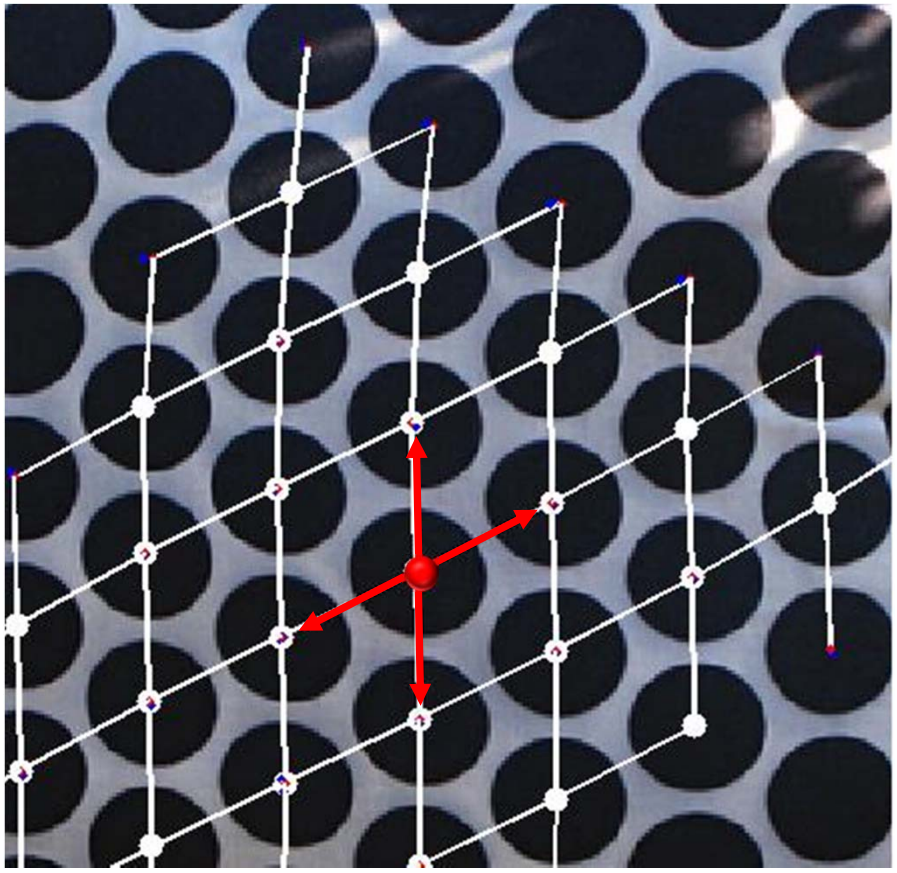

Find cluster points in a predefined distance from $\mathbf{p}_S \pm \alpha \mathbf{v}_1, \mathbf{p}_S \pm \alpha \mathbf{v}_2$

$0.5 \leq \alpha \leq 2$

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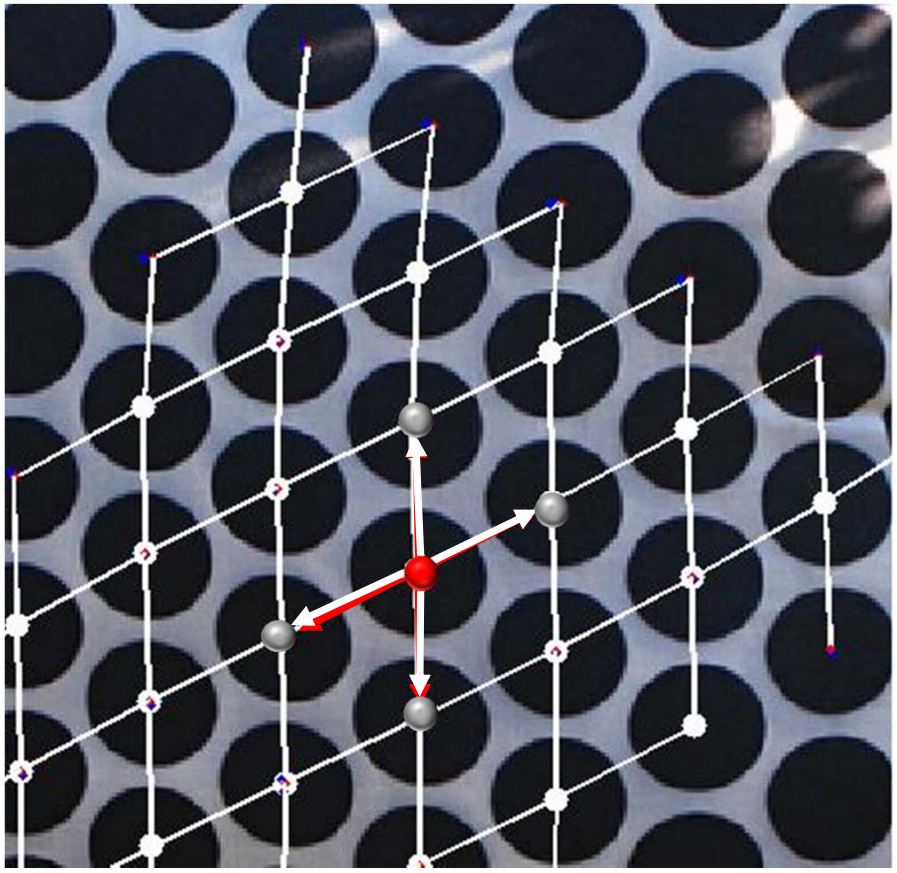

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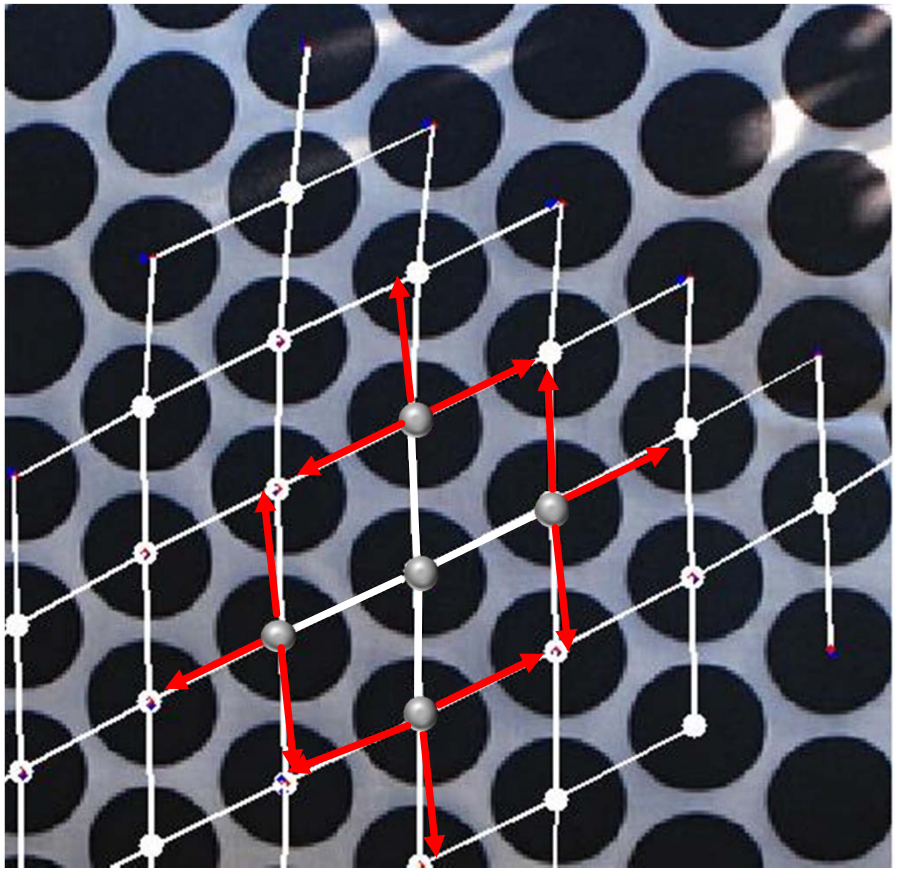
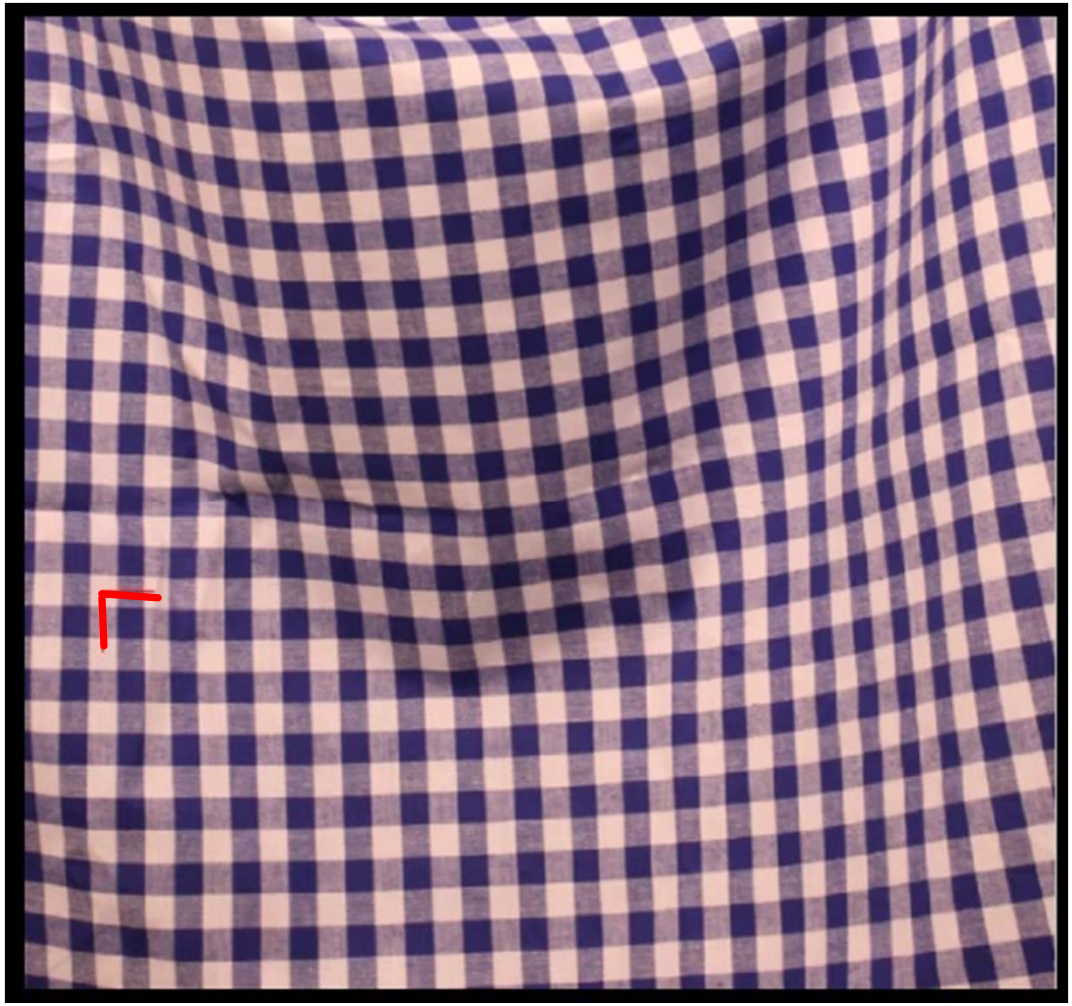


for all children update proposing vectors $\mathbf{v}_1, \mathbf{v}_2$

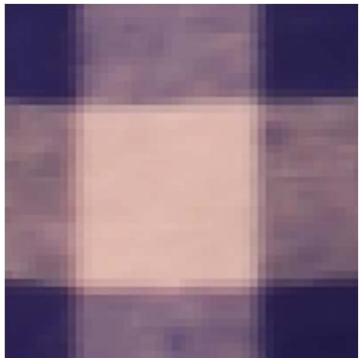
Lattice Generation



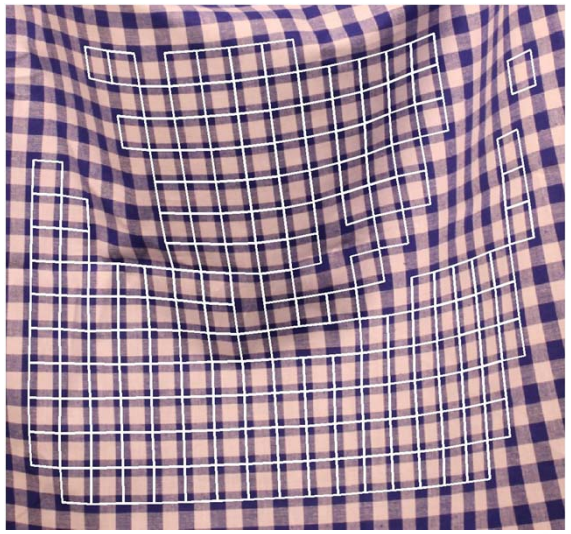
Mean Texel Appearance and Lattice Estimation

- Map all texels into a normalized texel coordinate system
- Normalize intensities
- Rectified and normalized mean texel
- MAD-based outlier rejection based on similarity to mean texel and additional continuity measure

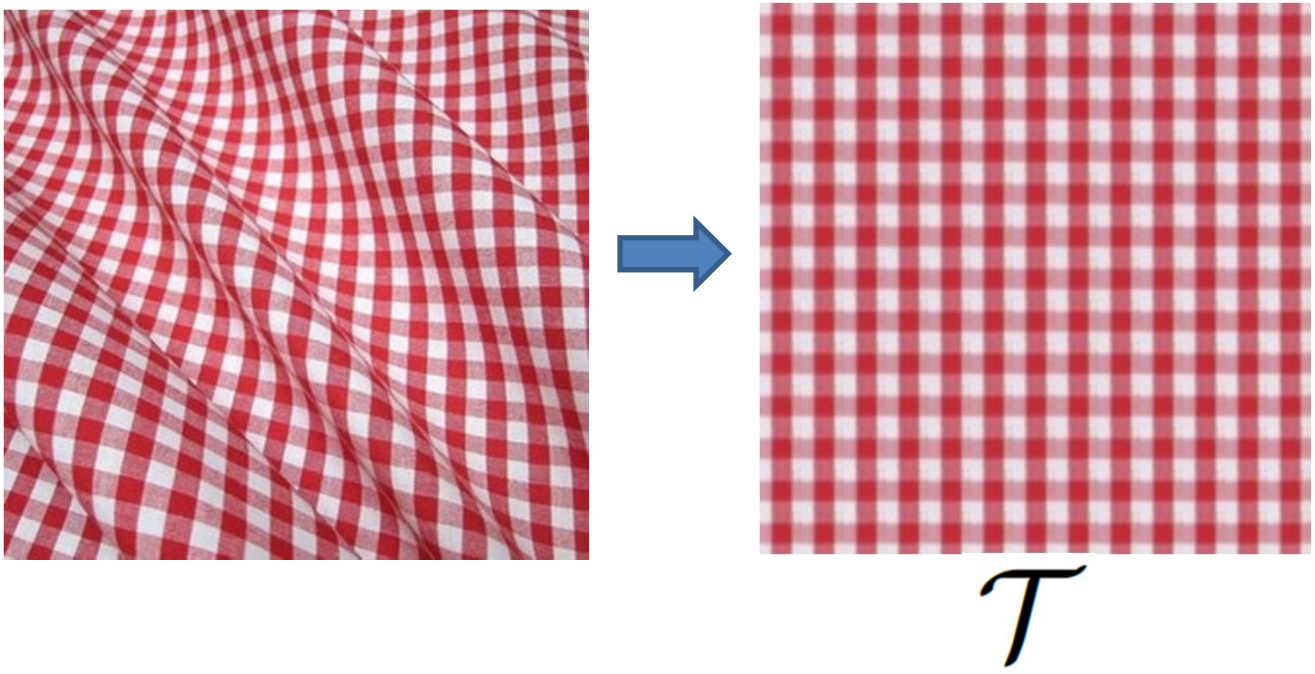
From remaining normalized texels estimate mean texel appearance and coarse lattice structure



texels in normalized texel coordinate frame



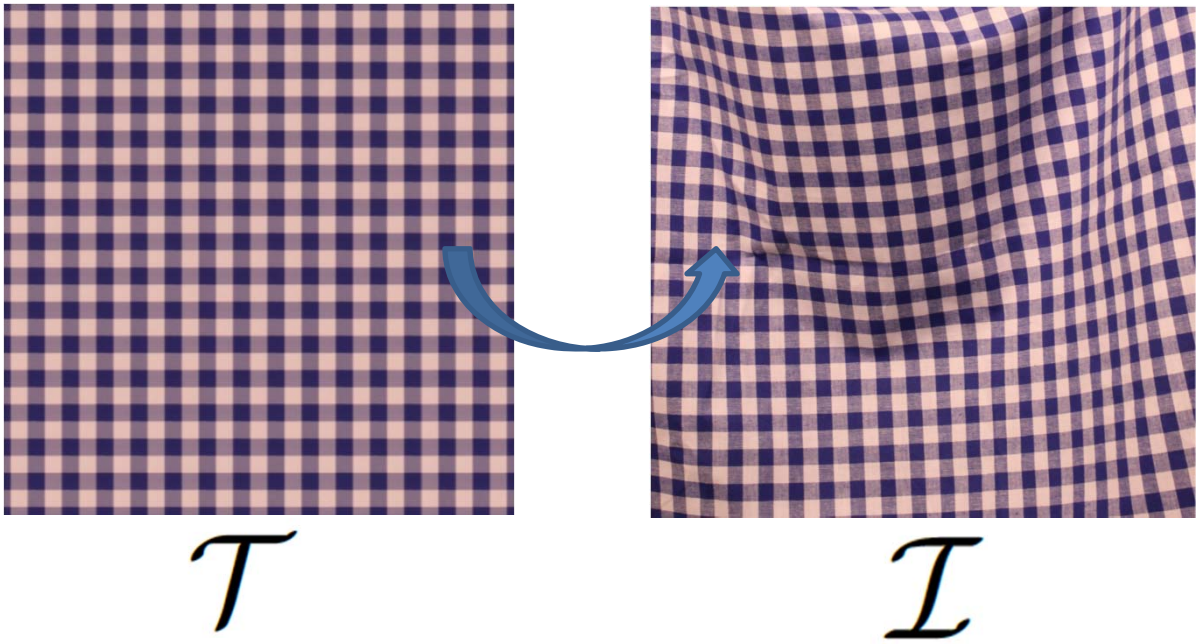
Results – Texel Appearance Estimation



Joint Deformation and Shading Optimization

- Joint optimization of a geometric and a photometric warp between the regular texture and the original image

→ Refinement of texture deformation with a finer mesh and estimation of a shading map



Joint Deformation and Shading Optimization

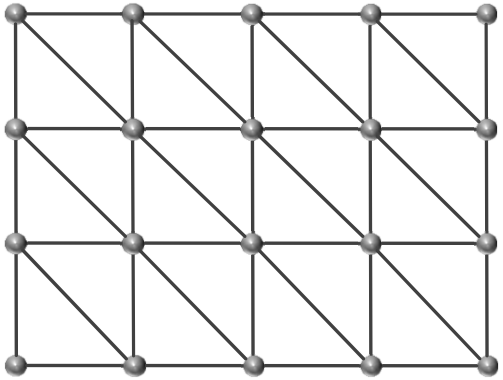
- **Relaxed** Brightness Constancy Assumption

$$r_i(\theta) = \mathcal{W}_p(\mathbf{x}_i;\theta_p) \cdot \mathcal{T}(\mathcal{W}_g(\mathbf{x}_i;\theta_g)) - \mathcal{I}(\mathbf{x}_i)$$

- Mesh-based Warps

geometric warp $\mathcal{W}_g(\mathbf{x}_i;\theta_g) = \mathbf{x}_i + \mathbf{B}_g^i \cdot \theta_g$ ← Vertex displacements

photometric warp $\mathcal{W}_p(\mathbf{x}_i;\theta_p) = \mathbf{B}_p^i \cdot \theta_p$ ← Intensity scale



$\mathbf{B}_g^i$ $\mathbf{B}_p^i$ Warp parameterization (e.g. barycentric or bilinear mesh coordinates)

A. Hilsmann and P. Eisert: "Joint Estimation of Deformable Motion and Photometric Parameters in Single View Video", *ICCV NORDIA Workshop*, Kyoto, Japan, Sept. 2009

Joint Deformation and Shading Optimization

- Joint optimization of a geometric and a photometric warp between the regular texture and the original image

$$\hat{\theta} = \arg\min_{\theta} \mathcal{E}_D(\theta) + \lambda^2 \mathcal{E}_S(\theta)$$

data $$\mathcal{E}_D(\theta) = \sum_i \psi(r_i(\theta))$$

smoothness $$\mathcal{E}_S(\theta) = \Gamma \cdot \theta$$

$$\Gamma = \begin{bmatrix} \mathbf{L} & \mathbf{0} & \mathbf{0} \\ \mathbf{0} & \mathbf{L} & \mathbf{0} \\ \mathbf{0} & \mathbf{0} & \lambda_p \mathbf{L} \end{bmatrix}$$ ← Mesh Laplacians

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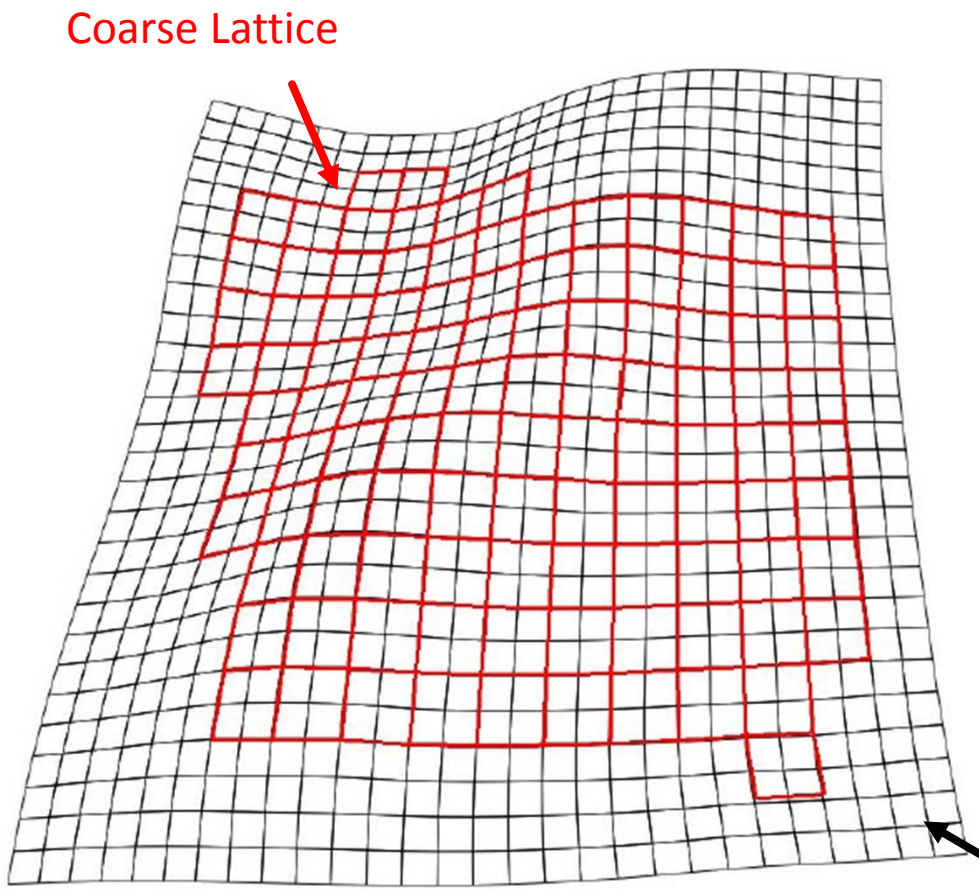
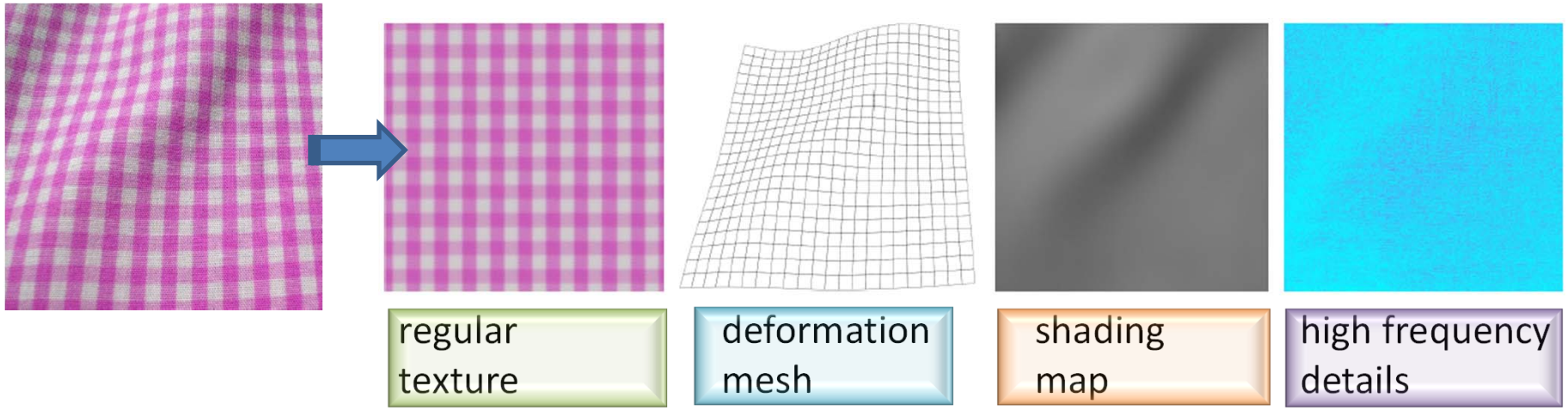
Mesh Initialization



Texture Decomposition- Image Model



$$\mathcal{HF}(\mathbf{x}) = \mathcal{W}_p(\mathbf{x};\hat{\theta}_p) \cdot \mathcal{T}(\mathcal{W}_g(\mathbf{x};\hat{\theta}_g)) - \mathcal{I}(\mathbf{x})$$

Results – Retexturing

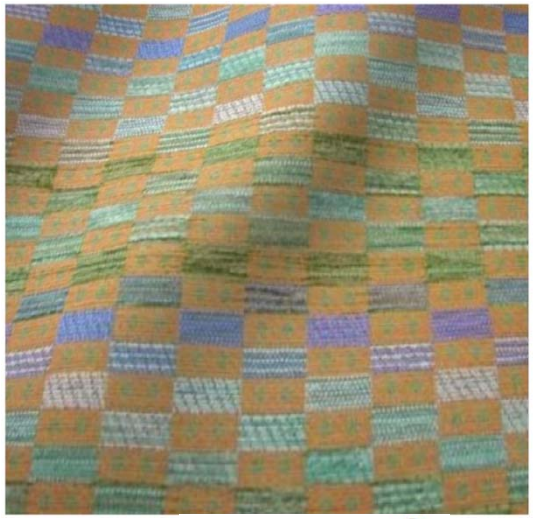
original

synthesized

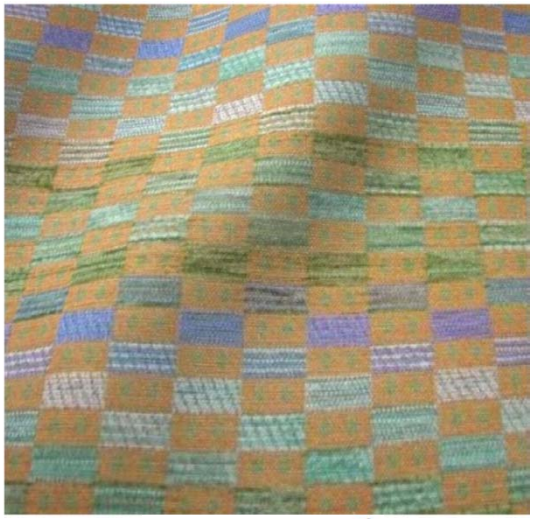
Results – Retexturing

original

synthesized

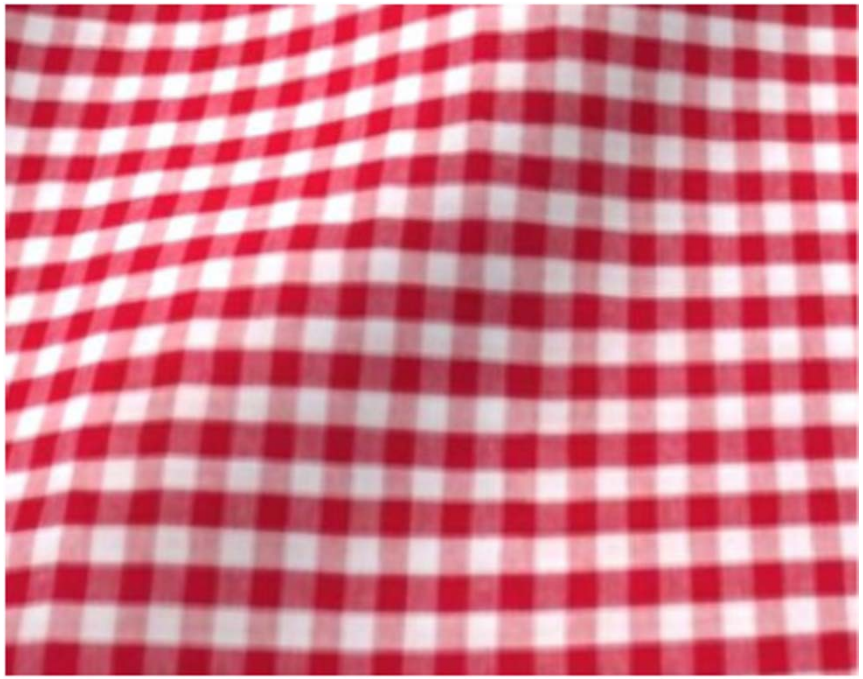


$\alpha = 0$

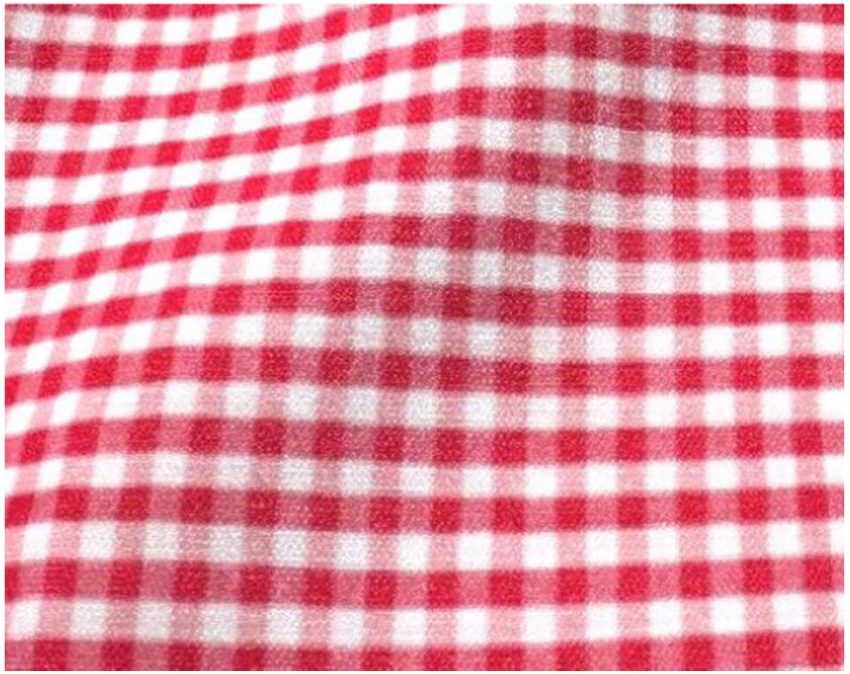


$\alpha = 1$

Results – Influence of Alpha



$\alpha = 0$



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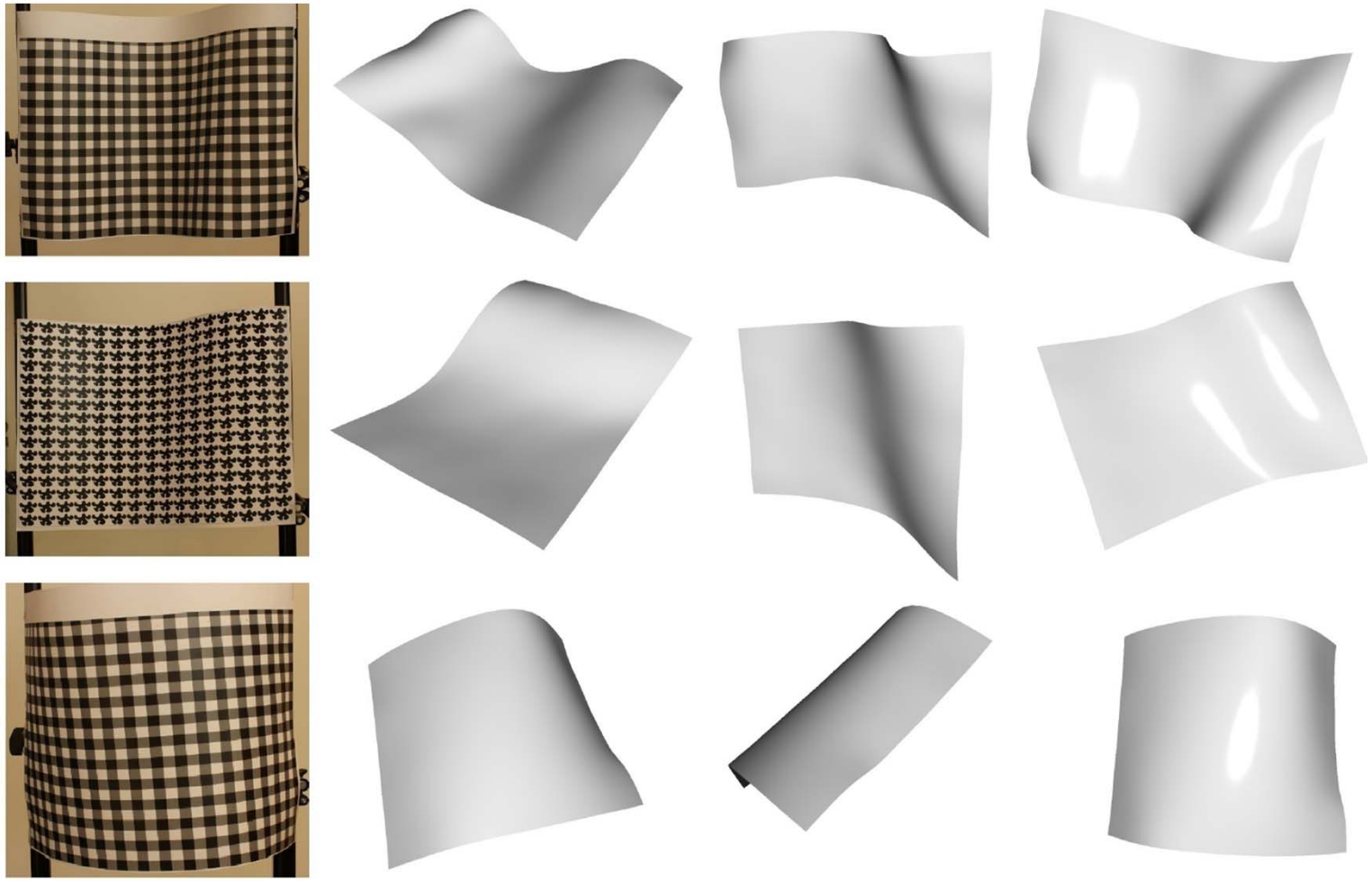
Application: Shape-from-Texture



A. Hilsmann et al: Template-free Shape-from-Texture with Perspective Cameras, Proc. BMVC 2011, Dundee, Scotland, Sep 2011

Conclusions

- Fully automatic decomposition of an image of an NRT for image-based retexturing
- Texel detection using unsupervised clustering of feature points (currently SIFT)
- Joint deformation and shading estimation as registration of a synthetic regular texture and the original image
- Self-occlusions, discontinuities?

Original image

reconstructed surface
from shape from texture

retextured results

THANK YOU