Construction of a 3D Model of Real-world Object Using Range Intensity Images

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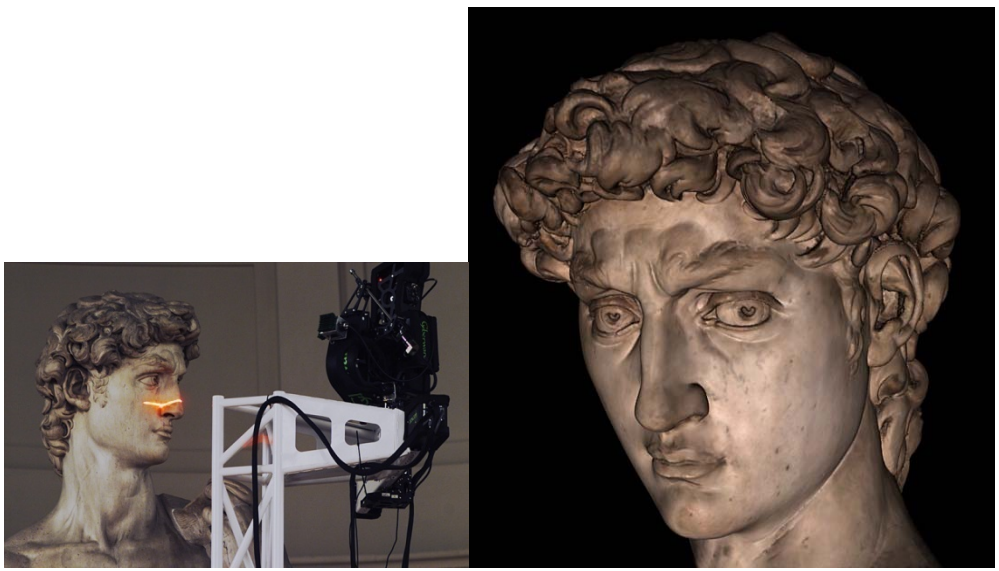
Outline

- Introduction
- Range intensity image
- Overview of the constructed system
- Experimental results
- Conclusion

Introduction: Background

Construction of a textured 3D model of a real-world object

- Important for many applications such as digital archiving of heritages



Digital Michelangelo Project
(Stanford Univ., etc.)

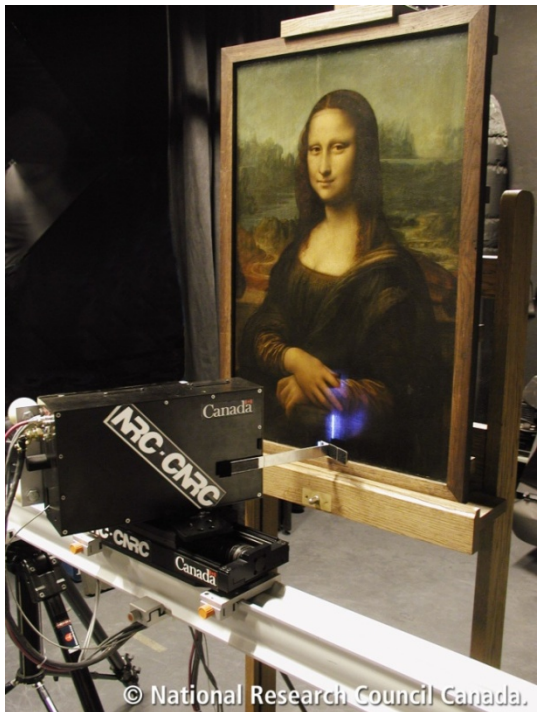
Great Buddha Project
(Univ. Tokyo)

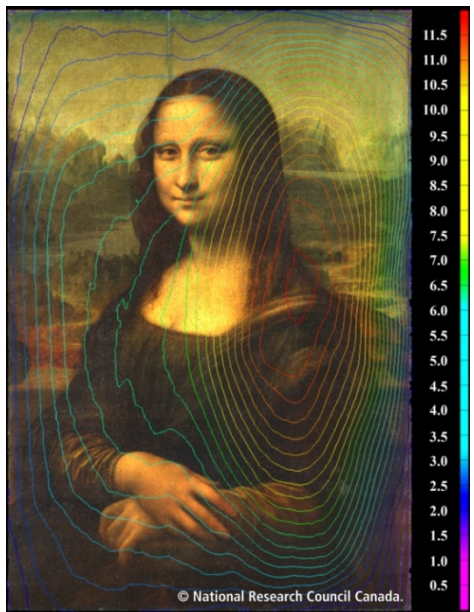
Introduction: Background

Construction of a textured 3D model of a real-world object

- Important for many applications such as digital archiving of heritages

Mona Lisa (NRC)

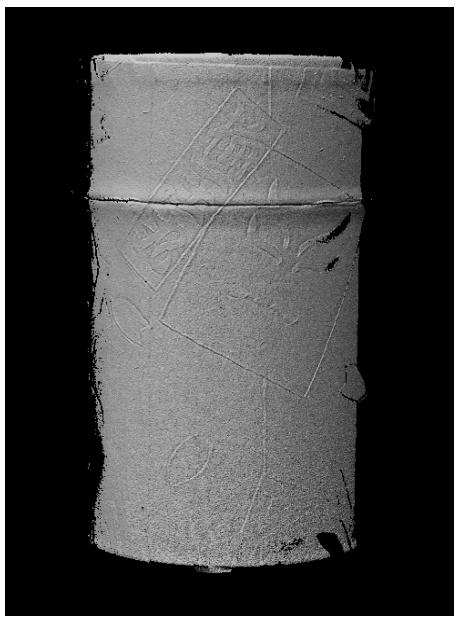




Introduction: Background

Texture Mapping

- Mapping of color images on a 3D shape
  - Shape: range image (range finder)
  - Texture: color image (digital camera)



Range image(3D)

Color image (2D)

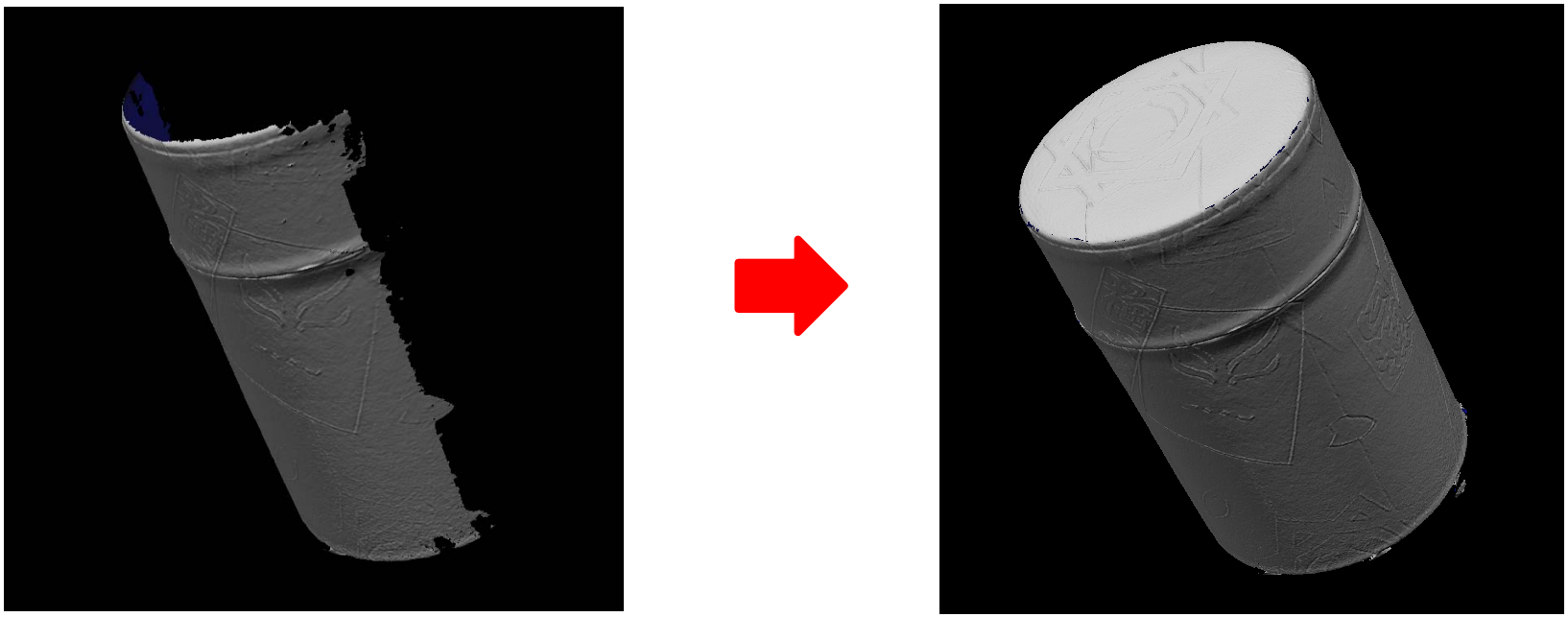
3D Model

Introduction: Background

Issues of texture mapping

Geometrical issues:

- Registration of range and color images
- Construction of an omnidirectional geometric model from range images



Introduction: Background

Optical issues:

- Influence of illumination environment
  - -highlights, shading
  - -illumination color

Standard lighting

Lighting position

Illumination color

Introduction: Background

Optical issues:

- Influence of illumination environment
  - -highlights, shading
  - -illumination color

False color seams
for multiple color images

Introduction: Purpose

- Construct a system to make a 3D model of a real-world object, coping with the issues of texture mapping

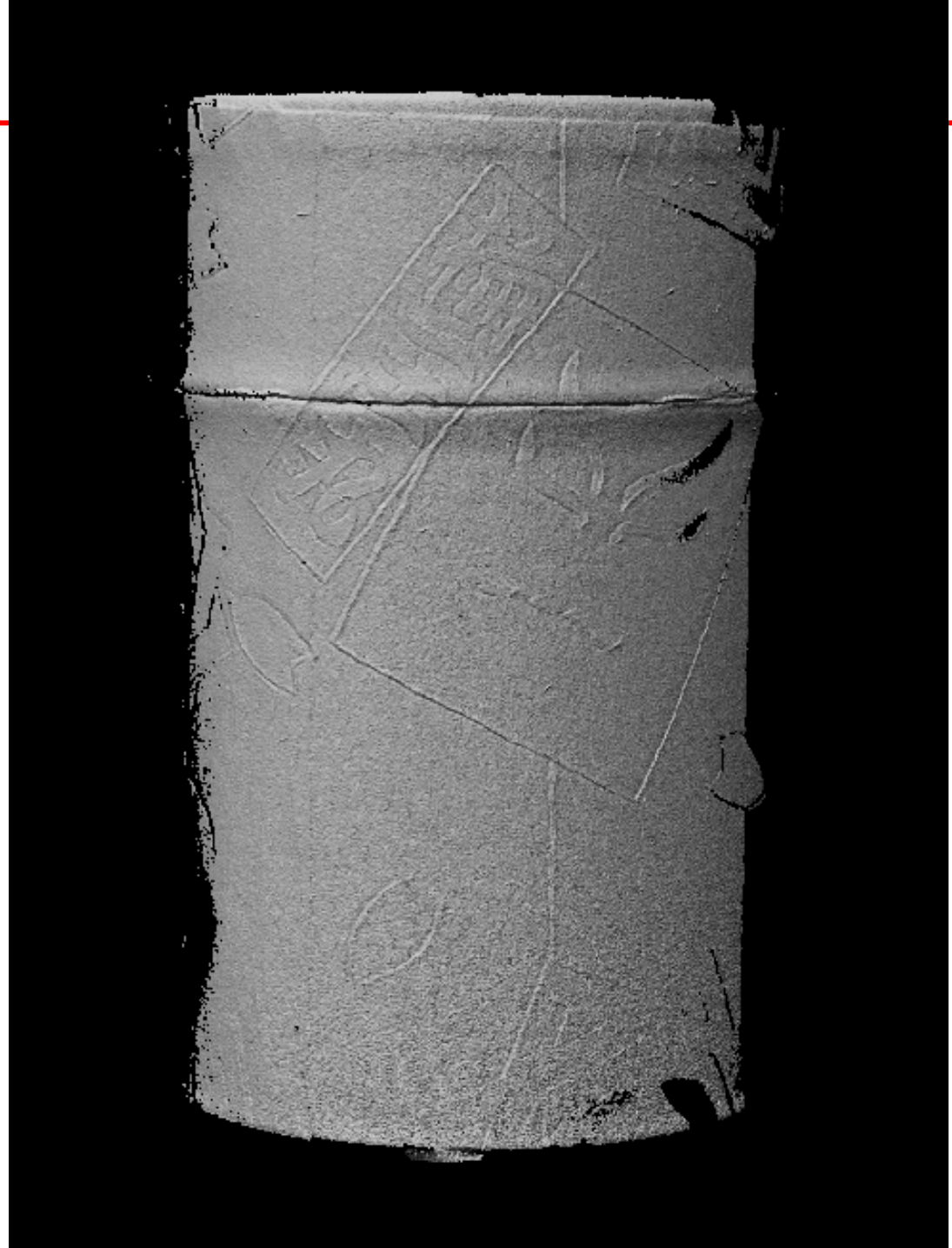
- Take advantage of range intensity images

  - Omnidirectional geometric model
  - Seamless textures

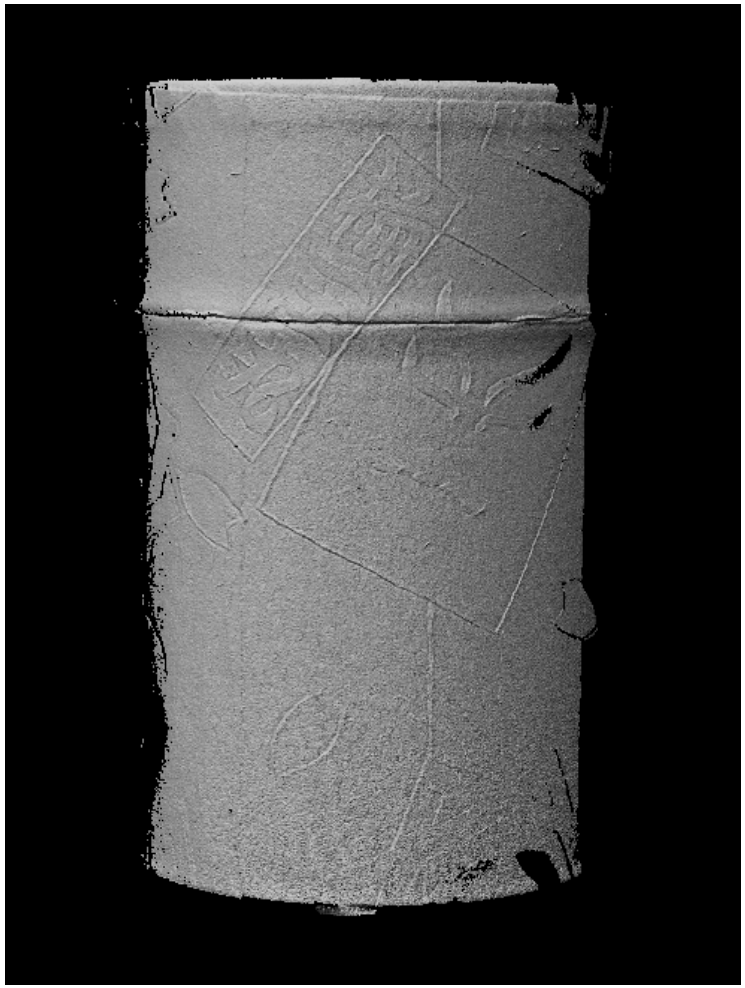
Range intensity image

- Intensity image that is acquired simultaneously with the range image captured using an active range sensor (triangulation, time of flight)
  - Power of reflected laser light

- Also called a reflectance image



Range intensity image



Range image
Geometry (x,y,z)

Range intensity image
Intensity I

Range intensity image

Illumination conditions such as the geometrical arrangement and power of illumination is known

cf. color image

Can be used as reference for color texture

Range intensity image

Related works

- Registration of range and color images

  [Boughorbel 1999] [Dias 2003]

  [Kurazume 2002] [Smith 2001]

  [Umeda 2004] [Böhm 2007]

- Color image correction

  [Umeda 3DIM05]

  [Shinozaki ICPR06]

  [Shinozaki CVIU09]

Flow of constructing a 3D model

Multiple range images
& range intensity images

Range & range intensity image

Color image

Correction of range intensity images

Construction
of an omnidirectional geometric model
with intensity information

Multiple color images

Registration of range and color images

Correction of color images

Construction of a 3D model with color texture

Correction of range intensity images

Multiple range images
& range intensity images

Correction of range intensity images

Construction
of an omnidirectional geometric model
with intensity information

Sensor-specific characteristics

Highlights

Multiple color images

Correction of color images

Construction of a 3D model with color texture

Omnidirectional color 3D model

Correction of range intensity images

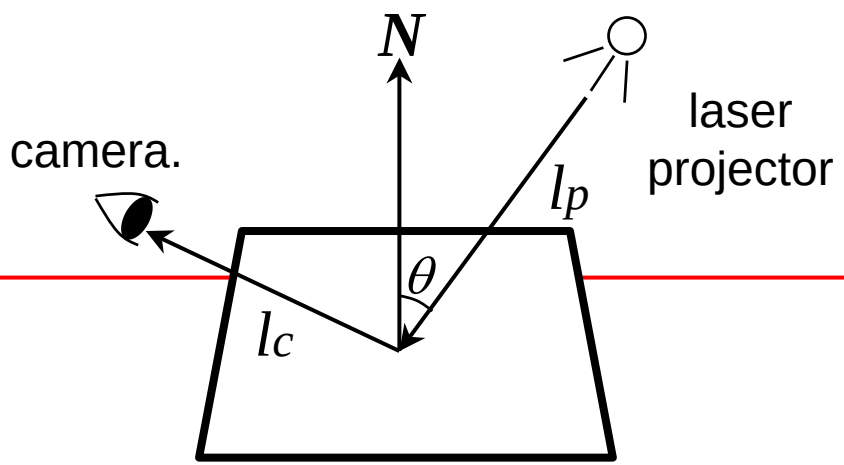
Effects of

- Distance to each measured point
- Normal vector at the measured point
- Sensor-specific characteristics

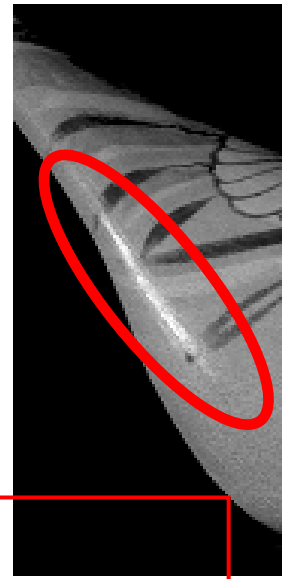
  -gamma characteristic, imaging geometry, etc.

$$I_{obs} = \left\{ k_i(l_c) \frac{\cos\theta}{l_p l_c} I \right\}^{\gamma}$$

I_{obs} observed range intensity
I range intensity to obtain
$k_i(l_c)$ coefficient function
γ gamma value
l_p distance from projector
l_c distance to camera
θ Incident angle



Correction of range intensity images



Specular components

- Dichromatic reflection model

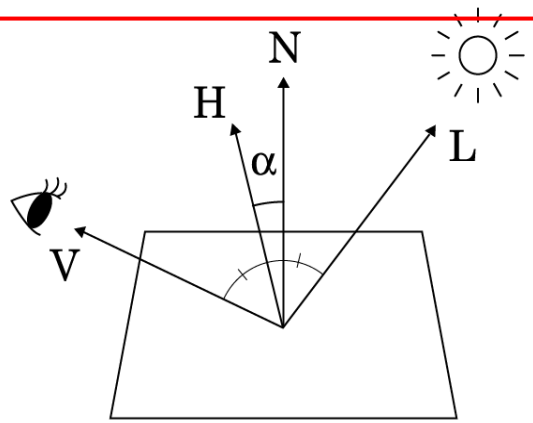
  Reflection=Diffuse + Specular

  Remove

- Simplified Torrance-Sparrow model

$$I = I_d \left\{ 1 + k \exp\left(-\frac{\alpha^2}{2\sigma^2} \right) \right\}$$

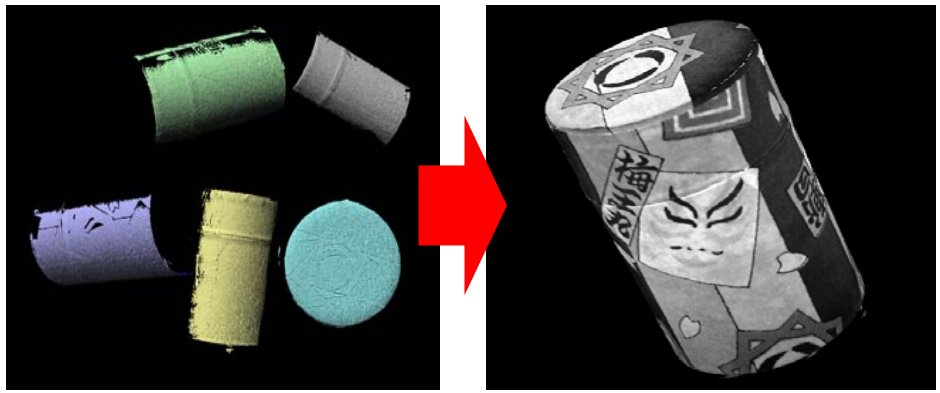
I_d. diffuse component
I. obtained intensity
k. ratio of specular component
σ. dispersion of specular component



- **L**. Lighting direction
- **V**. Camera direction
- **H**. Bisector of **L** and **V**
- **N**. Normal vector

Construction of an omnidirectional geometric model with intensity information

Multiple range images
& range intensity images



Correction of range intensity images

Construction
of an omnidirectional geometric model
with intensity information

Multiple color images

Correction of color images

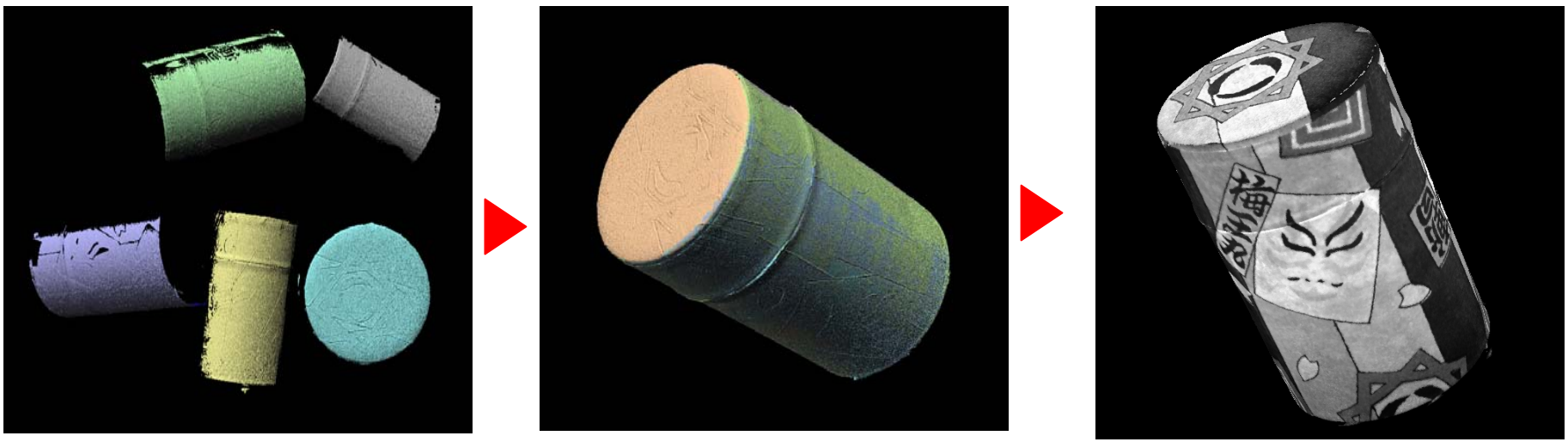
Construction of a 3D model with color texture

Omnidirectional color 3D model

Construction of an omnidirectional geometric model with intensity information

- Multiple range images from different viewpoints
- Registration and integration
- Range intensity images, too

  Intensity information of geometric model



Correction of color images

Multiple range images
& range intensity images

Correction of range intensity images

Construction
of an omnidirectional geometric model
with intensity information

Illumination color

Highlights

Shading

Multiple color images

Correction of color images

Construction of a 3D model with color texture

Omnidirectional color 3D model

Correction of color images

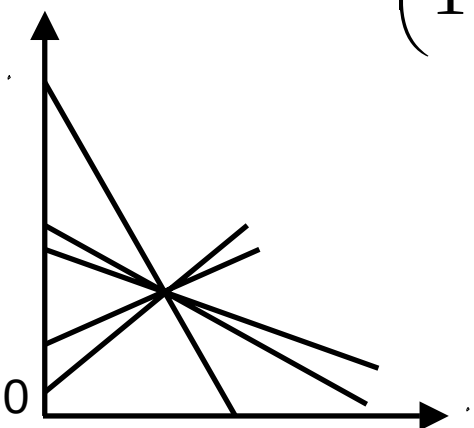
Compensation of illumination color

Changes of chromaticity in regions containing specular reflection

➡ Chromaticity of illumination color (p_r, p_g)

[Lehmann et al. 2001]

➡
$$\begin{pmatrix} R_{new} \\ G_{new} \\ B_{new} \end{pmatrix} = \begin{pmatrix} \frac{p_g}{p_r} R \\ G \\ \frac{p_g}{1 - p_r - p_g} B \end{pmatrix}$$



Chromaticity:

$$r = \frac{R}{R+G+B}$$

$$g = \frac{G}{R+G+B}$$

Correction of color images

Correction of the intensity of a color image

(corrected) range intensity image is used as reference

- Coefficient to correct intensity of color image

$$c = I_{ri} / I_c$$

I_{ri}: Range intensity

I_c: R-channel of color image

(When laser color is red)

- Interpolation to obtain the coefficient at each pixel of color image

  -Different resolution, bad S/N ratio

- R, G, B values are multiplied by the coefficient

Construction of a 3D model with color texture

Multiple range images
& range intensity images

Correction of range intensity images

Construction
of an omnidirectional geometric model
with intensity information

Projecting corrected color images

Multiple color images

Correction of color images

Construction of a 3D model with color texture

Omnidirectional color 3D model

Experimental results

Tea leaf can (φ70mm×h105mm)

Experimental apparatus

- Range image sensor
  - -ShapeGrabber
    PLM300+ SG-102
  - -Laser wavelength: 670nm
  - -1280 points / slit
  - -Range & range intensity images

- Digital camera
  - -Nikon D70
  - -Image size 3008×2000
  - -Color images

Correction of range intensity image

Original image

After correction

Construction of an omnidirectional geometric model with intensity information

InnovMETRIC

PolyWorks

Effect of correction of range intensity image

- Overlapped regions (magnified)

w/o correction

w/ correction

Correction of color images

Original image
Illumination. INC A (2850K)
(p_r, p_g). (0.553,0.321)

Correction of color images

With color correction
Estimated (p_r,p_g) (0.540,0.310)

	Color (*pr*, *pg*)
True	(0.553,0.321)
Estimated	(0.540,0.310)
Errors	(0.013,0.011)

Correction of color images

With color and intensity correction

Construction of a 3D model with color texture

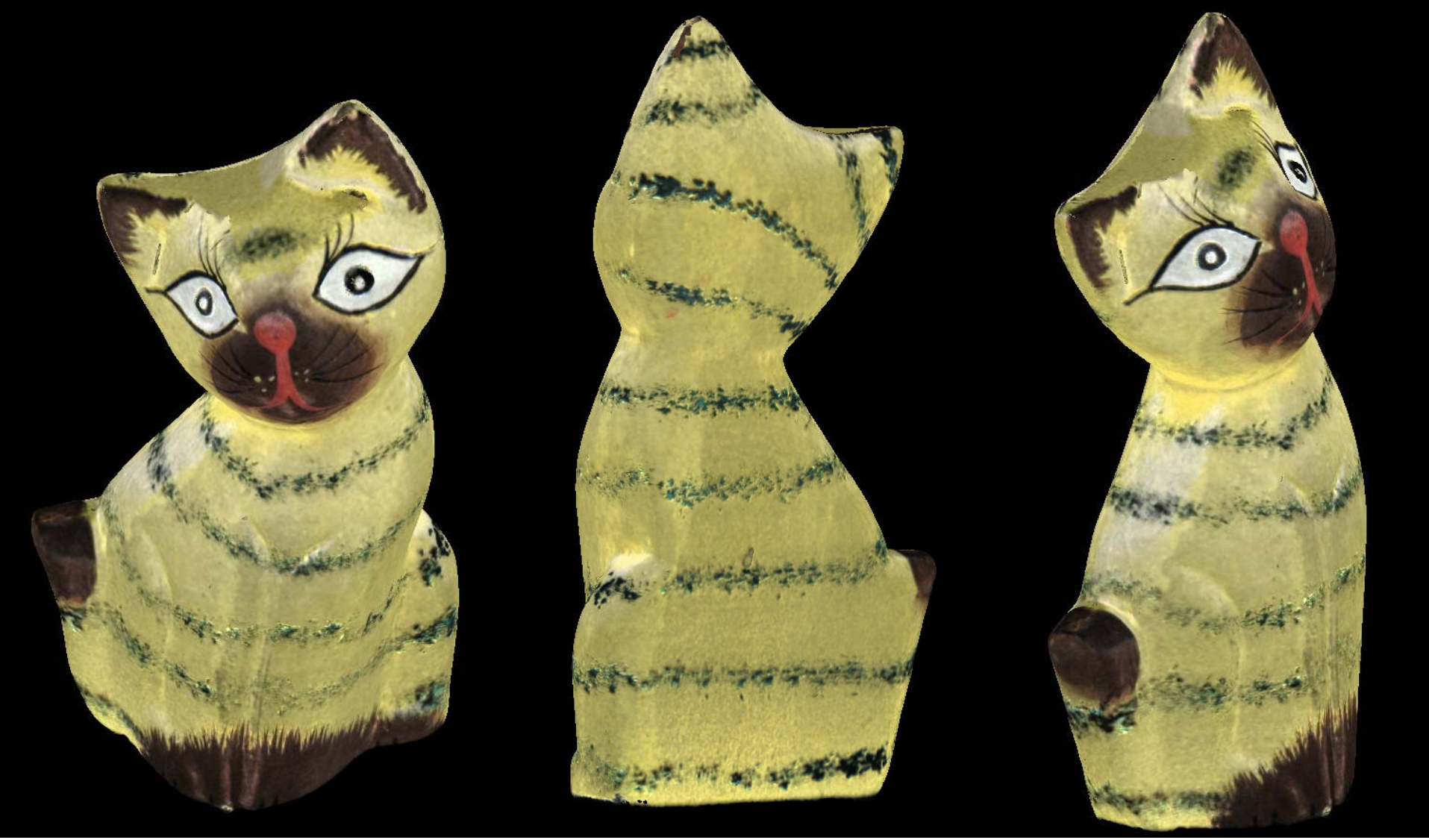
Effect of correction of color images

- Overlapped regions (magnified)

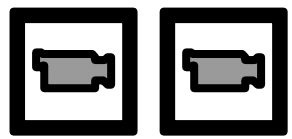
w/o correction

w/ correction

Other examples

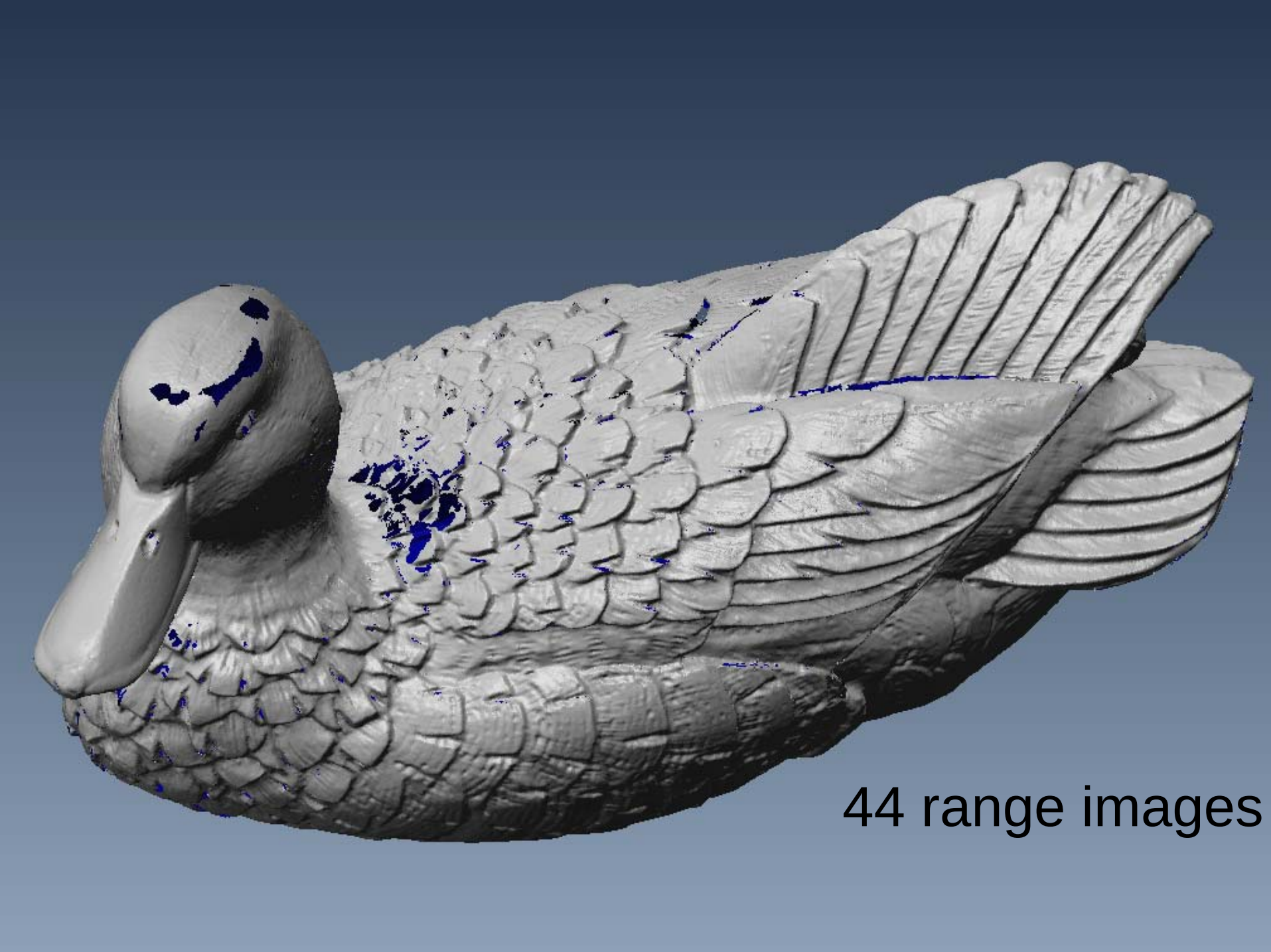


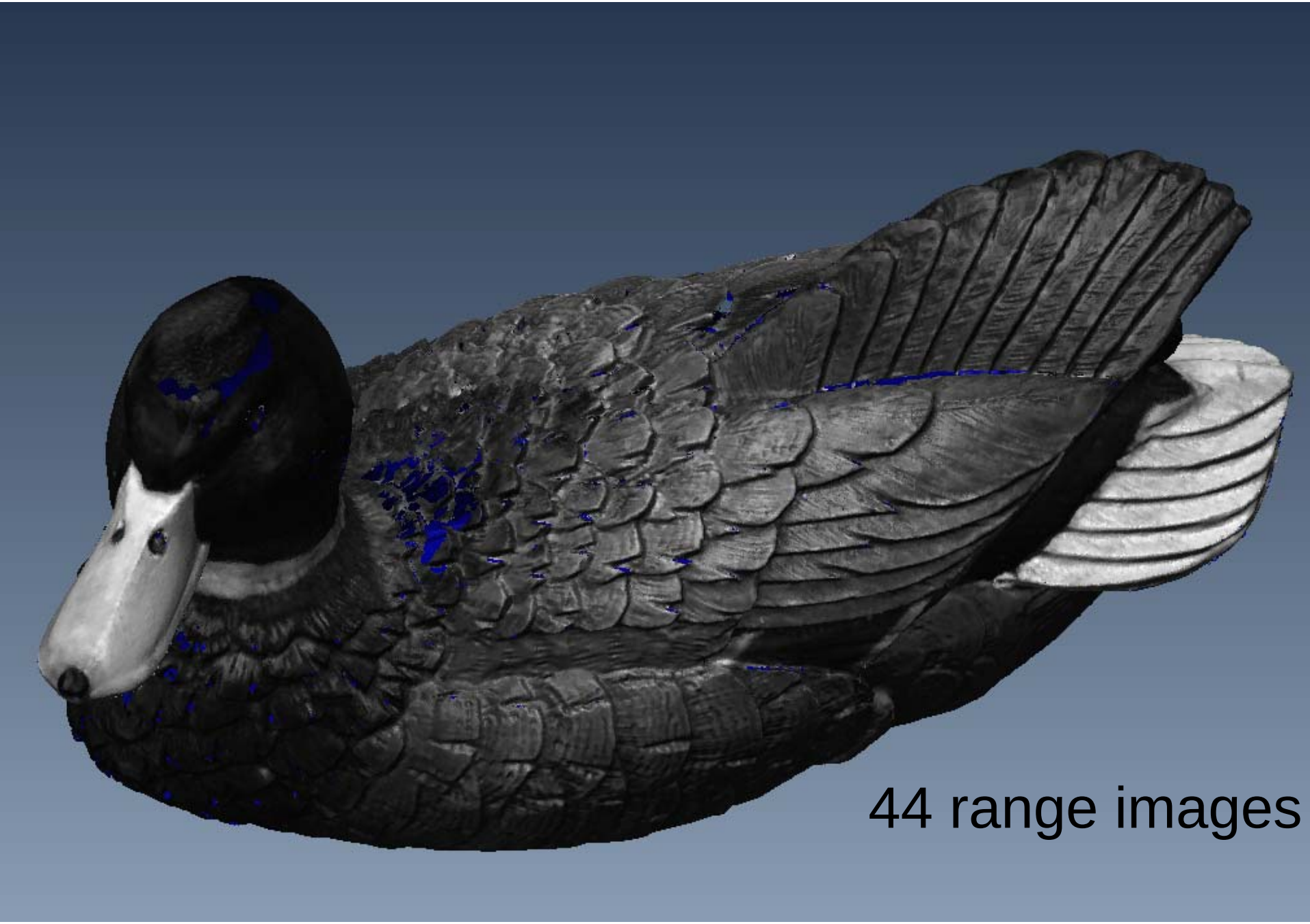
15 range images, 5 color images
CWF illumination (4150K)



INC A (2850K)


5 color images


44 range images


44 range images

Conclusion

Constructed a system to make a 3D model of a real-world object using range intensity images

- Correction of range intensity images
- Construction of an omnidirectional geometric model with intensity information [Polyworks]
- (Registration of range and color images)
- Correction of color images
  - Compensation of illumination color [Lehmann]
  - Correction of the intensity of a color image

    Corrected range intensity image as reference
- Texture mapping of corrected color images