A Virtual Restoration Stage for Real-World Objects

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Accepted to SIGGRAPH Asia 2008

Goal

To enable visual restoration of damaged and historically significant objects without needing to touch or alter them.

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Photo of
original object

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Image of
synthetic restoration

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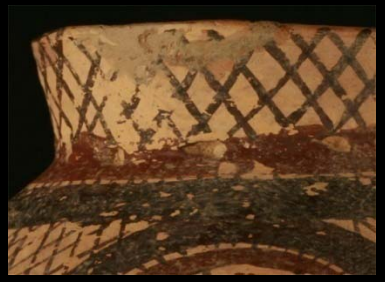
Photo of
visually compensated
object

Video of China

Original and result

Restoration Challenges

1) Computing a synthetic restoration of the object which corrects for its physical deterioration



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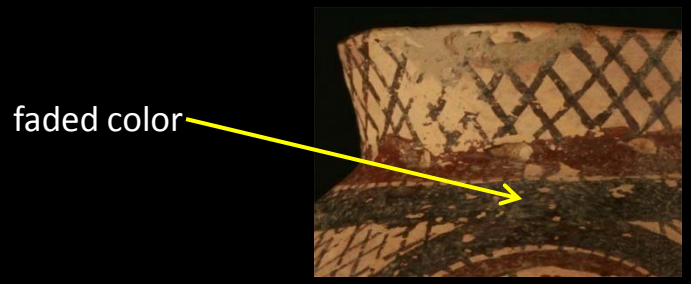

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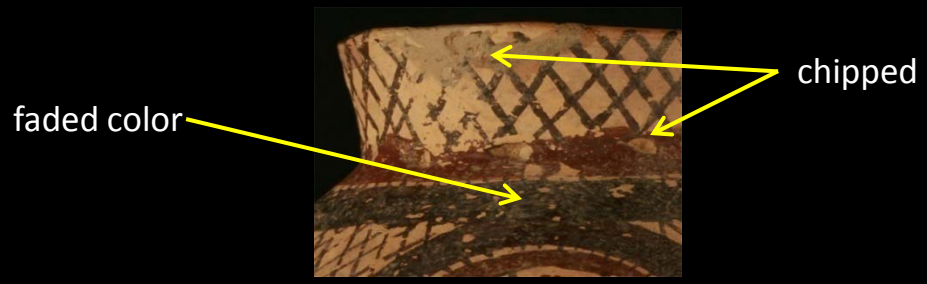

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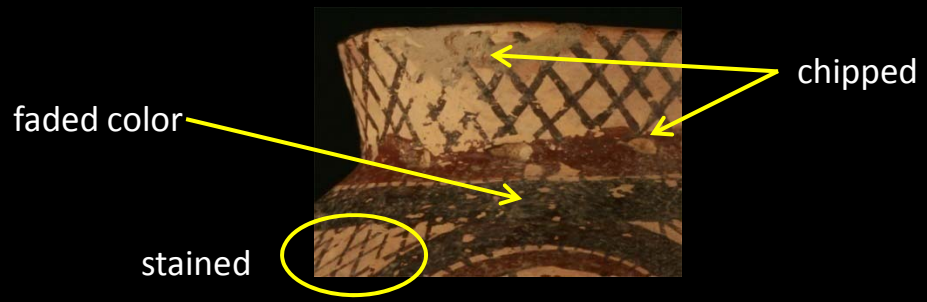

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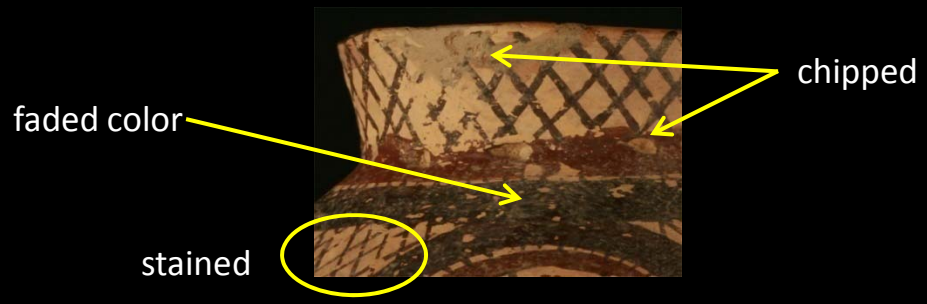

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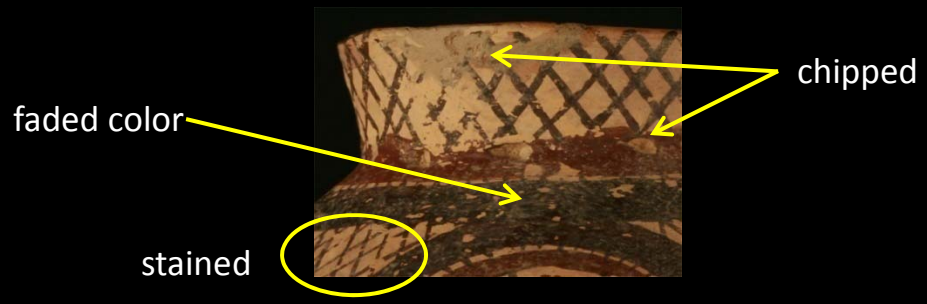

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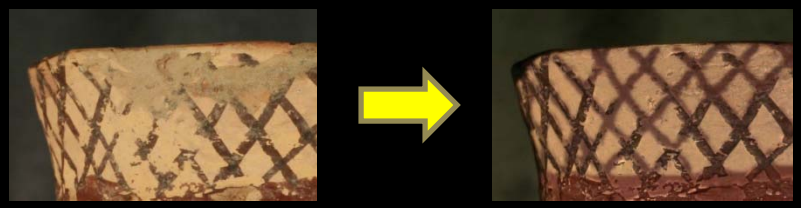
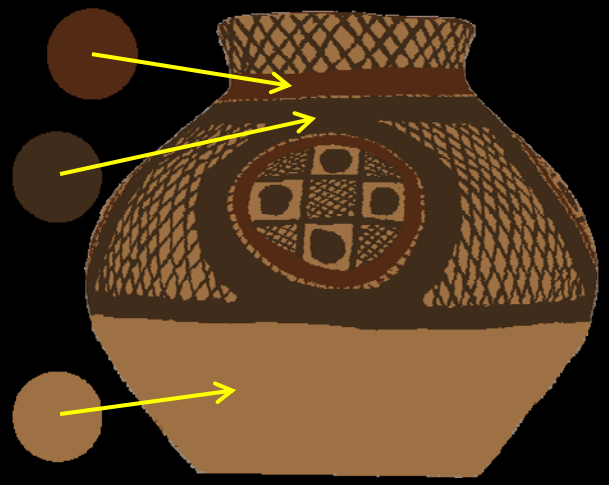


Key Observations

1) Our targeted objects have a few distinct colors which enables a robust synthetic restoration

2) Multiple overlapping digital projections can generate a light-efficient visual compensation



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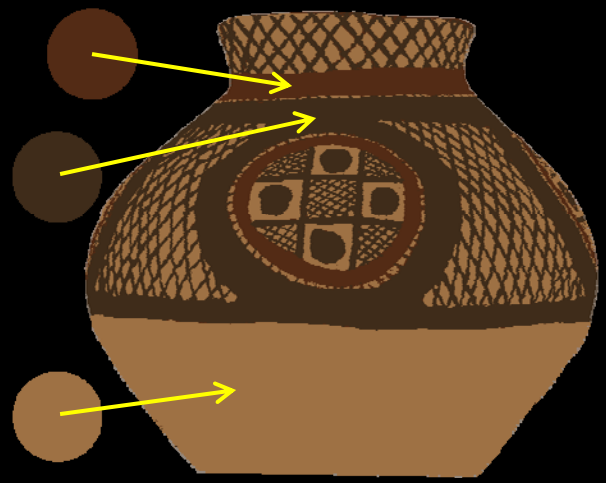

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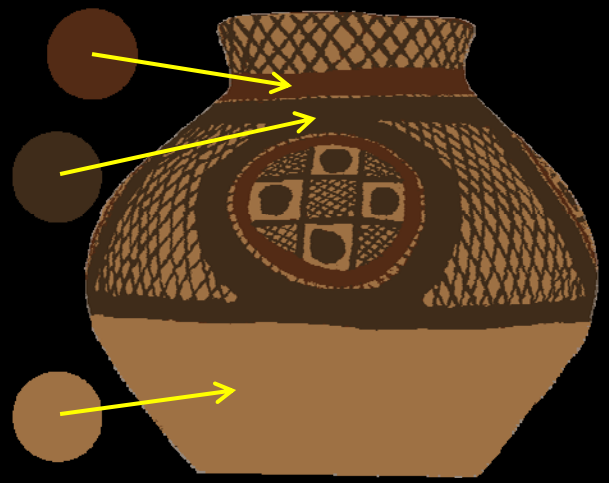

Contributions

1) An image restoration method to infer the original appearance of an object.

2) A light transport based radiometric compensation algorithm to represent material and radiometric properties of the object and projectors.

3) A surface radiance model that best enables altering the object's appearance under a user-specified maximum light per unit surface area.

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Restoration Pipeline

1) Object and acquisition stage
2) Image restoration
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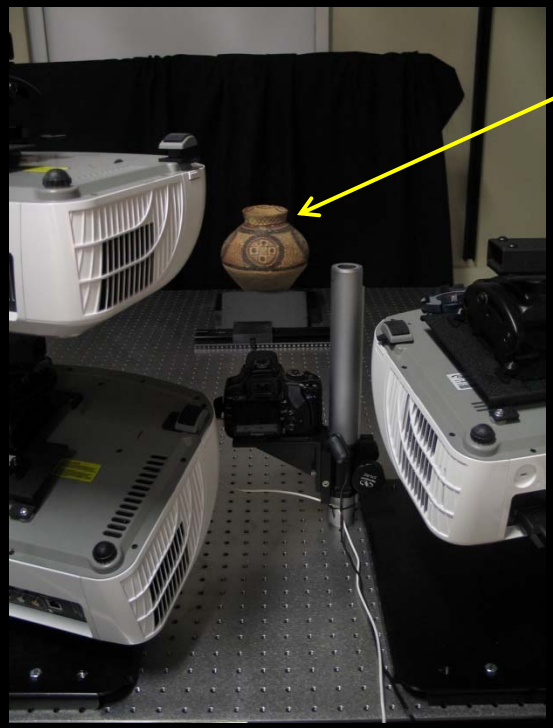

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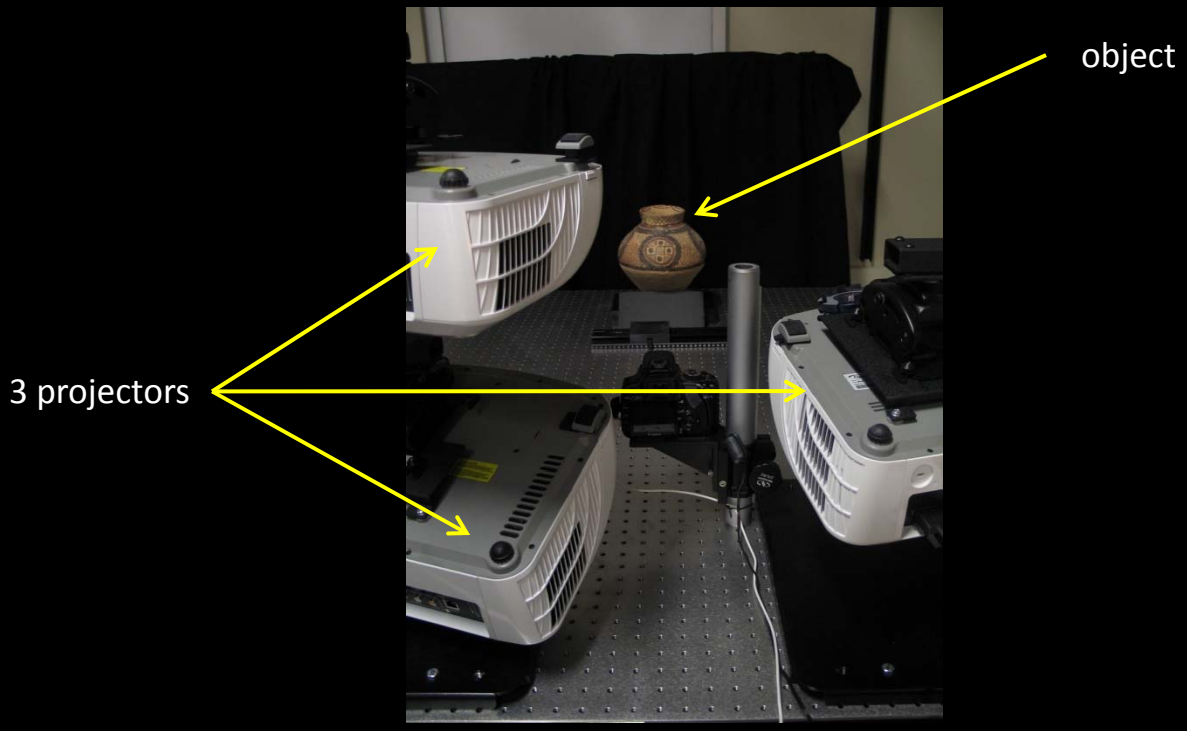

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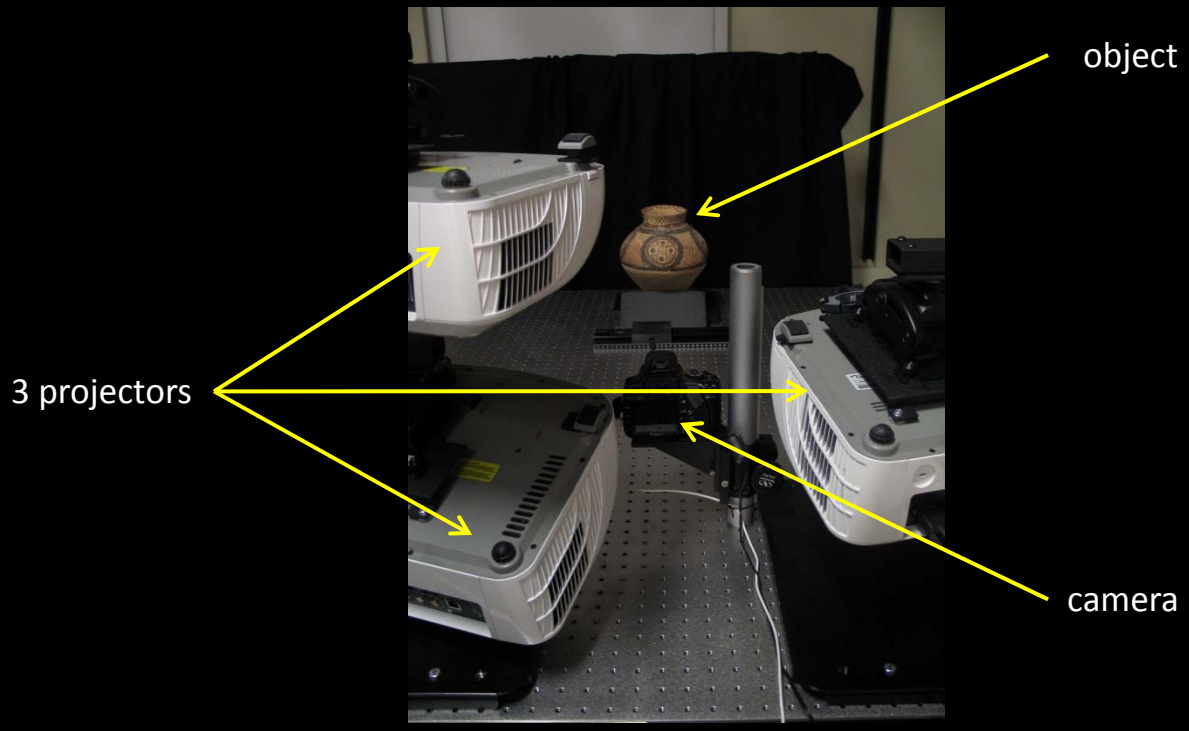

Restoration Pipeline

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Image Restoration

Color classification

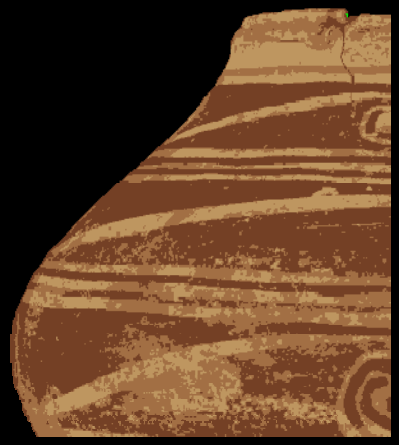
Image Restoration

Color classification

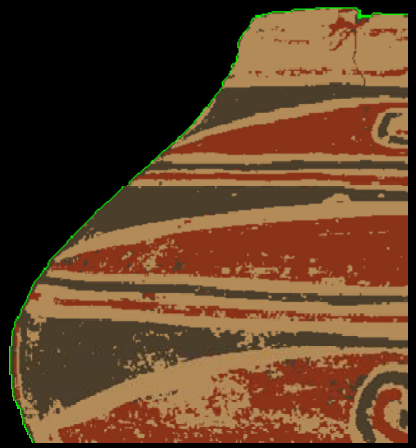
Image Restoration

Comparison of color classification techniques

mean-shift segmentation



naïve k-means clustering



our optimized approach

Image Restoration

Restoration criteria for energy minimization:

Image Restoration

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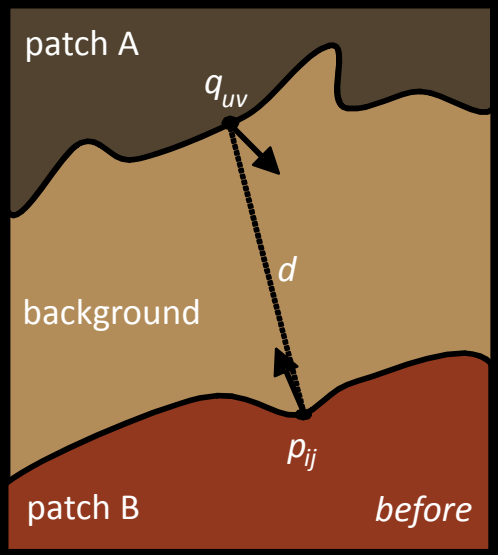
- Contour smoothness and patch-to-patch distance similarity

Image Restoration

Restoration criteria for energy minimization:

Contour smoothness and patch-to-patch distance similarity



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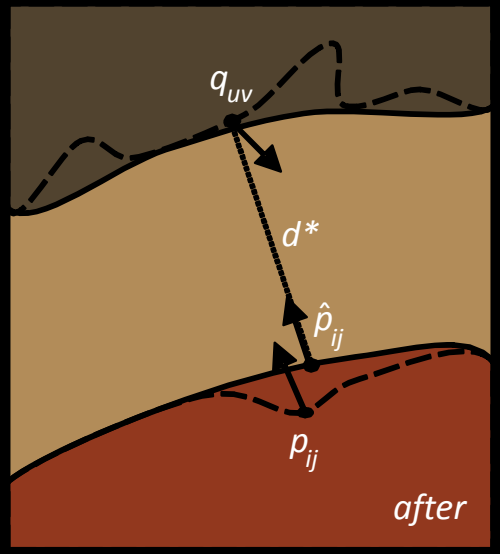

Image Restoration

Restoration criteria for energy minimization:

- Compensation-compliant restoration

Image Restoration

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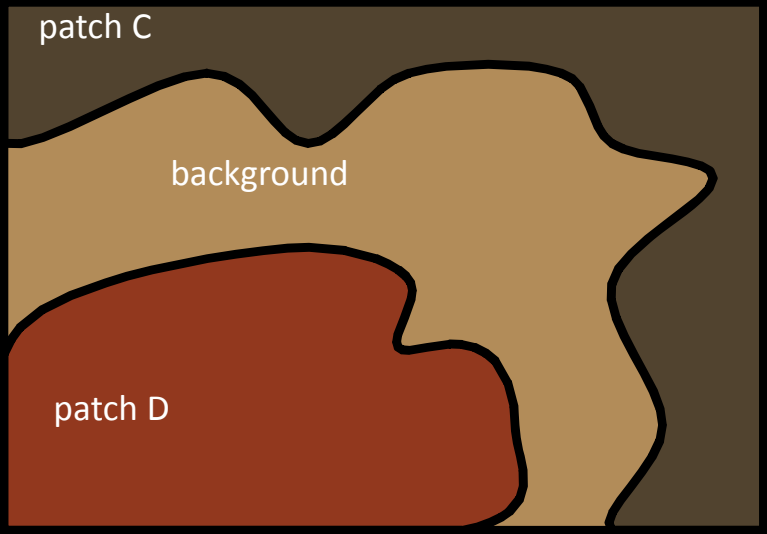

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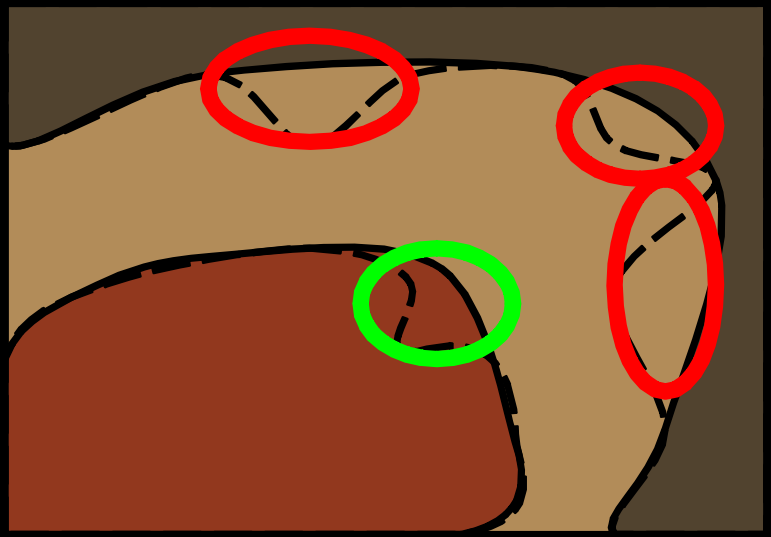


bad

Image Restoration

Restoration criteria for energy minimization:

Compensation-compliant restoration

good

Image Restoration

Restoration criteria for energy minimization

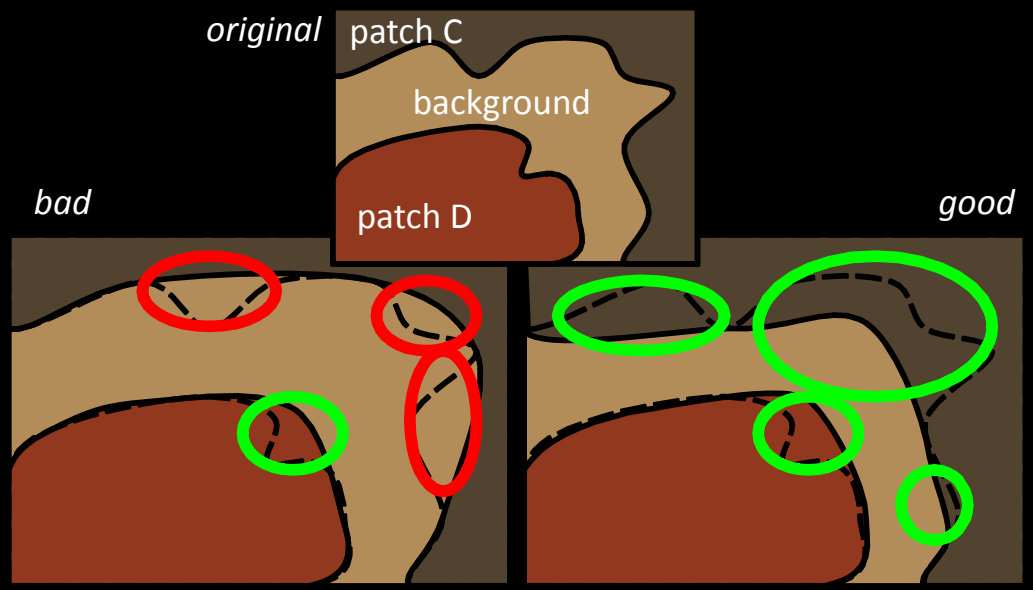


Image Restoration

Varying different parameters

original

highly smooth
α, β small

rigid contours
β large

final balance
of α, β

original photograph

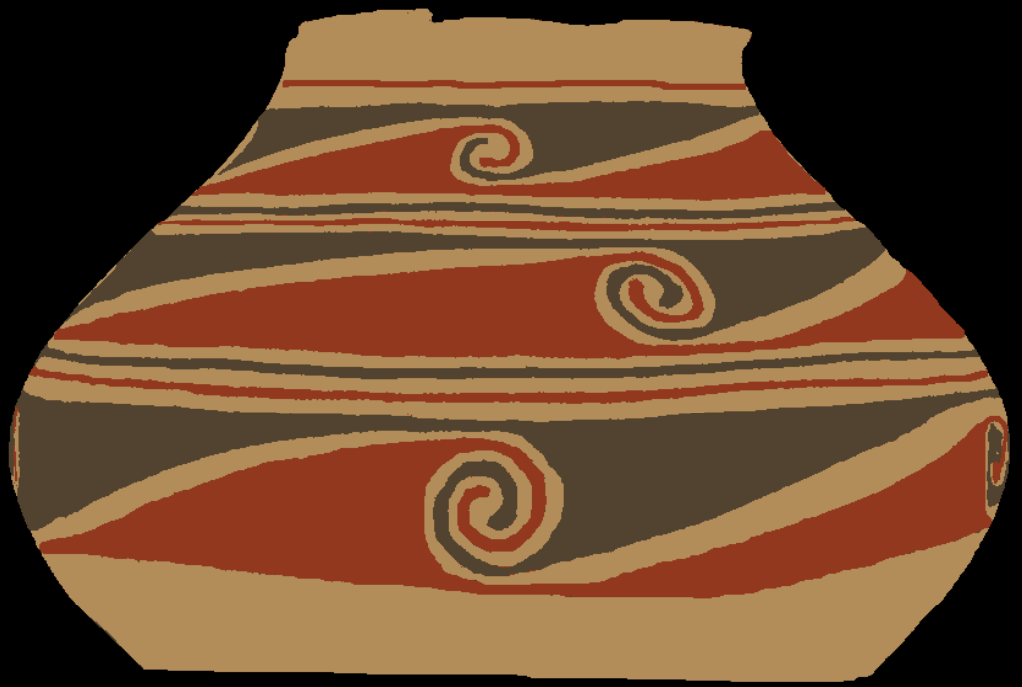
non-compensation
compliant restoration

compensation compliant
restoration

α: controls amount of smoothing
β: weighs importance of moving towards optimal distance

Image Restoration

Restored synthetic image



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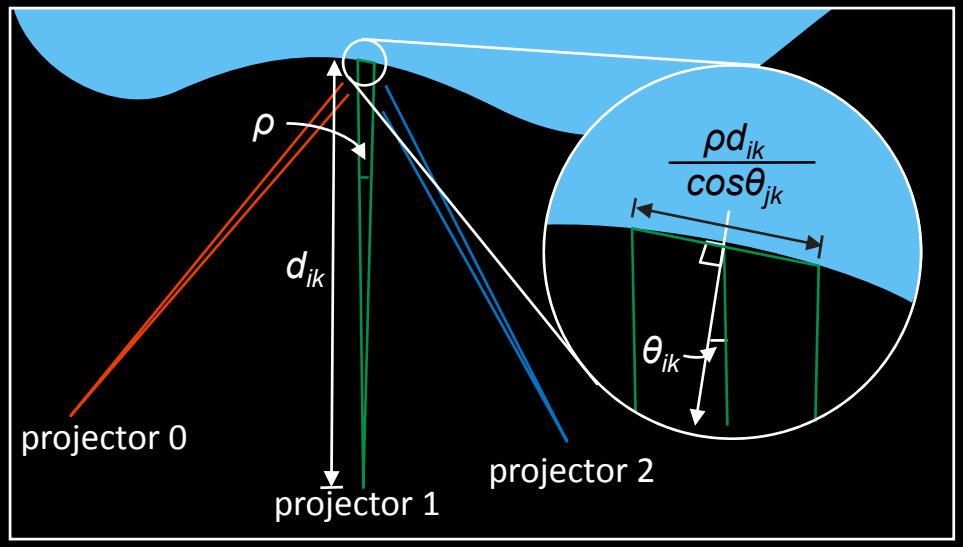
Surface Radiance Model

The amount of light incident on a unit surface area object point from all projectors is modeled based on a diffuse surface illumination model



Visual Compensation

Maximally efficient compensation

Photo of first projector contribution

Visual Compensation

Maximally efficient compensation

Photo of second projector contribution

Visual Compensation

Maximally efficient compensation

Photo of third projector contribution

Visual Compensation

Maximally efficient compensation

Photo with all projectors contributing

Visual Compensation

Maximally efficient compensation

Photo with all projectors contributing

Visual Compensation

Linear compensation

Photo with all projectors contributing

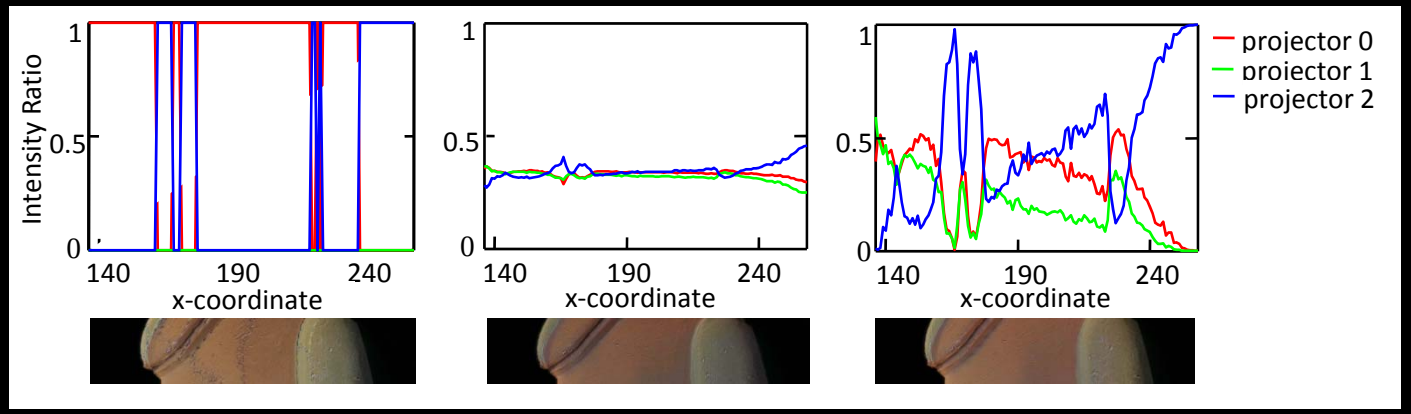
Visual Compensation

Non-linear weighted compensation

Photo with all projectors contributing

Visual Compensation

Combinations of projectors under different weighting schemes



maximally-bright

linear

our non-linear approach

Restoration Pipeline

Photo of virtual restoration with bounded light per unit surface area

Restoration Pipeline

Mexico object

original photograph

synthetic restoration image

restored objet photograph

Results

Before/after

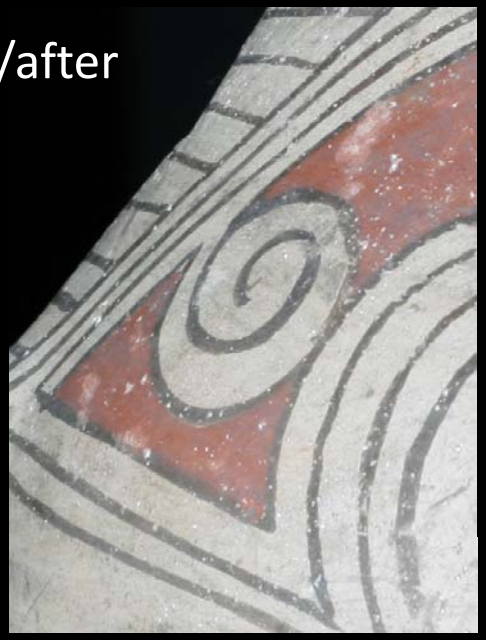


photo of original

photo of restored

Results

Virtual lighting

original photo

virtually re-lit and restored photos

Results

Photos of weighted contributions from projectors

Linear weighting

Results

Photos of weighted contributions from projectors

Linear weighting

Non-linear weighting

brightest

Videos

Original and results

The End