MEASUREMENT-BASED COLOR CORRECTION METHOD FOR 3D SCANNING SYSTEM

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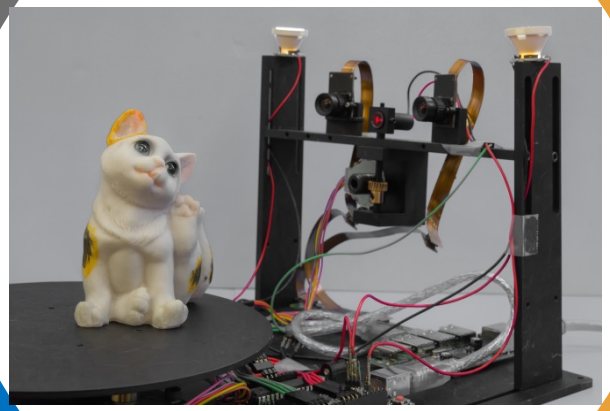
- Why do we need 3D scanning?
- How does 3D scanner work?
- Color Corrections & Evaluations
  - 2D Color Correction
  - 3D Color Correction

WHY

Personal Statue

Virtual Reality

3D Scanning



Augmented Reality

Something Memorable

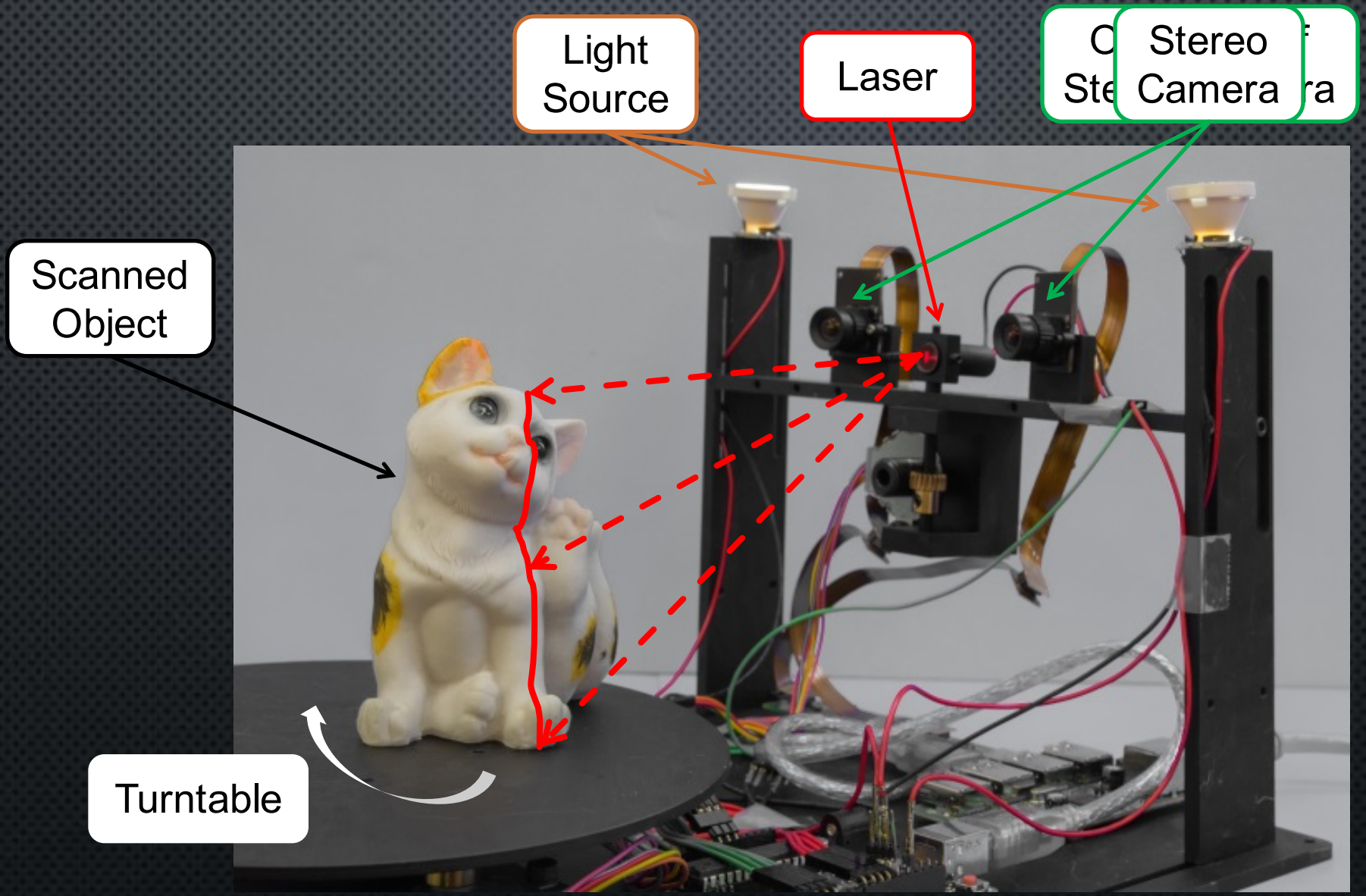
Fetus

Specific Application

HOW

Watch CI3D Scanner Video

3D Scanning Steps



3D Scanning Result

- Color Texture Images

0°	45°	90°	135°	180°	225°	270°	315°
							

COLOR CORRECTION

Experiment Route

Scanned 3D Model

One Lens of Stereo Camera

Color Texture Images (Raw)

X-rite ColorChecker

2D Colorimeter (Topcon UA-1000A)

2D Color Correction

Calibration Ball

2D Colorimeter (Topcon UA-1000A)

3D Color Correction

Evaluation

Corrected 3D Model

2D Color Correction

3D Color Correction

2D COLOR CORRECTION

Uniformity Correction

Camera Color Correction

Uniformity Correction

Uniformity Correction

	Raw	Uniformity
White Board		
ColorChecker		

Reference Values of ColorChecker

Polynomial Regression

Uniformity Correction

Topcon UA-1000A (Ref.)

Unknown

$$[A]_{24xN} \times [M]_{Nx3} = [B]_{24x3}$$

- [A] and [B] are normalized RGB, which is normalized to 0~1.

Camera Color Correction

Uniformity

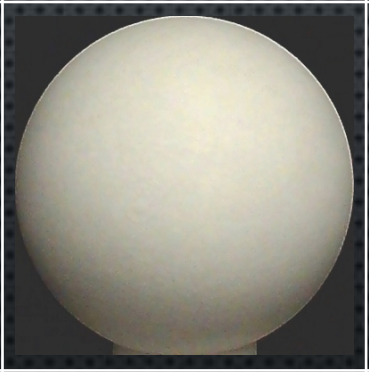
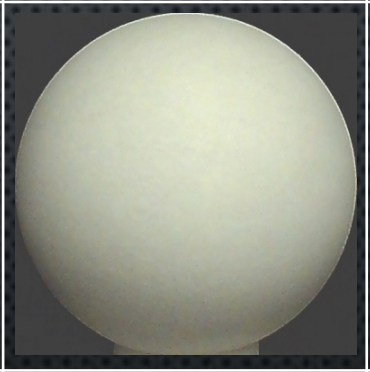
Polynomial Regression

The 1st Order

The 2nd Order

- The 1st Order: [A] = [R, G, B, K], K is constant
- The 2nd Order: [A] = [R^2, G^2, B^2, RG, GB, RB, R, G, B, K], K is constant

2D Color Correction – Color Difference Comparison

	Raw	Uniformity Correction	The 1st Order	The 2nd Order
Colorchecker				
Calibration Ball				
ΔE^*_{94}	**25**	**9**	**5**	**4**

- ΔE^*_{94} is calculated according to ColorChecker.

3D COLOR CORRECTION

What is Final Target?

2D Color Correction

Simulation

Topcon UA-1000A (Ref.)

- Polynomial Regression
- Look-up Table

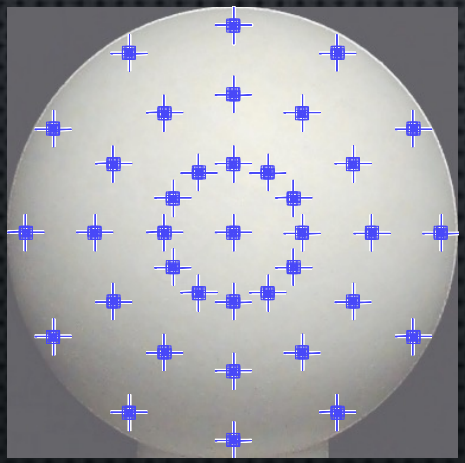
Polynomial Regression

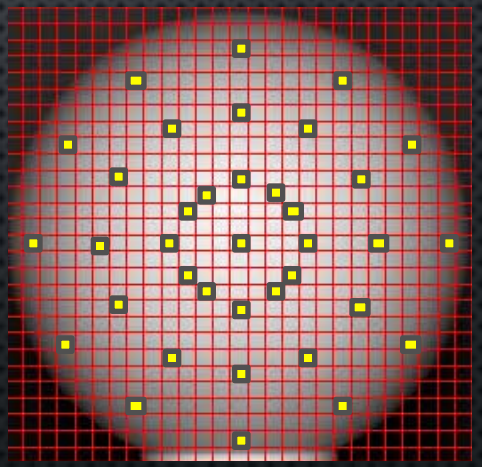
2D Color Correction

Topcon UA-1000A (Ref.)

Unknown

$$[A]_{37xN} \times [M]_{Nx1} = [B]_{37x1}$$





- [A] and [B] are stimulus values, Y.

Polynomial Regression

2D Color Correction

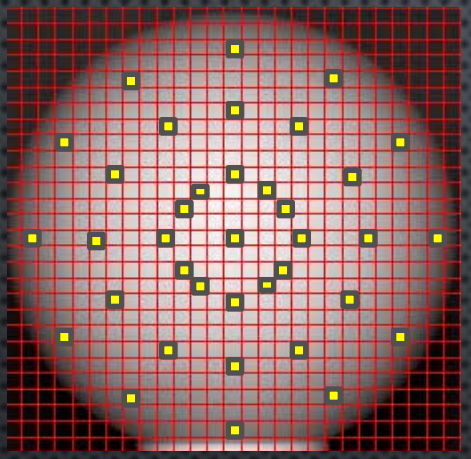
Polynomial Regression

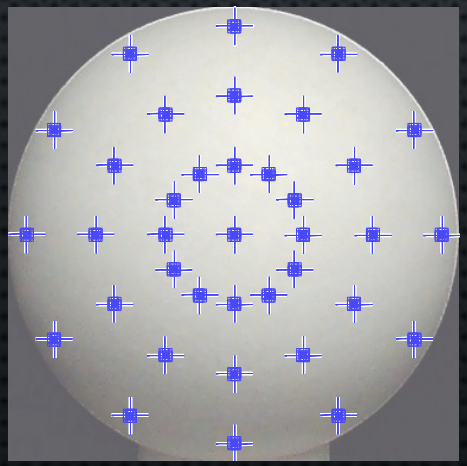
The 1st Order

The 2nd Order

- The 1st Order: [A] = [Y]
- The 2nd Order: [A] = [Y^2, Y]

Look-up Table





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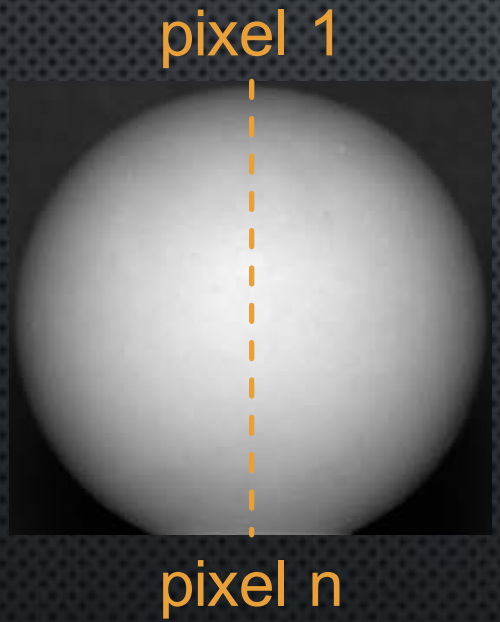
Ratio Table

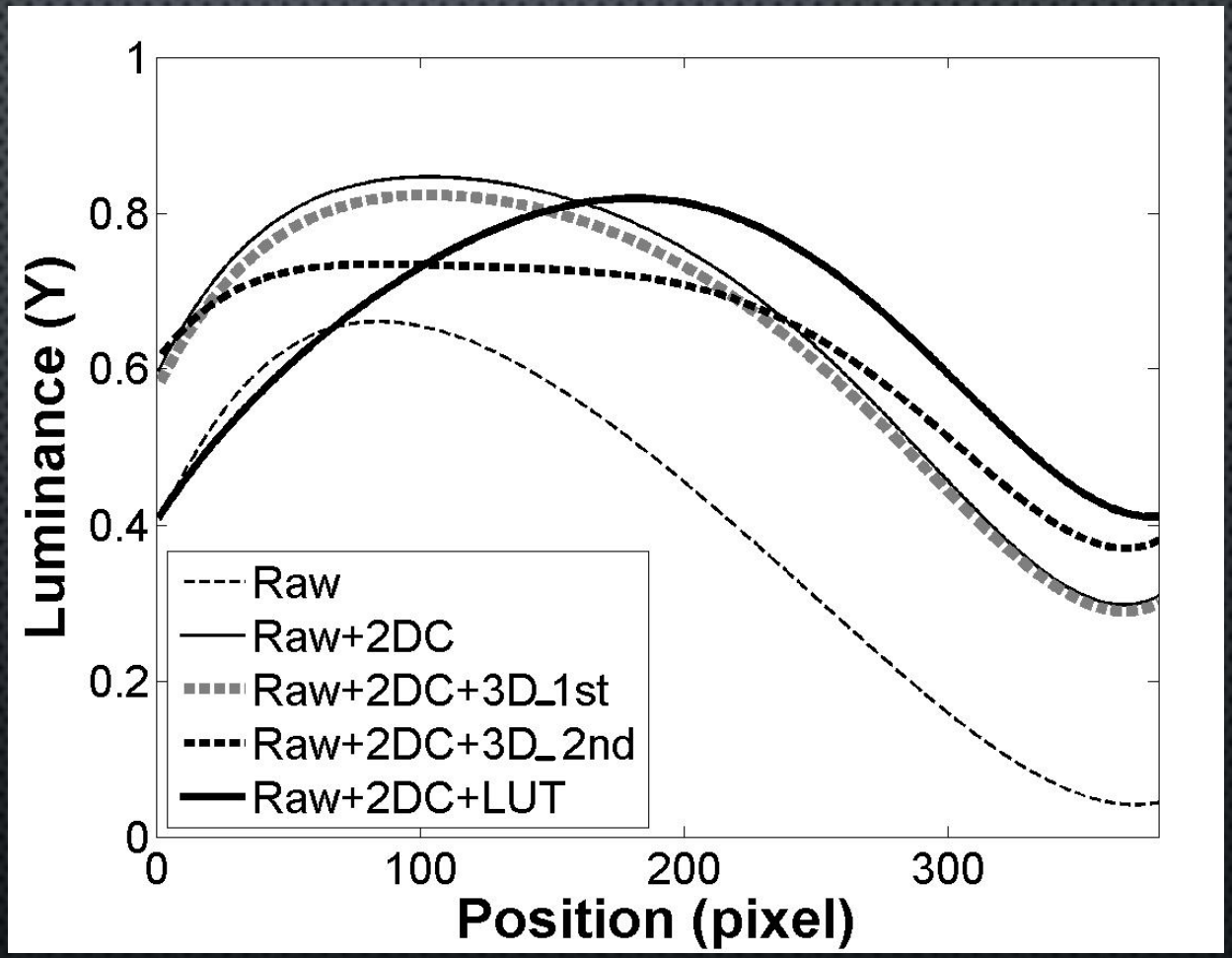
3D Color Correction – Color Difference Comparison

	Raw	2DC	3D_1st (Luminance)	3D_2nd (Luminance)	LUT (Color)
Calibration Ball					
Scanned Model					
ΔE^*_{94}	**24.7**	**15.7**	**15.5**	**15.0**	**0.5**

- ΔE^*_{94} is calculated according to calibration ball.
- 2DC: 2D Color Correction
- 3D_1st: 3D Color Correction–1st Order Polynomial Regression
- 3D_2nd: 3D Color Correction–2nd Order Polynomial Regression
- LUT: 3D Color Correction–Look-up Table

3D Color Correction – Luminance Distribution Curve





3D Color Correction – Contrast Ratio

	Raw	2DC	3D_1st (Luminance)	3D_2nd (Luminance)	LUT (Color)
Calibration Ball					
Contrast Ratio	**16:1**	**3:1**	**3:1**	**2:1**	**2:1**

Overall of Results

Scanned 3D Model → **2D Color Correction** (The 2nd Order) → **3D Color Correction** (Look-up Table)

CONCLUSION

➢ Proposed Color Correction for 3D Scanning

- 2D Color Correction
  - The 1st Order Polynomial Regression
  - The 2nd Order Polynomial Regression
- 3D Color Correction
  - The 1st Order 3D Color Correction
  - The 2nd Order 3D Color Correction
  - Look-up Table

➢ 2D Color Correction

- Correction tool is ColorChecker
- Polynomial regression based on normalized RGB is better
- The 2nd order polynomial regression is better than the 1st order

➢ 3D Color Correction

- Correction tool is calibration ball
- Look-up table method has the best performance of all

➢ All the correction can be applied on realistic 3D scanned object well.

FUTURE WORK

- **Different material** of calibration ball for 3D Color Correction
- **High-end DSLR** replaces 2D colorimeter to capture reference values

THANK YOU.

Picture Source at P.2:
http://3dprintingindustry.com/wp-content/uploads/2014/08/facialhair-3d-scanning.png
https://s3-us-west-1.amazonaws.com/cubify/website/resources/images/products/sense/sense_physicaltodigital.jpg
http://media02.hongkiat.com/augmented-reality-smart-glasses/meta.jpg
http://1.bp.blogspot.com/-cO-lOcFe63M/VMsrZ4I-cfI/AAAAAAAAC7Y/KH3OlOitixE/s1600/virtual-reality.jpg
http://www.beardmillclinic.com/images/3d-4d-scans.png