Sep 26, 2016

Active stereo vision system for object position estimation

Lab Seminar

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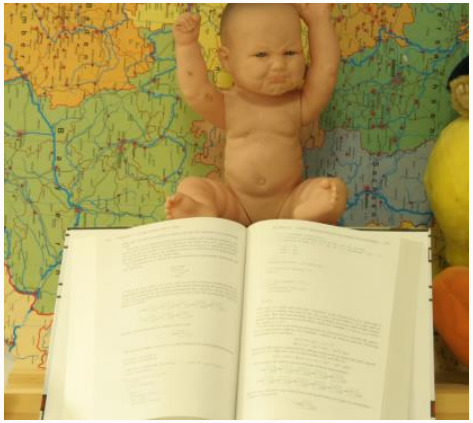
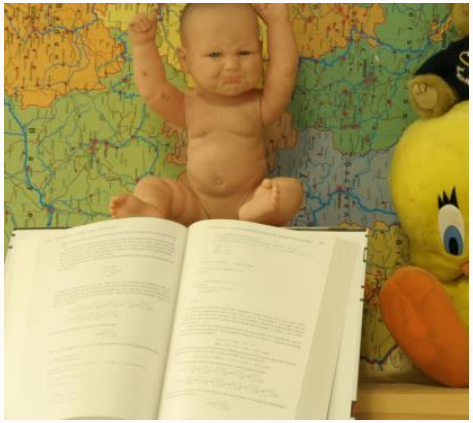
Introduction

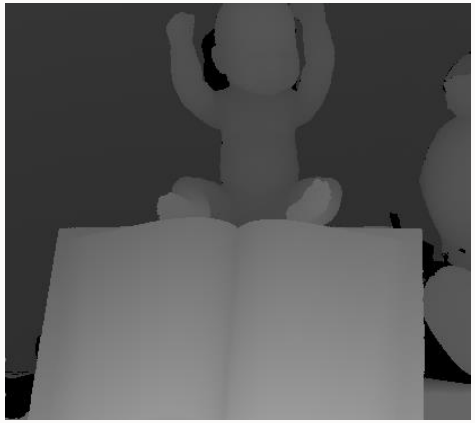
Conventional Stereo Vision

❖ Conventional Stereo Vision

: Stereo vision is the extraction of 3D information from digital images, such as obtained by a CCD camera. **By comparing information about a scene from two vantage points**, 3D information can be extracted by examination of the relative positions of objects in the two panels. This is similar to the biological process **stereopsis**.





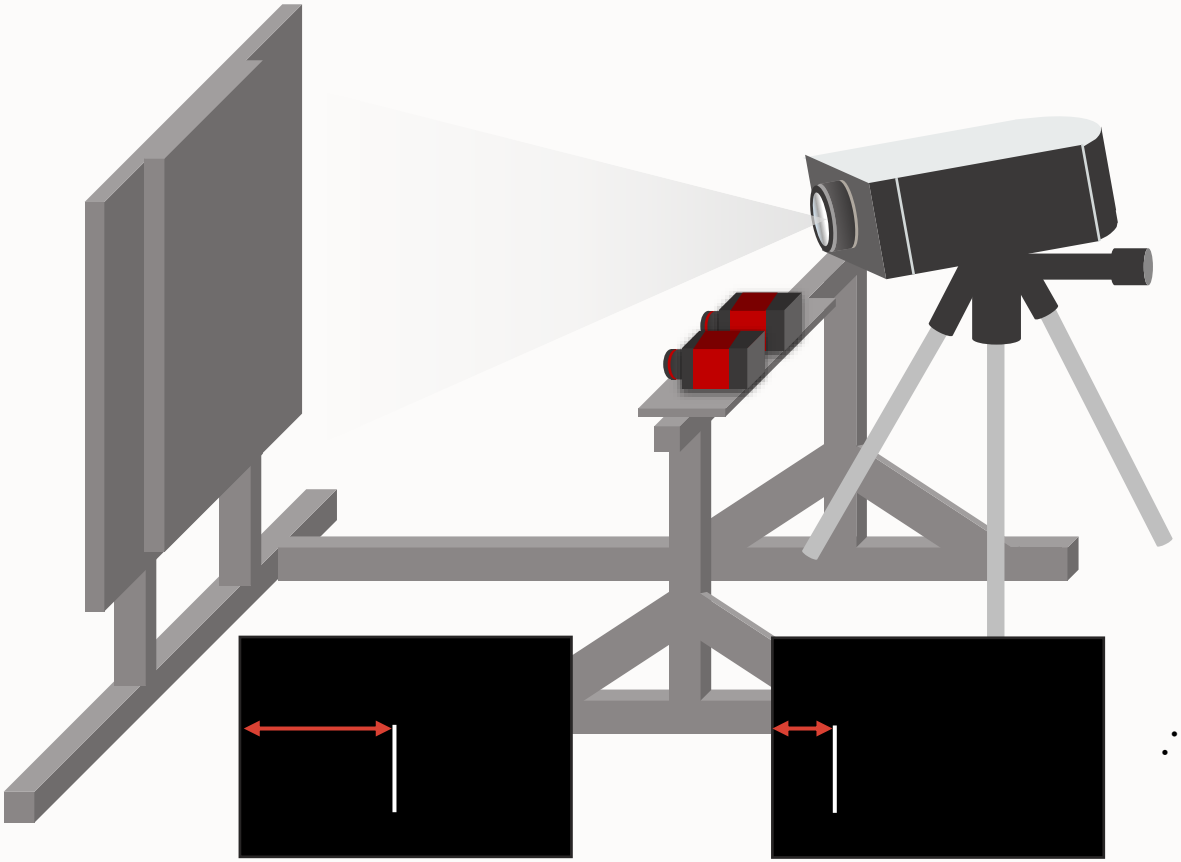


Introduction

Active Stereo Vision

Active Stereo Vision

: The active stereo vision is a form of stereo vision which actively employs a light such as **a laser or a structured light** to simplify the stereo matching problem.



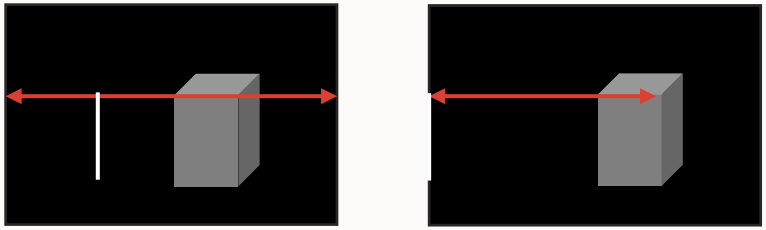
Left Image *Right Image*

$$\therefore Z = \frac{bf}{x_l - x_r}$$

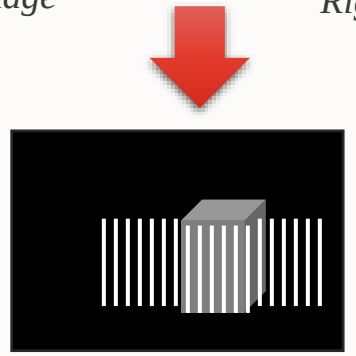
Progress of the Project

Line Scanning, Phase Shifting, Binary Code

❖ Line Scanning



Left Image *Right Image*



Disparity map

$$\therefore Z = \frac{bf}{x_l - x_r}$$

Progress of the Project

Line Scanning, Phase Shifting, Binary Code

❖ Phase Shifting – Three step algorithm

$$I_1(x,y) = I'(x,y) + I''(x,y)\cos[\phi(x,y) - \alpha]$$

$$I_2(x,y) = I'(x,y) + I''(x,y)\cos[\phi(x,y)]$$

$$I_3(x,y) = I'(x,y) + I''(x,y)\cos[\phi(x,y) + \alpha]$$

cf. Four step algorithm

$$I_4 - I_2 = 2I''(x,y)\sin[\phi(x,y)]$$

$$I_1 - I_3 = 2I''(x,y)\cos[\phi(x,y)]$$

$$\frac{I_4 - I_2}{I_1 - I_3} = \frac{\sin[\phi(x,y)]}{\cos[\phi(x,y)]} = \tan[\phi(x,y)]$$

Using the trigonometric addition identities

$$I_1(x,y) = I'(x,y) + I''(x,y)\{\cos[\phi(x,y)]\cos(\alpha) + \sin[\phi(x,y)\sin(\alpha)]\}$$

$$I_2(x,y) = I'(x,y) + I''(x,y)\cos[\phi(x,y)]$$

$$I_3(x,y) = I'(x,y) + I''(x,y)\{\cos[\phi(x,y)]\cos(\alpha) - \sin[\phi(x,y)\sin(\alpha)]\}$$

$$I_1 - I_3 = 2I''(x,y)\sin[\phi(x,y)]\sin(\alpha)$$

$$I_2 - I_1 = I''(x,y)\cos[\phi(x,y)]\{1 - \cos(\alpha)\} - I''(x,y)\sin[\phi(x,y)]\sin(\alpha)$$

$$I_2 - I_3 = I''(x,y)\cos[\phi(x,y)]\{1 - \cos(\alpha)\} + I''(x,y)\sin[\phi(x,y)]\sin(\alpha)$$

$$2I_2 - I_1 - I_3 = 2I''(x,y)\cos[\phi(x,y)]\{1 - \cos(\alpha)\}$$

Progress of the Project

Line Scanning, Phase Shifting, Binary Code

❖ Phase Shifting – Three step algorithm

$$I_1 - I_3 = 2I''(x,y)\sin[\phi(x,y)]\sin(\alpha)$$

$$2I_2 - I_1 - I_3 = 2I''(x,y)\cos[\phi(x,y)]\{1-\cos(\alpha)\}$$

$$\frac{I_1 - I_3}{2I_2 - I_1 - I_3} = \frac{2I''(x,y)\sin[\phi(x,y)]\sin(\alpha)}{2I''(x,y)\cos[\phi(x,y)]\{1-\cos(\alpha)\}}$$

$$= \frac{\sin[\phi(x,y)]\sin(\alpha)}{\cos[\phi(x,y)]\{1-\cos(\alpha)\}} = \frac{\sin(\alpha)}{1-\cos(\alpha)}\tan(\phi(x,y))$$

$$\phi(x,y) = \tan^{-1}\left\{\left[\frac{1-\cos(\alpha)}{\sin(\alpha)}\right]\frac{I_1 - I_3}{2I_2 - I_1 - I_3}\right\}$$

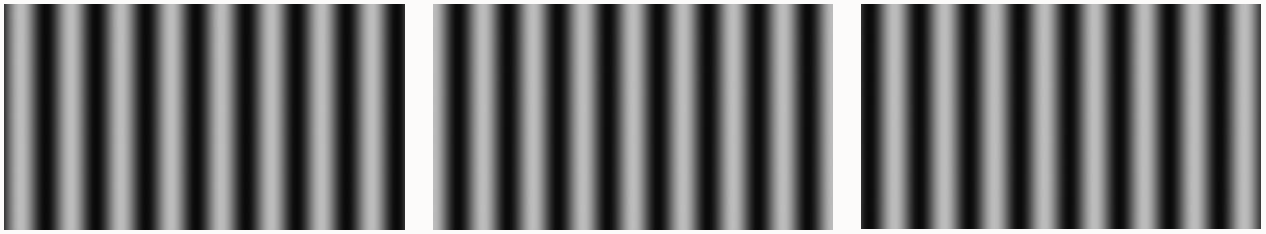
$$when\ \alpha = \frac{2\pi}{3}$$

$$\phi(x,y) = \tan^{-1}\left(\sqrt{3}\,\frac{I_1 - I_3}{2I_2 - I_1 - I_3}\right)$$

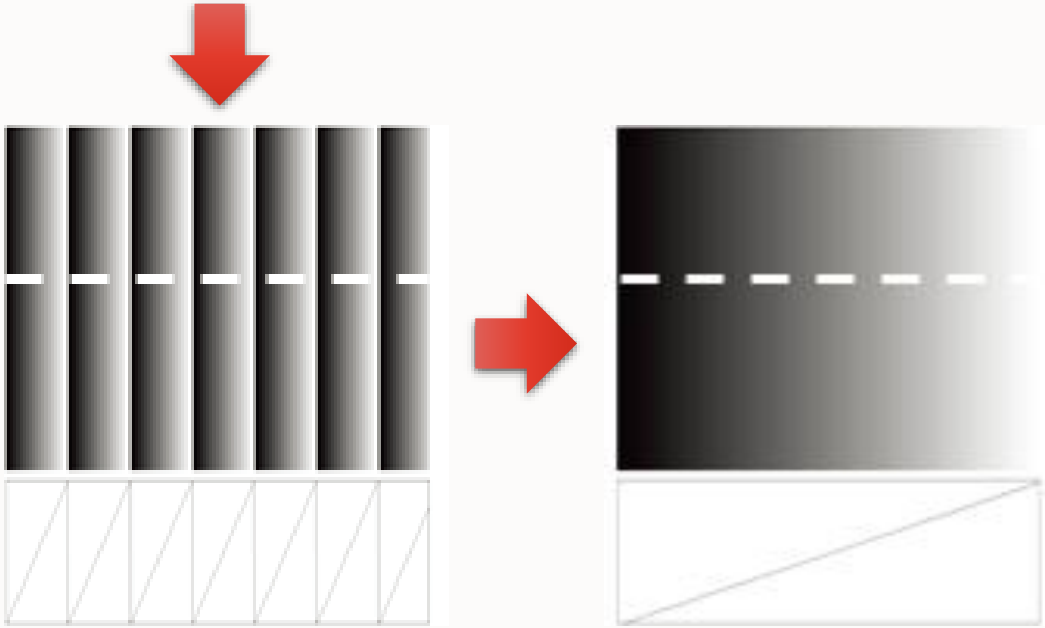
Progress of the Project

Line Scanning, Phase Shifting, Binary Code

❖ Phase Shifting – Three step algorithm



Phase Image



Before unwrapping (0~2π)

After unwrapping

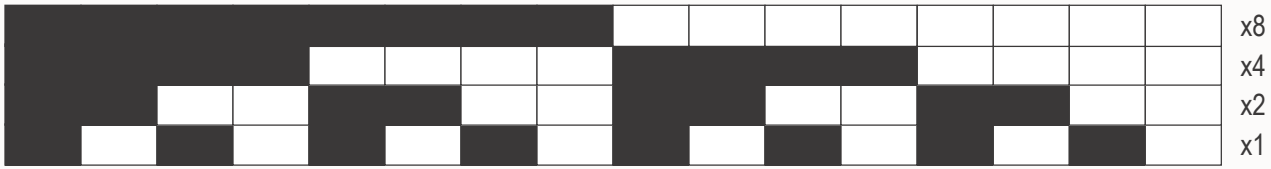
Progress of the Project

Line Scanning, Phase Shifting, Binary Code

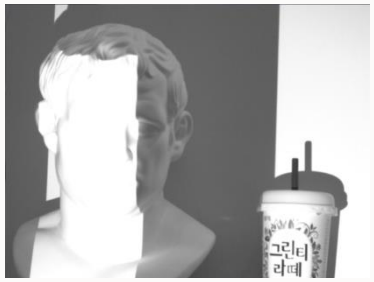
❖ Binary Code

$2^n = X$ n : the number of image
X : resolution

eg. 1024x768 : 10 images



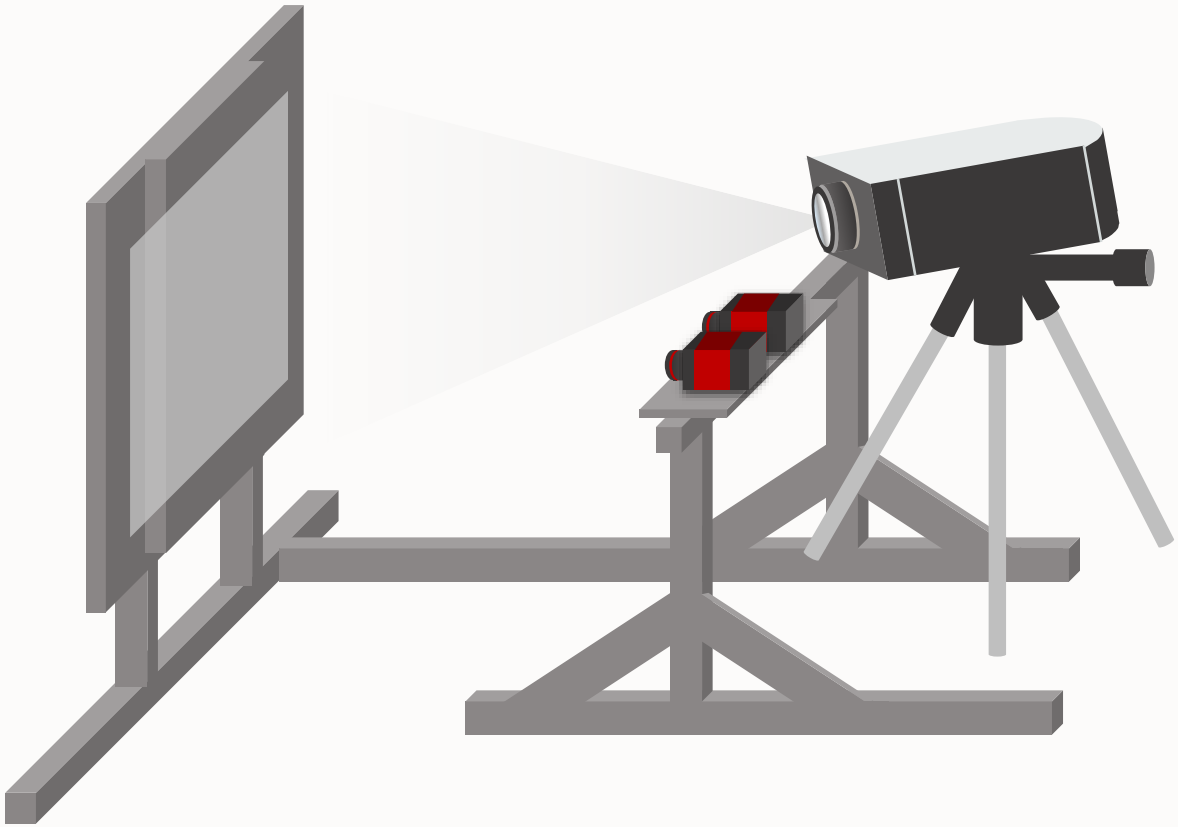
0	0	0	0	0	0	0	0	8	8	8	8	8	8	8	8
0	0	0	0	4	4	4	4	0	0	0	0	4	4	4	4
0	0	2	2	0	0	2	2	0	0	2	2	0	0	2	2
0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1
0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15

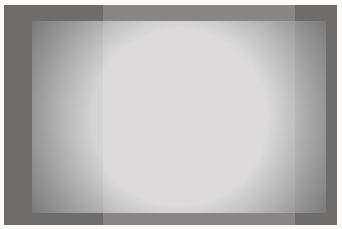


Progress of the Project

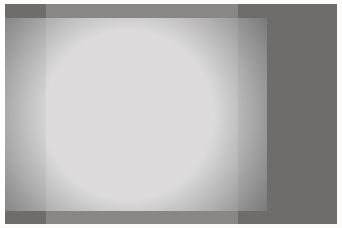
Projector Intensity Correction

❖ Projector Intensity Problem





Left Image

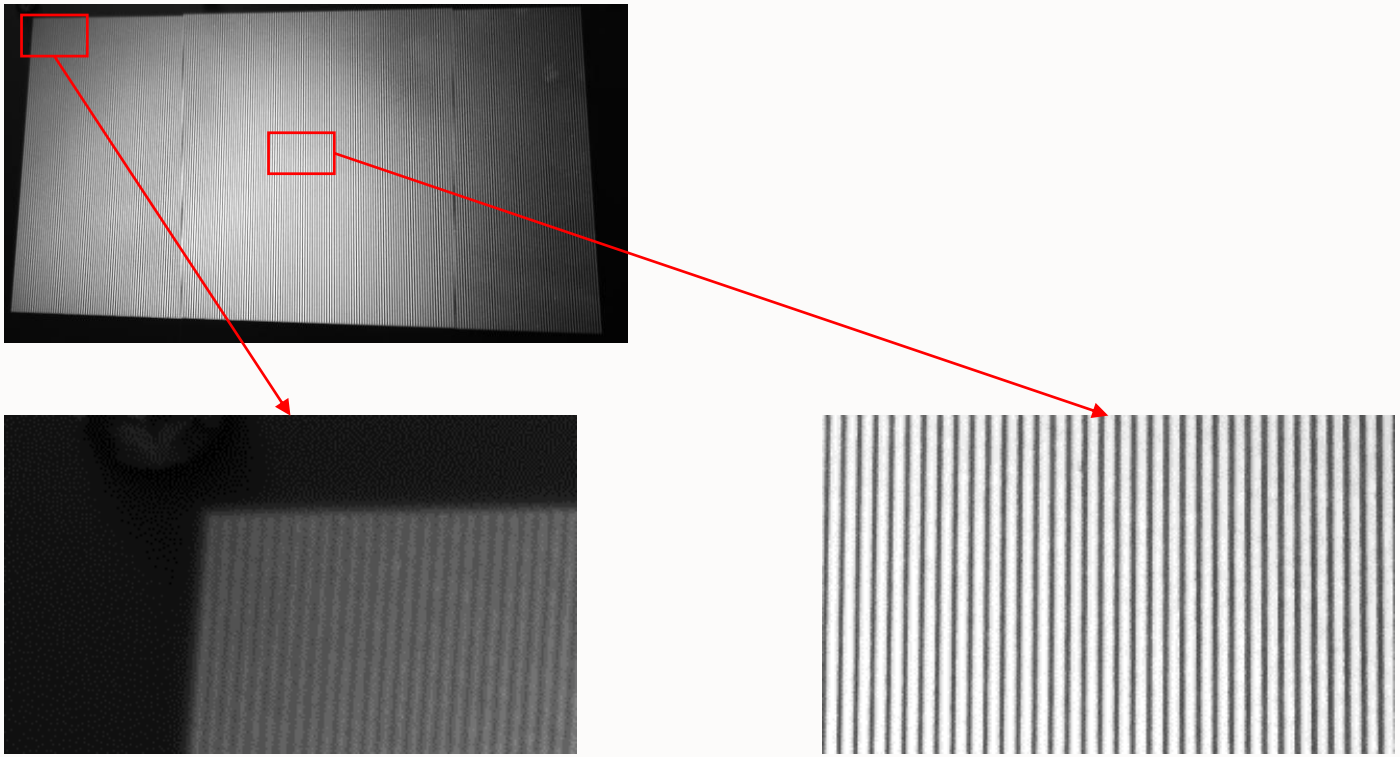


Right Image

Progress of the Project

Projector Intensity Correction

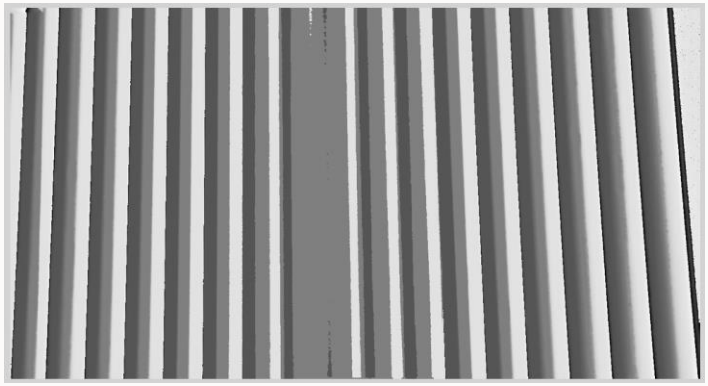
❖ Projector Intensity Problem

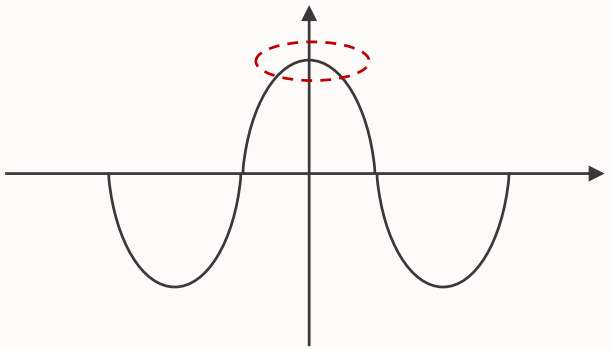


Progress of the Project

Projector Intensity Correction

❖ Projector Intensity Problem

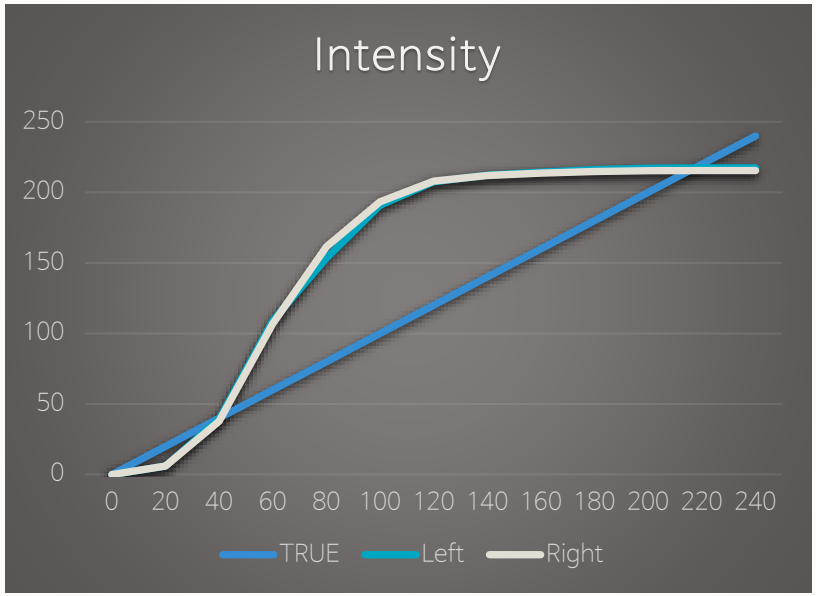


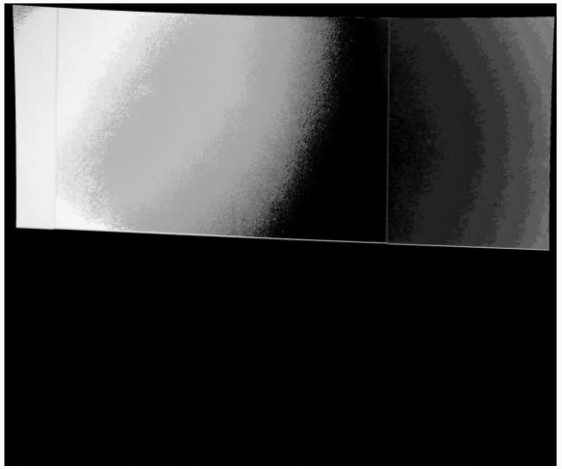


Progress of the Project

Projector Intensity Correction

❖ Projector Intensity Problem





Progress of the Project

Projector Intensity Correction

❖ Projector Intensity Correction

Observed Intensity :

0	0	0	1	0
0	1	1	1	0
0	1	2	1	0
0	1	1	0	0
0	1	1	0	0

…

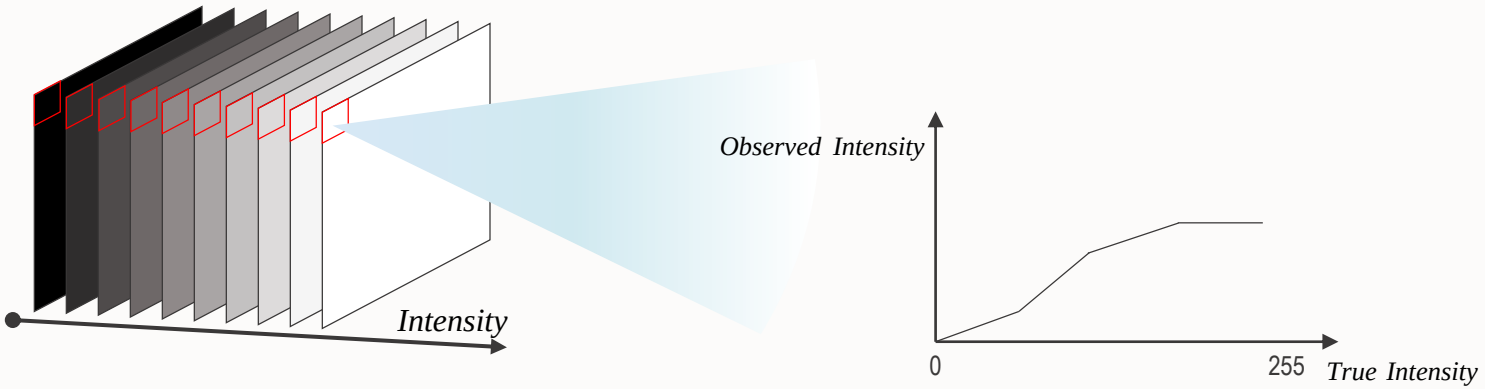
8	8	10	8	7
9	10	10	10	7
9	10	12	10	8
9	10	10	8	7
8	8	10	7	6

…

48	50	50	49	48
50	56	58	58	52
50	55	59	57	54
50	56	57	57	53
49	49	50	49	49

…

True Intensity : 0 10 50



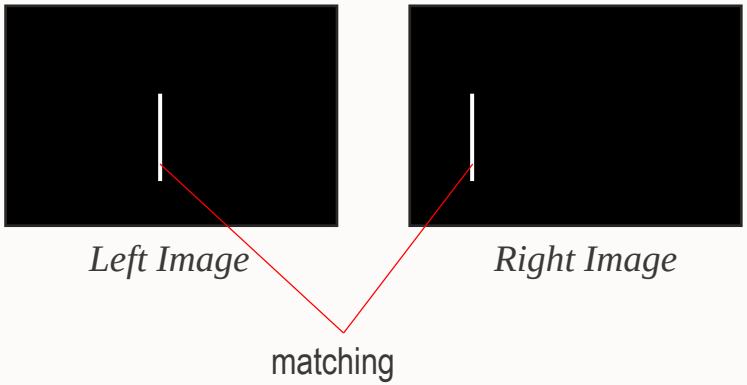
data size : 256x4240x2824x2

Progress of the Project

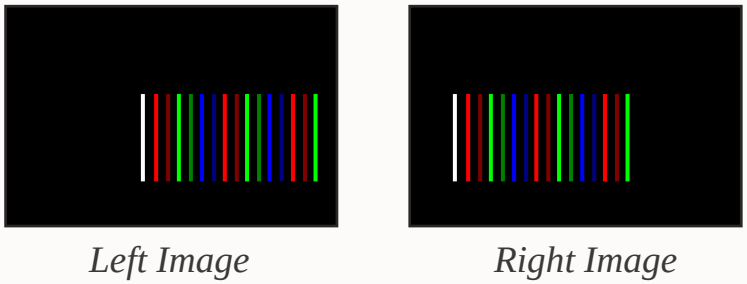
Periodic Color Code

❖ Periodic Color Code

- Stereo matching using line scanning



- Stereo matching using periodic color code

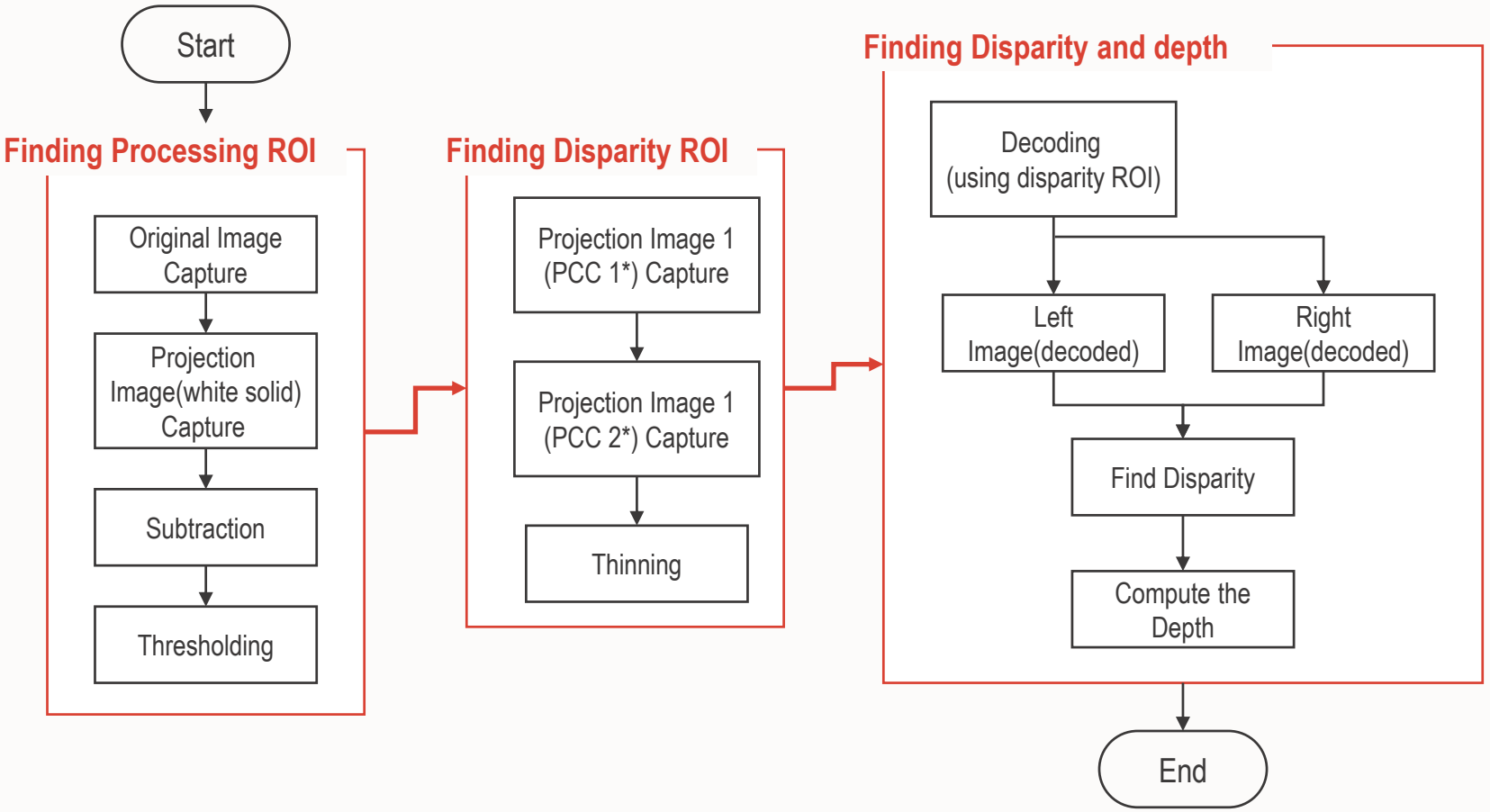


matching using coded pattern

Progress of the Project

Periodic Color Code

❖ Flow Chart

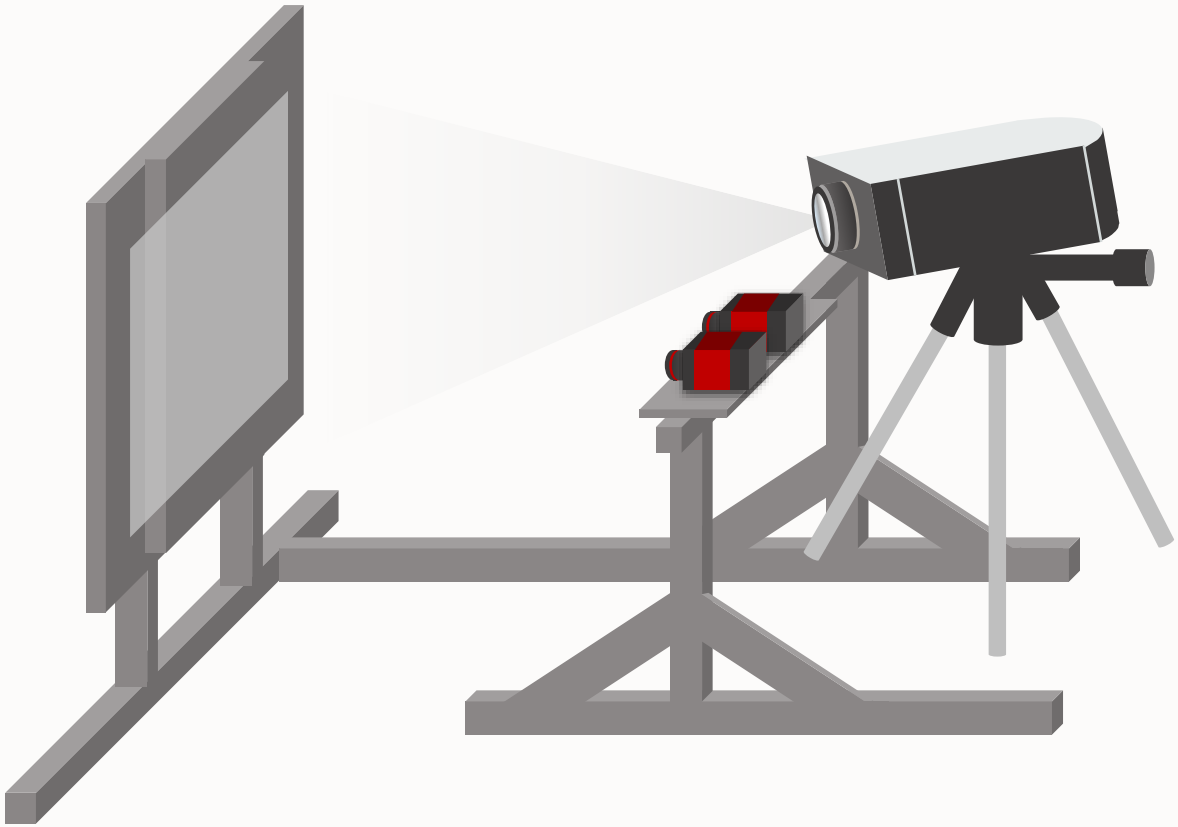


*PCC : Periodic Color Code

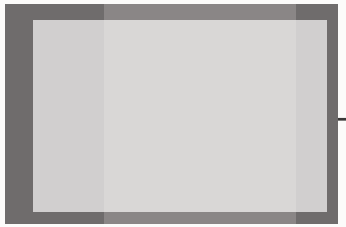
Progress of the Project

Periodic Color Code

❖ Processing ROI



Original Image



Projection Image

subtraction

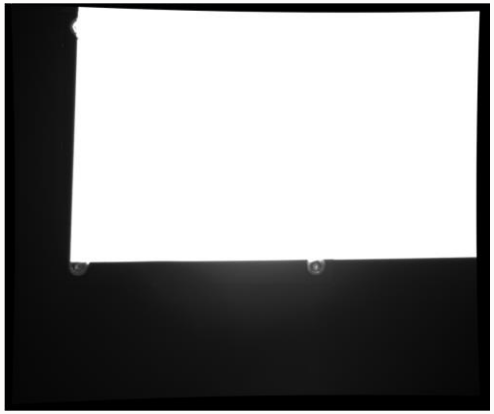
ROI image

Progress of the Project

Periodic Color Code

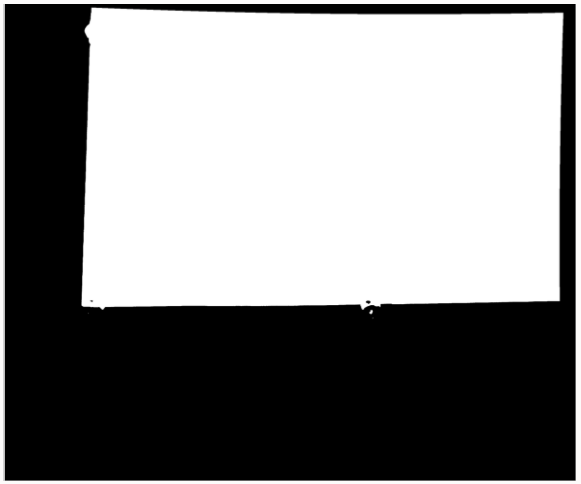
❖ Processing ROI

Original Image



Projection Image

Subtraction & Thresholding →

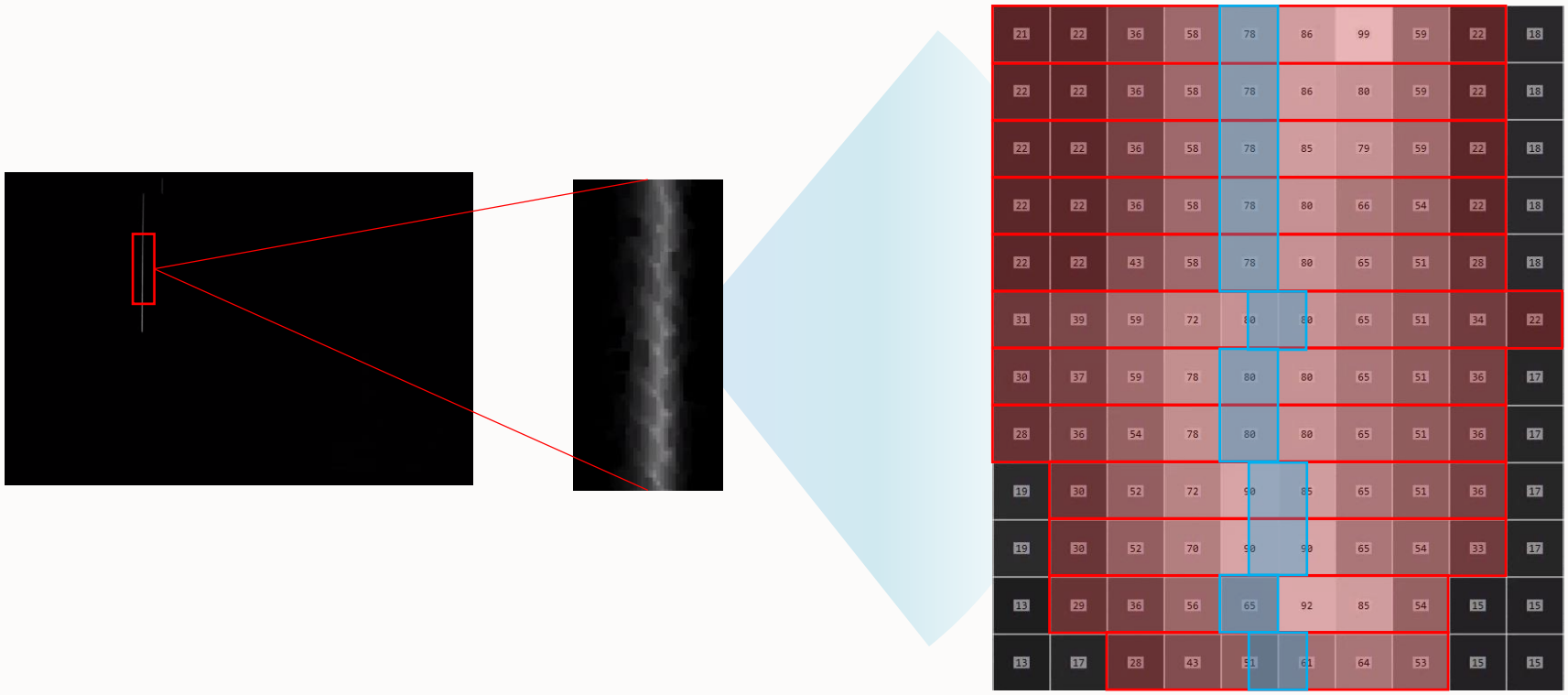


Processing ROI

Progress of the Project

Periodic Color Code

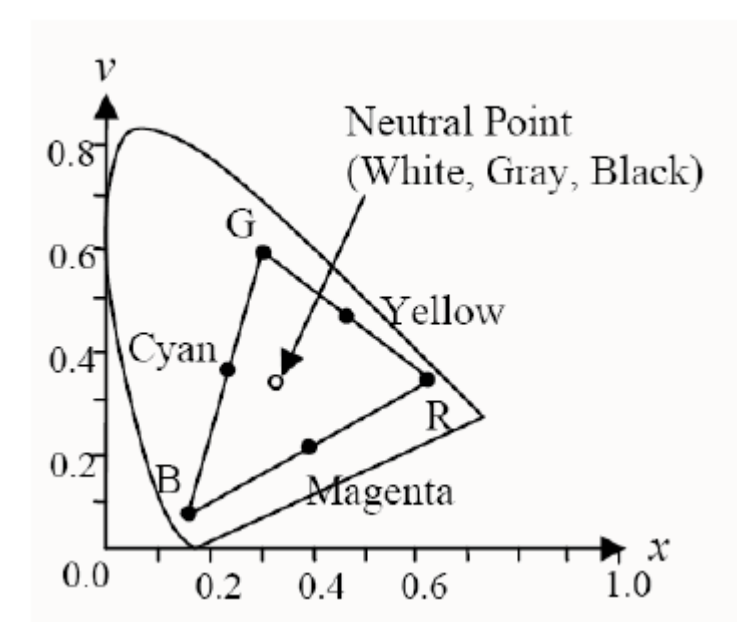
❖ Disparity ROI

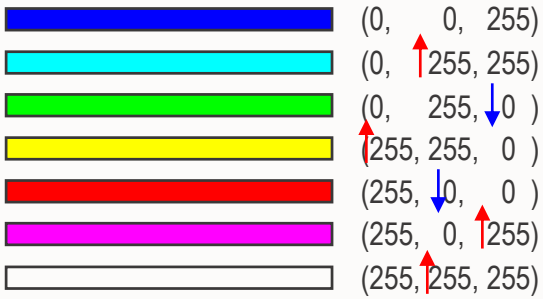


Progress of the Project

Periodic Color Code

❖ Decoding

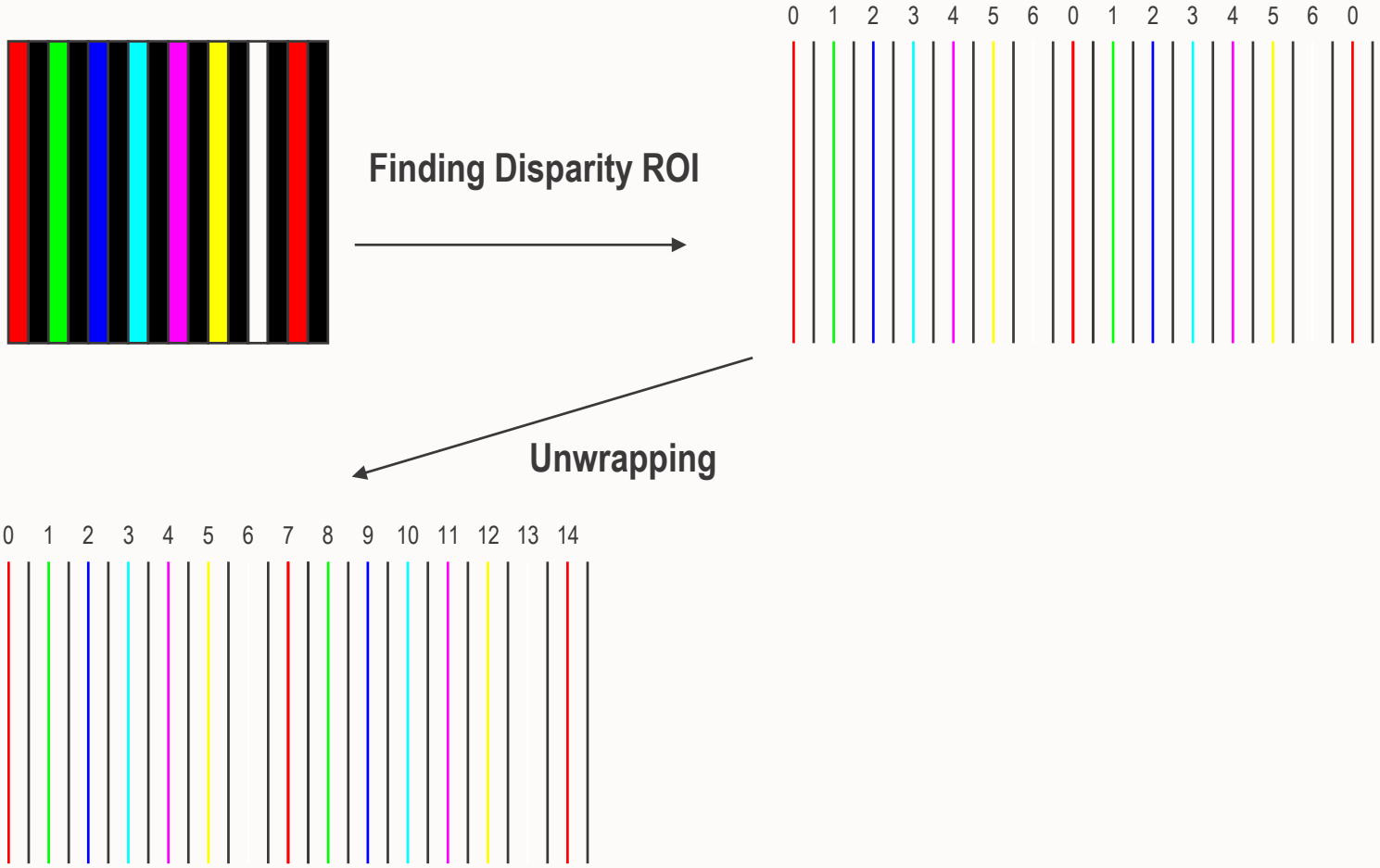




Progress of the Project

Periodic Color Code

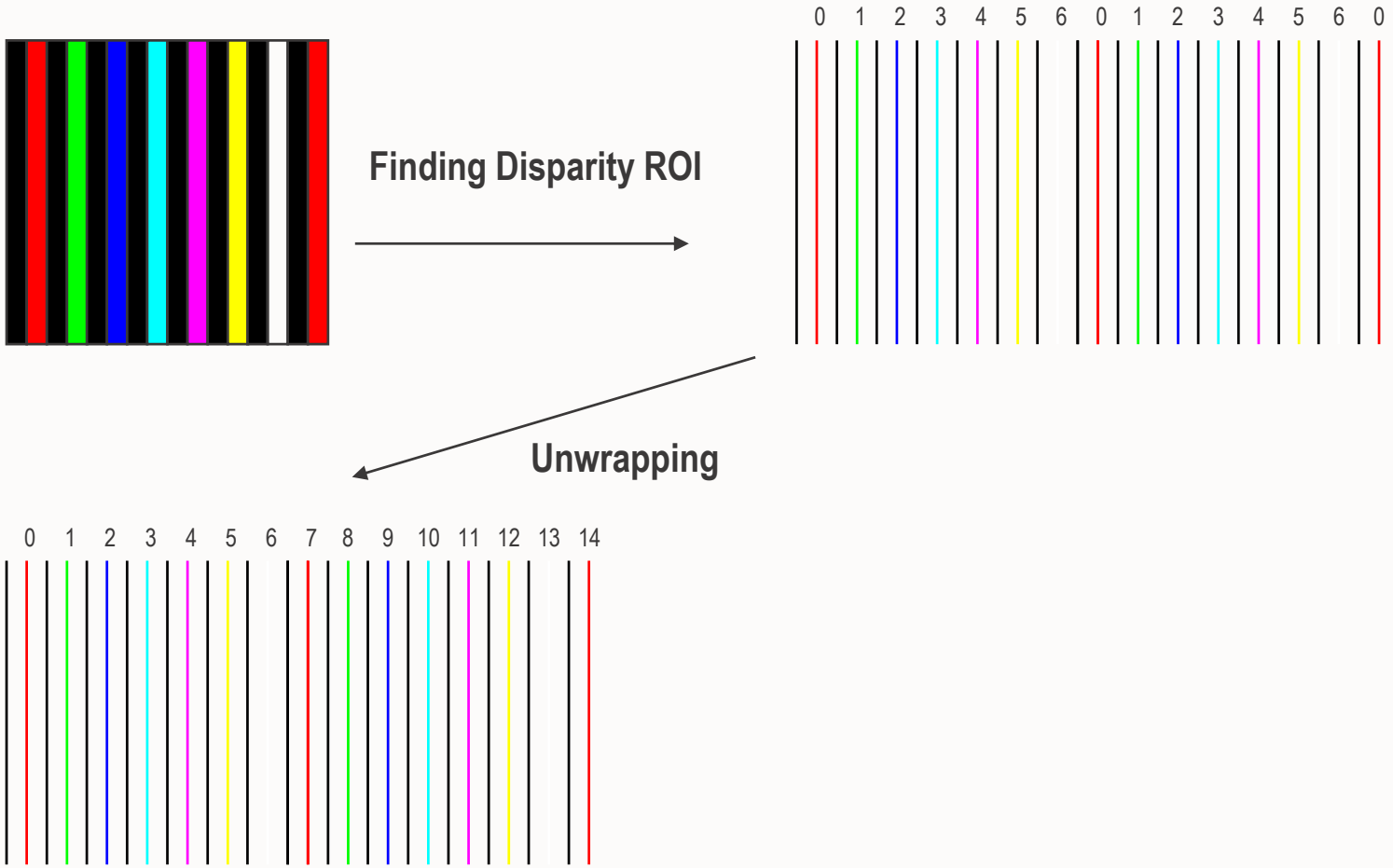
❖ Decoding



Progress of the Project

Periodic Color Code

❖ Decoding

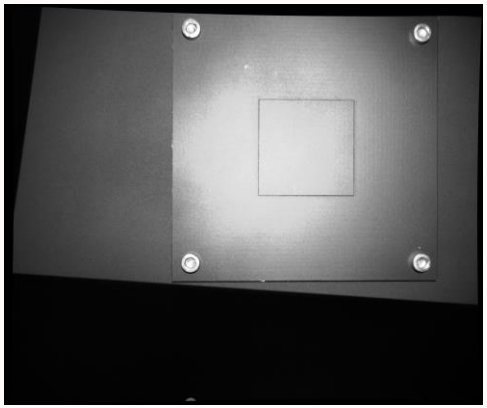


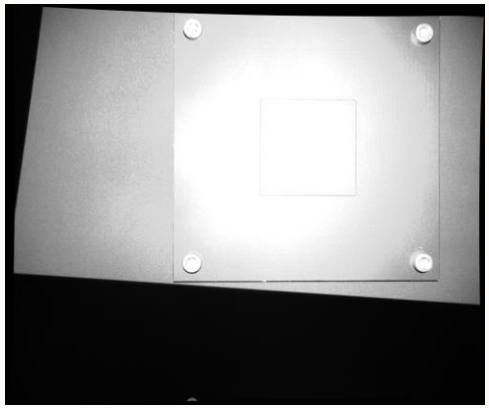
Progress of the Project

Experimental Results

❖ Intensity Correction

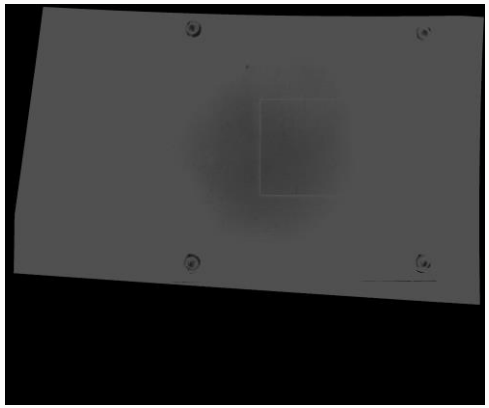
Uncorrected :





Corrected :

True Intensity : 51

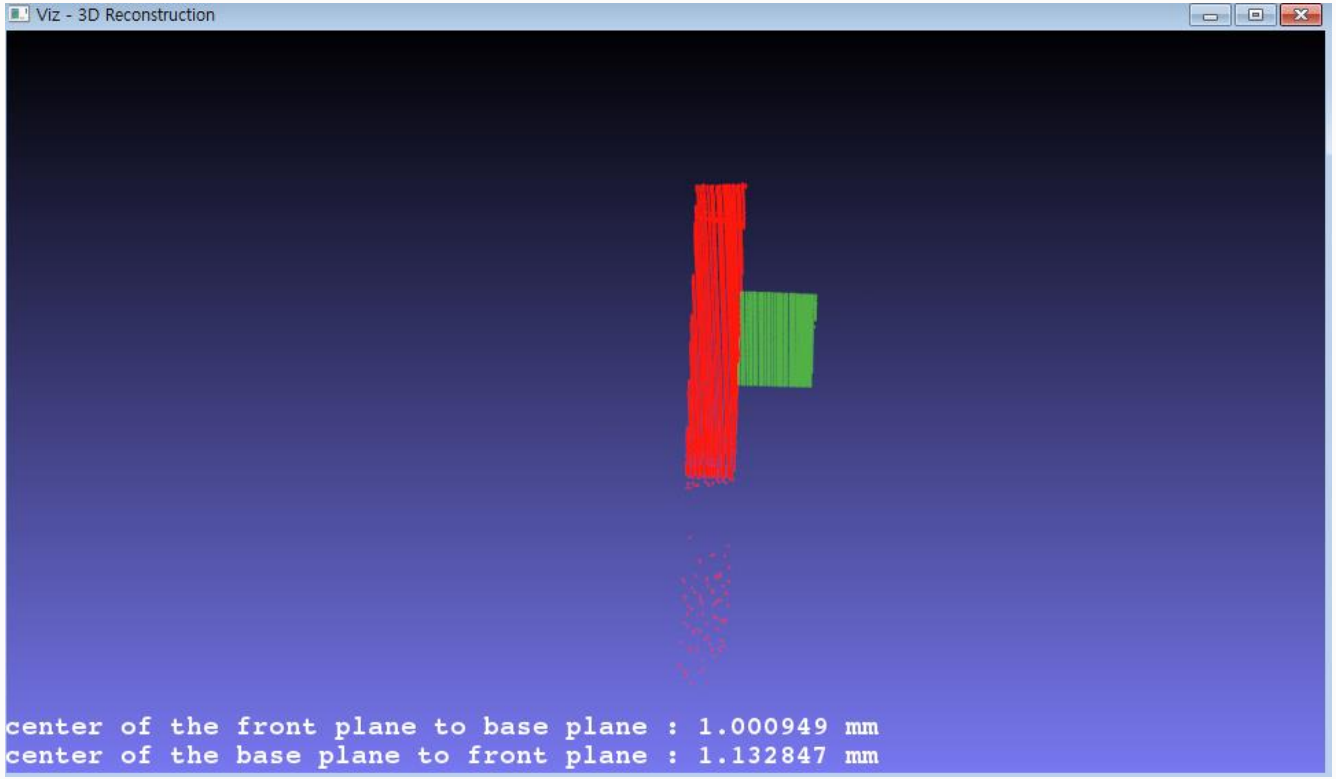


True Intensity : 81

Progress of the Project

Experimental Results

❖ Line Scan method

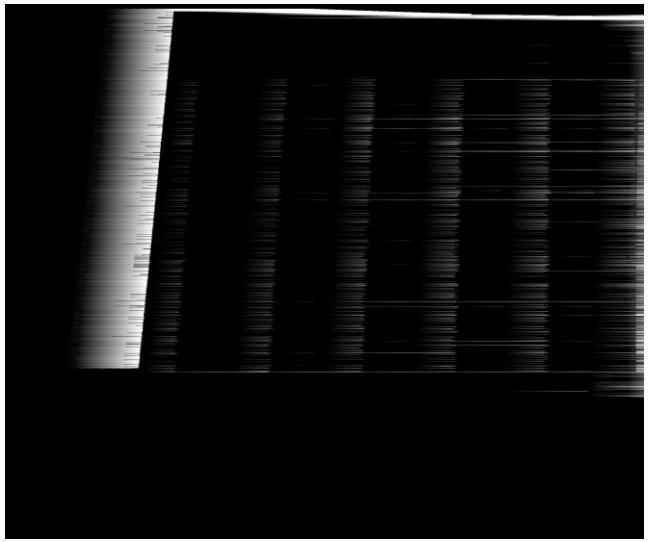


2448x2048

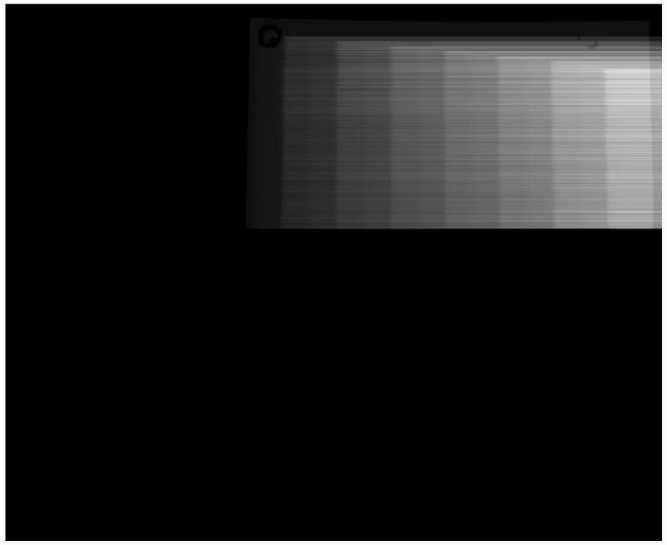
Progress of the Project

Experimental Results

❖ Phase Shifting method



Uncorrected unwrapping

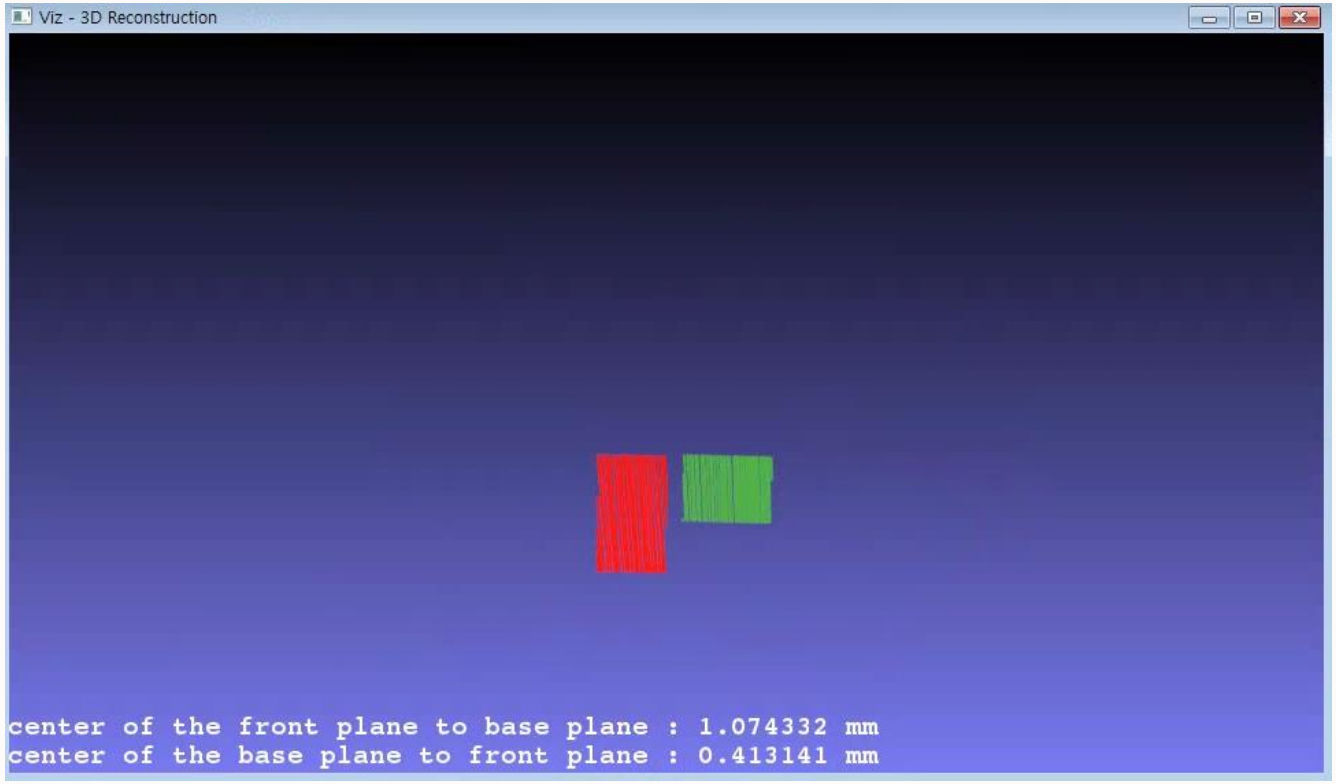


Corrected unwrapping

Progress of the Project

Experimental Results

❖ Phase Shifting method

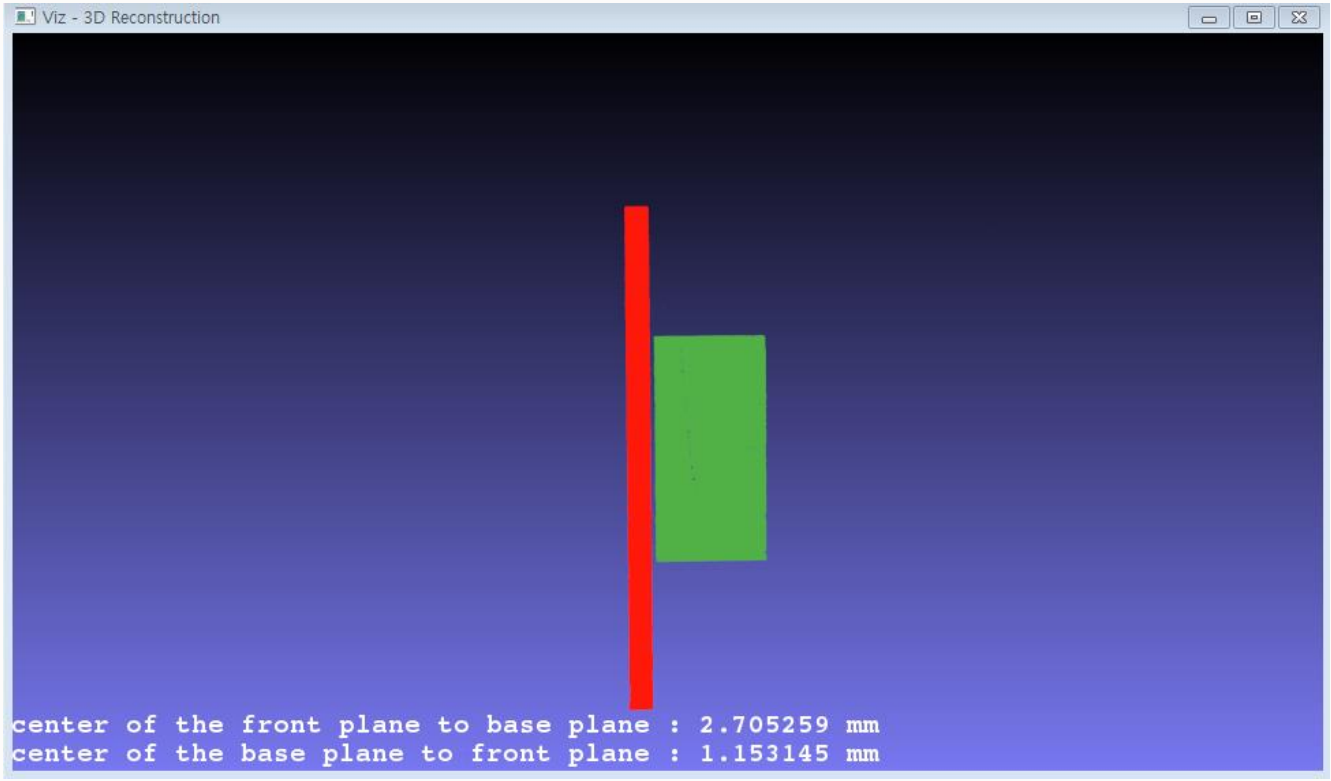


2448x2048

Progress of the Project

Experimental Results

❖ Binary Code method



2448x2048

Conclusion

- Measure the 1mm thick object
- Perform the intensity correction of projector
- Propose the PCC method

Q & A

Thank You!!!