Aug 22, 2016

Active stereo vision system for object position estimation

Lab Seminar

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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.

- **Conventional structured-light vision (SLV)**
  : employs a structured light or laser, and **finds projector-camera correspondences**

- **Conventional active stereo vision (ASV)**
  : employs a structured light or laser, however, the stereo matching is performed only for camera-camera correspondences, in **the same way as the passive stereo vision.**

- **Structured-light stereo(SLS)**
  : a hybrid technique, which **utilizes both camera-camera and projector-camera correspondences.**

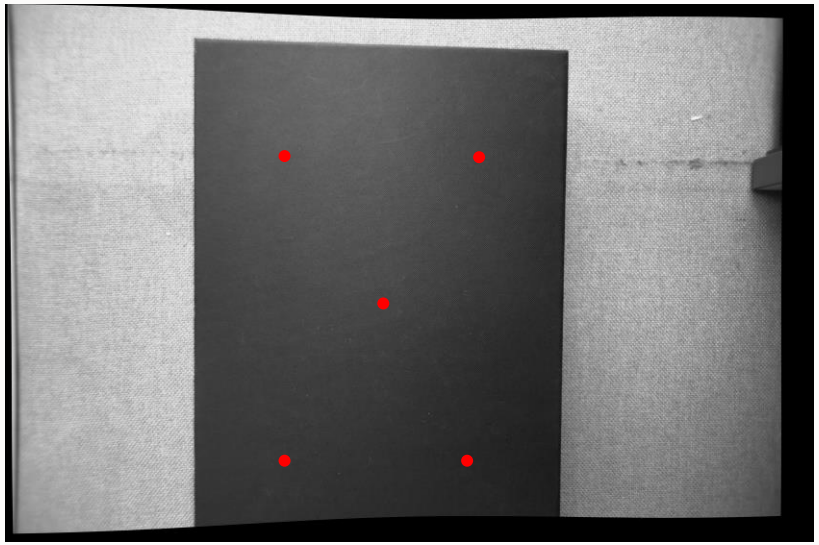
Active Stereo Vision

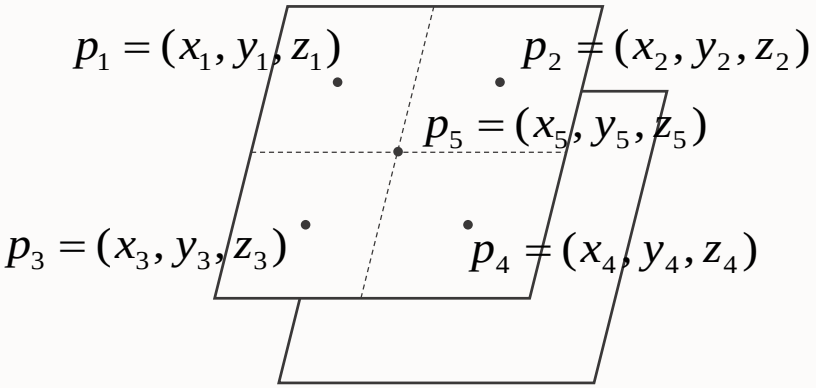
Distance Computation

Distance from a point to a plane

$$ax + by + cz + d = 0$$

$$D = \frac{|ax_1 + by_1 + cz_1 + d|}{\sqrt{a^2 + b^2 + c^2}}$$

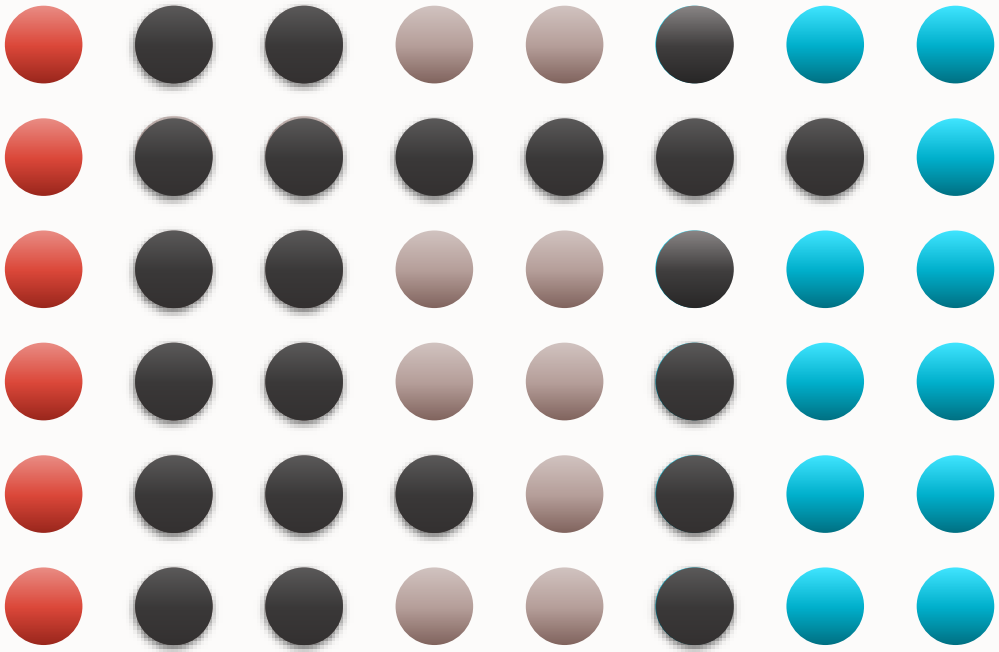




Active Stereo Vision

Filling method for empty disparity region

❖ Using neighbor value



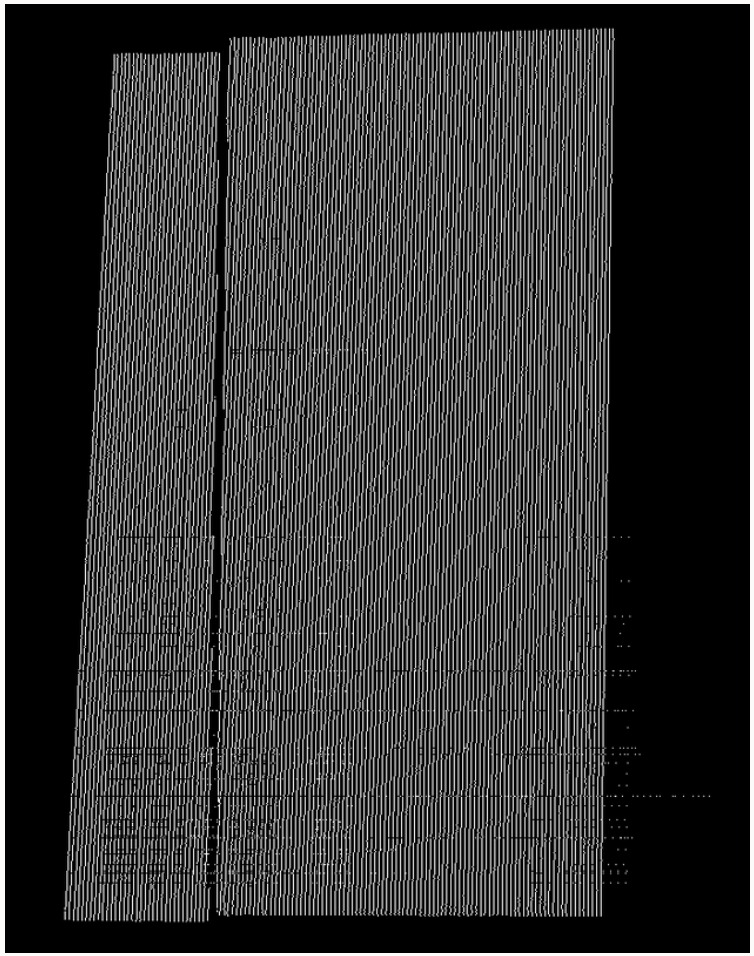

: disparity

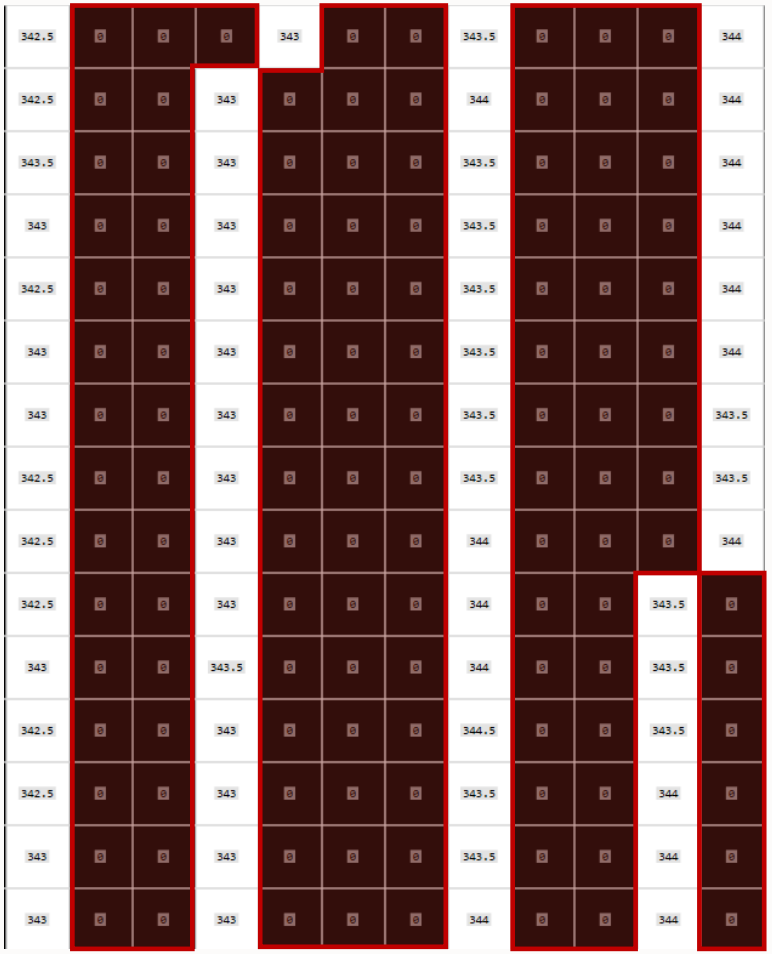

: no disparity region

Active Stereo Vision

Filling method for empty disparity region

❖ Using neighbor value

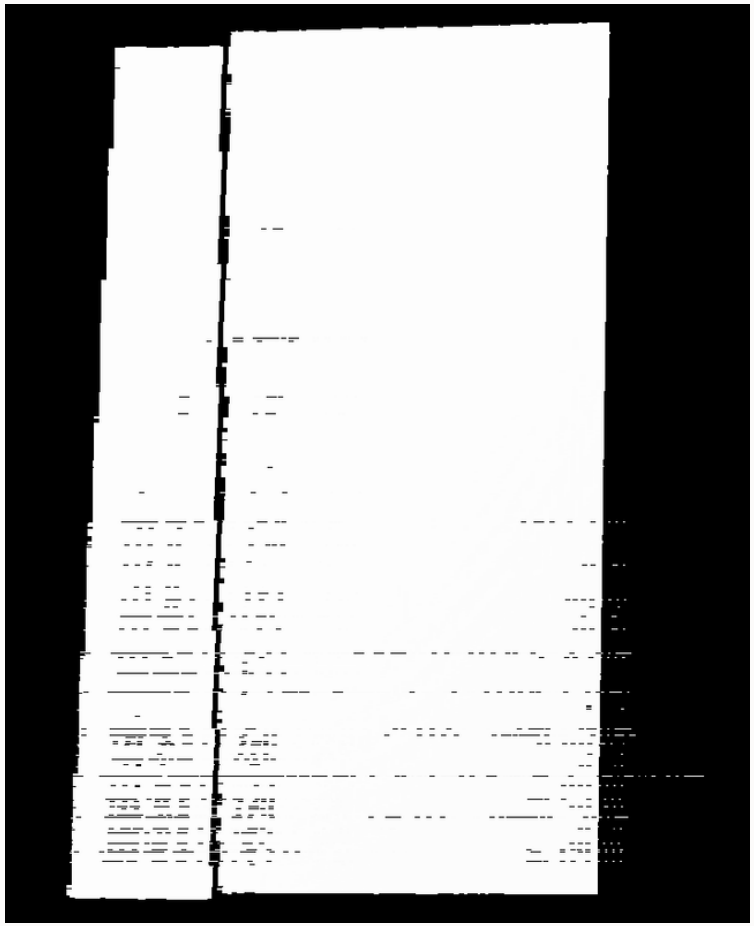




Active Stereo Vision

Filling method for empty disparity region

❖ Using neighbor value



342.5	343	343	343	343	343.5	343.5	343.5	344	344	344	344
342.5	343	343	343	344	344	344	344	344	344	344	344
343.5	343	343	343	343.5	343.5	343.5	343.5	344	344	344	344
343	343	343	343	343.5	343.5	343.5	343.5	344	344	344	344
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342.5	343	343	343	344	344	344	344	343.5	343.5	343.5	343.5
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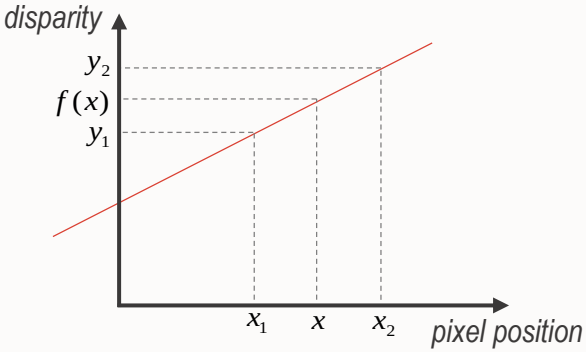
342.5	343	343	343	344.5	344.5	344.5	344.5	343.5	343.5	343.5	344
342.5	343	343	343	343.5	343.5	343.5	343.5	344	344	344	344
343	343	343	343	343.5	343.5	343.5	343.5	344	344	344	344
343	343	343	343	344	344	344	344	344	344	344	344

Active Stereo Vision

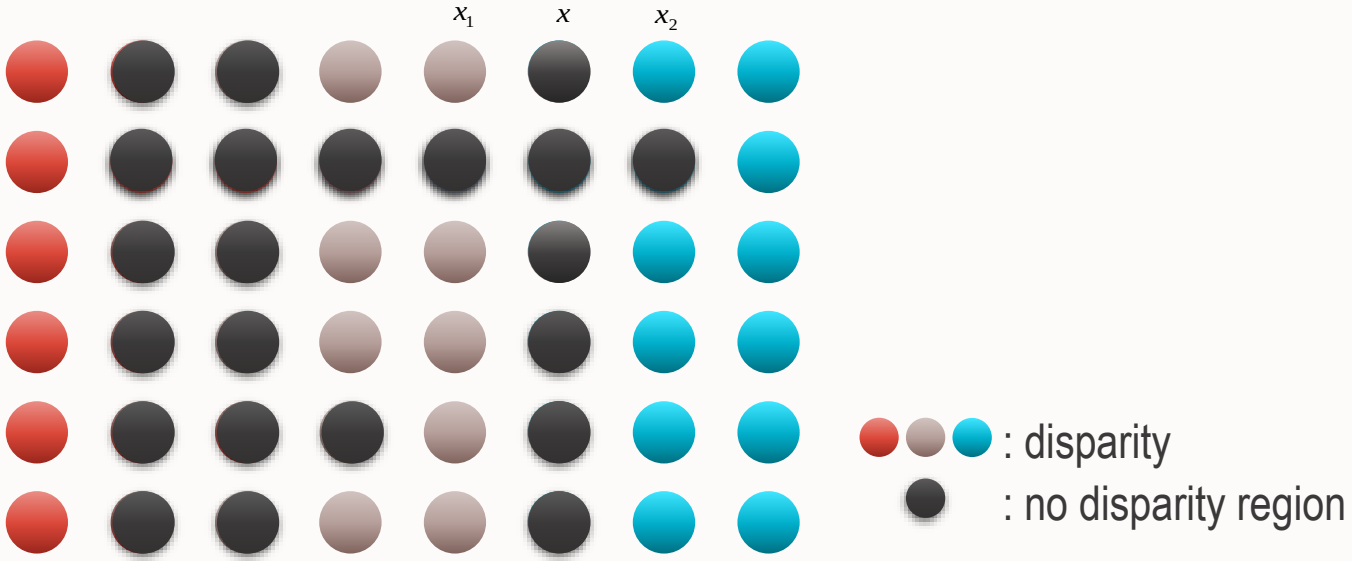
Filling method for empty disparity region

❖ Linear Interpolation



$$\frac{y_2 - y_1}{x_2 - x_1} = \frac{f(x) - y_1}{x - x_1}$$

$$f(x) = y_1 + \frac{y_2 - y_1}{x_2 - x_1}(x - x_1)$$

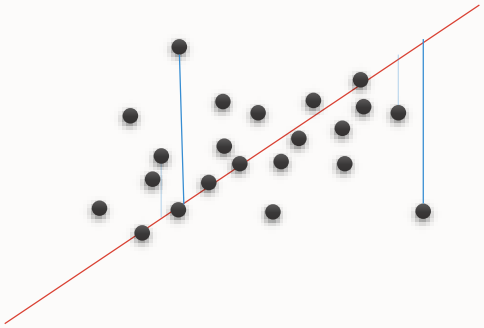


Active Stereo Vision

Filling method for empty disparity region

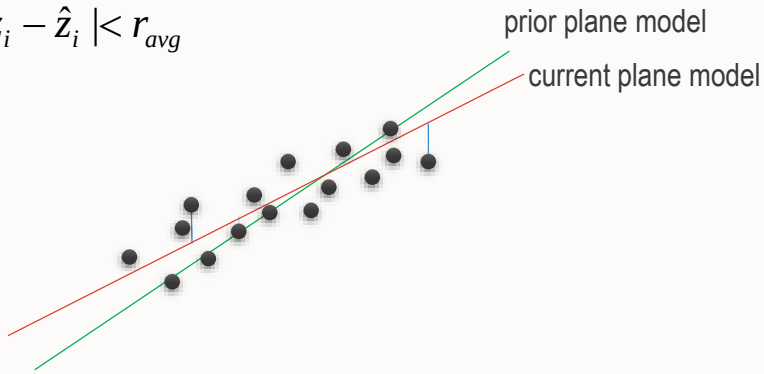
❖ Residual error filtering

residual error $z_i - \hat{z}_i$



$$r_{avg} = \frac{1}{n}\sum_{i=0}^{n} | z_i - \hat{z}_i |$$

$$| z_i - \hat{z}_i | < r_{avg}$$

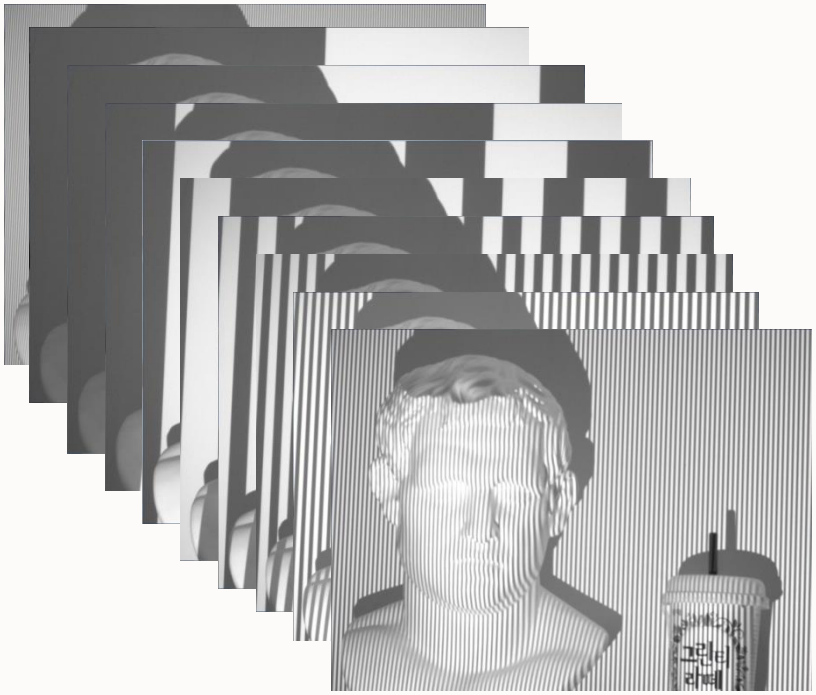


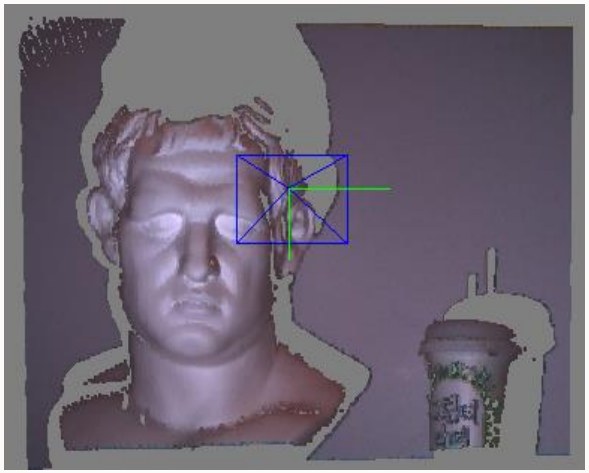
Active Stereo Vision

Phase shifting

❖ **Structured light**

: Structured light is the process of projecting **a known pattern (often grids or horizontal bars)** on to a scene. The way that these deform when striking surfaces allows vision systems **to calculate the depth and surface information of the objects** in the scene.

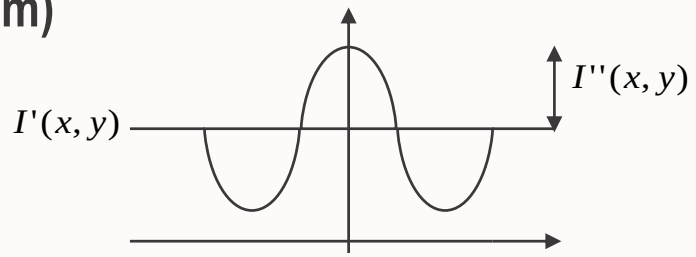




Active Stereo Vision

Phase shifting

❖ Phase shifting method (four step algorithm)



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

$$I_2(x,y) = I'(x,y) + I''(x,y)\cos[\phi(x,y) + \frac{\pi}{2}]$$

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

$$I_4(x,y) = I'(x,y) + I''(x,y)\cos[\phi(x,y) + \frac{3}{2}\pi]$$

Using simple trigonometric identity

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

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

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

$$I_4(x,y) = I'(x,y) + I''(x,y)\sin[\phi(x,y)]$$

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

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

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

$$\phi(x,y) = \tan^{-1}\left[\frac{I_4 - I_2}{I_1 - I_3}\right]$$

Active Stereo Vision

Phase shifting

❖ Phase shifting method (three step algorithms)

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

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

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

Using the trigonometric addition identities

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

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

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

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

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

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

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

Active Stereo Vision

Phase shifting

3-step phase shifting

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

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

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

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

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

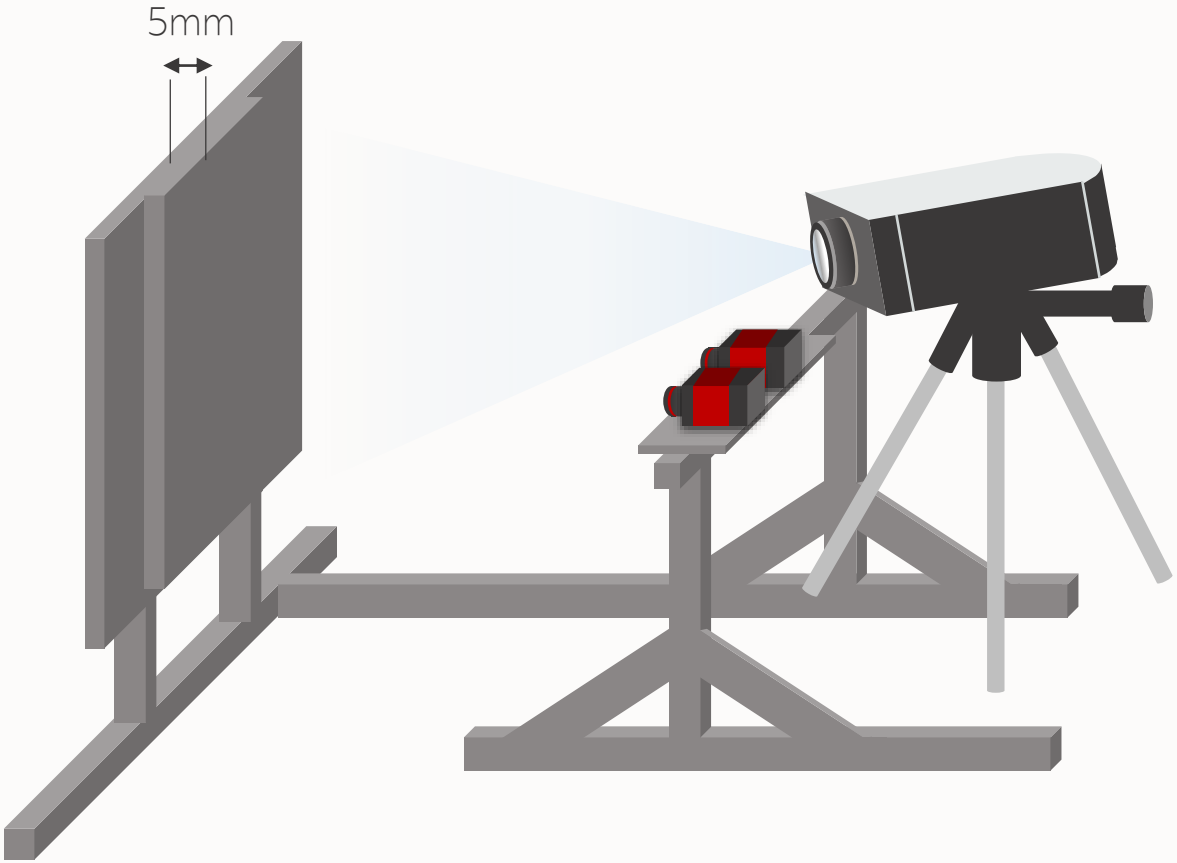
$$when\ \alpha = \frac{3\pi}{2}$$

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

Active Stereo Vision

Experimental results

❖ Experimental environment



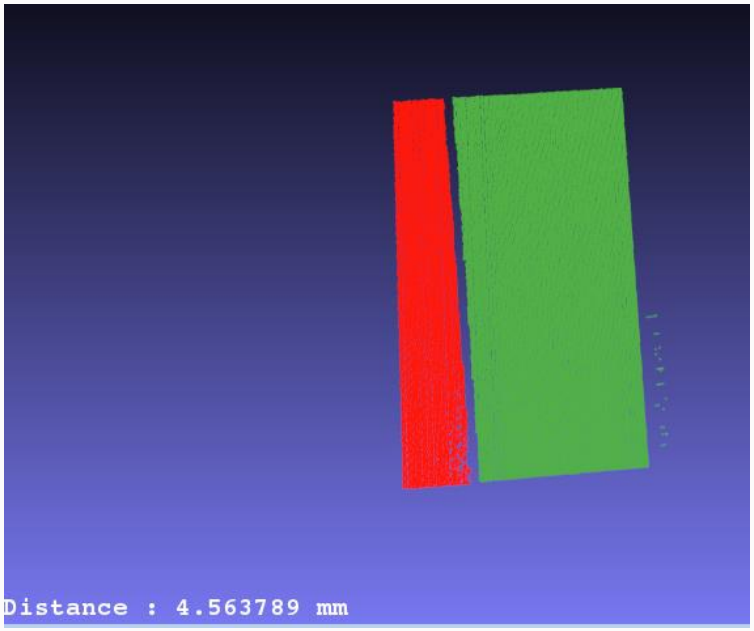
Left Image

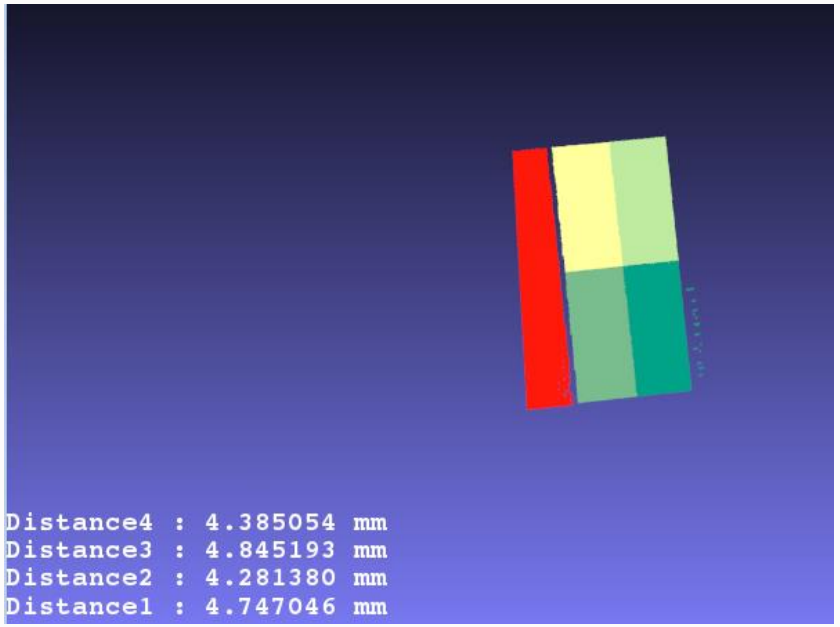
Right Image

Active Stereo Vision

Experimental results

❖ Experimental results (distance)



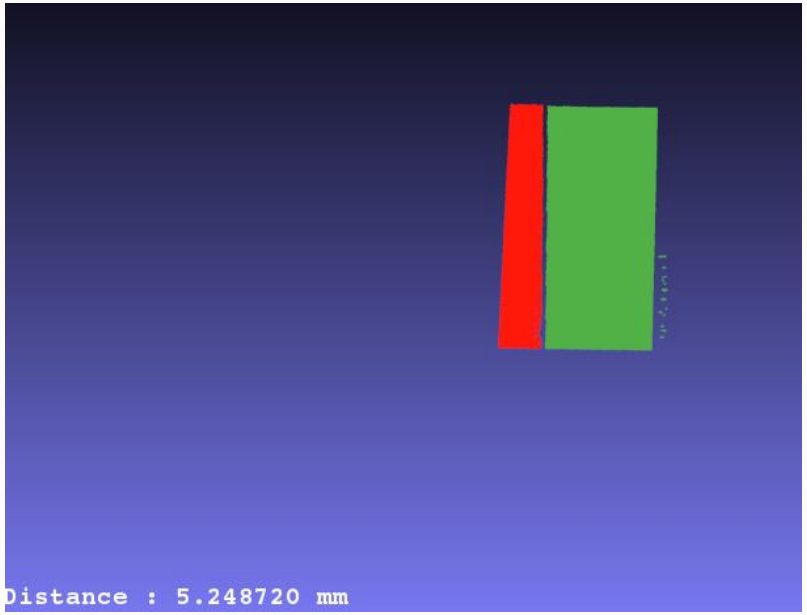


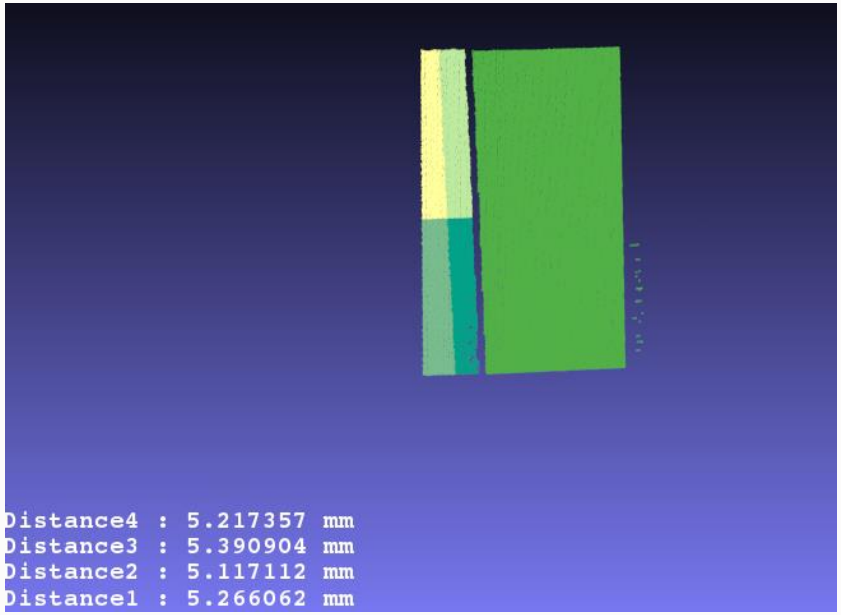
Front point to base plane

Active Stereo Vision

Experimental results

❖ Experimental results (distance)





Base point to front plane

Active Stereo Vision

Experimental results

❖ Experimental results (distance)

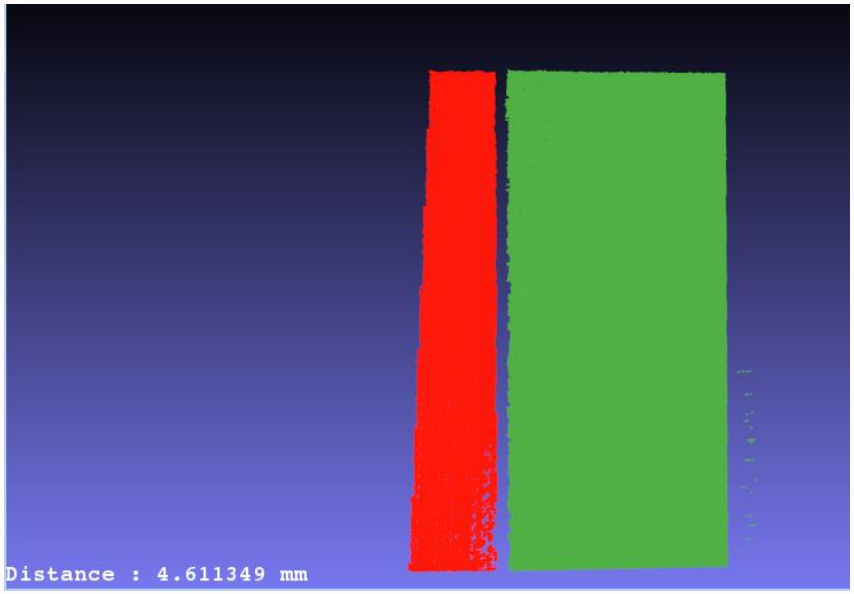
unit : mm

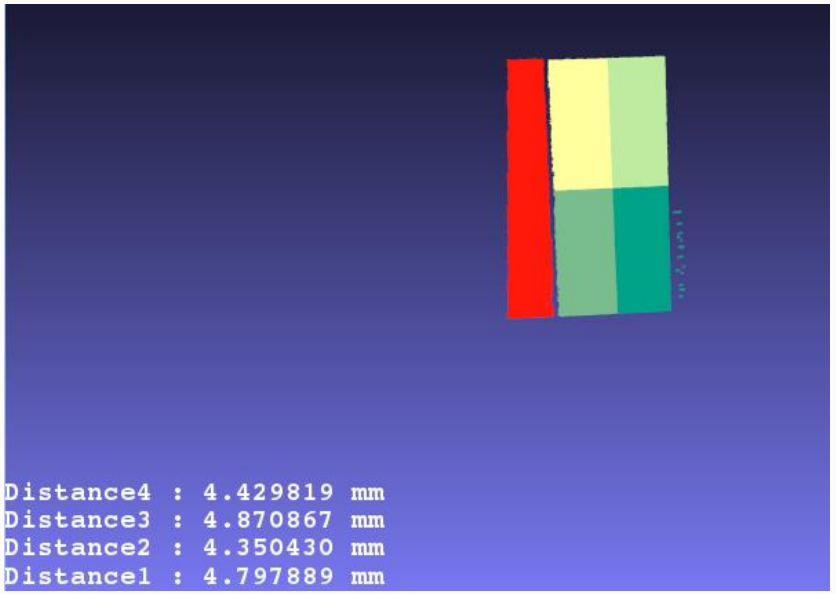
Processing	Center		Quadrant	
	Value	error	Value	error
no processing (front point to base plane)	4.563789	-0.436211	q1. 4.385054	-0.614946
			q2. 4.845193	-0.154807
			q3. 4.281380	-0.71862
			q4. 4.747046	-0.252954
no processing (base point to front plane)	5.24870	0.24870	q1. 5.217357	0.217357
			q2. 5.390904	0.390904
			q3. 5.117112	0.117112
			q4. 5.266062	0.266062

Active Stereo Vision

Experimental results

❖ Experimental results (filling method – neighbor value)



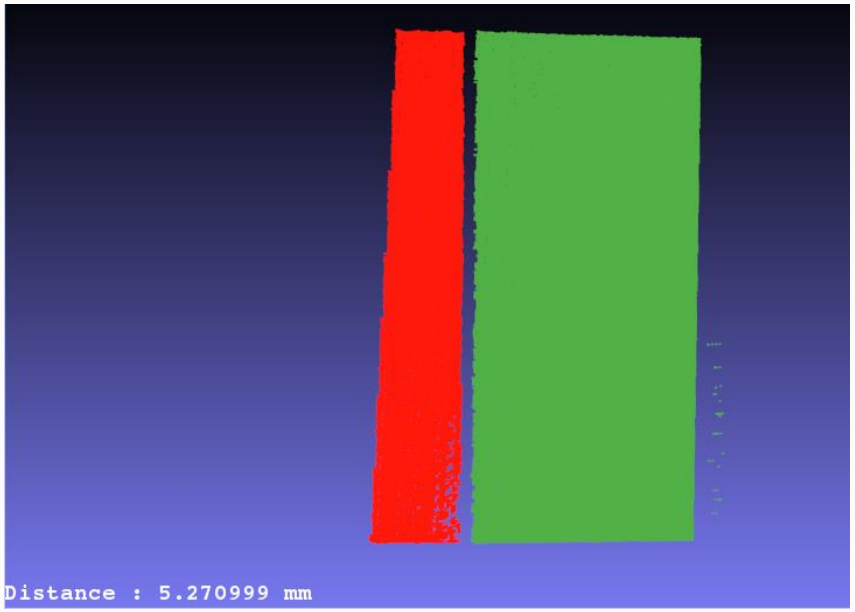


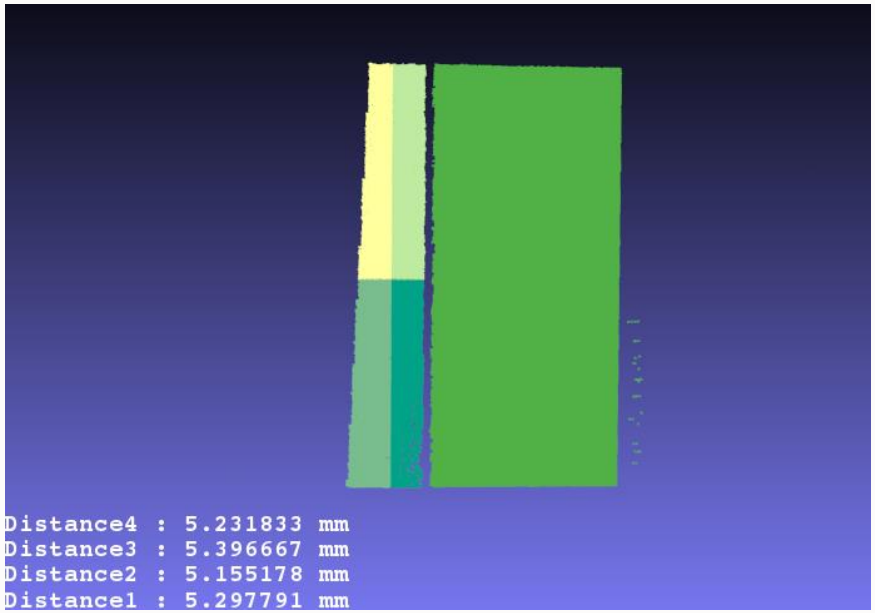
Front point to base plane

Active Stereo Vision

Experimental results

❖ Experimental results (filling method – neighbor value)





Base point to front plane

Active Stereo Vision

Experimental results

❖ Experimental results (filling method – neighbor value)

q1	q2
q3	q4

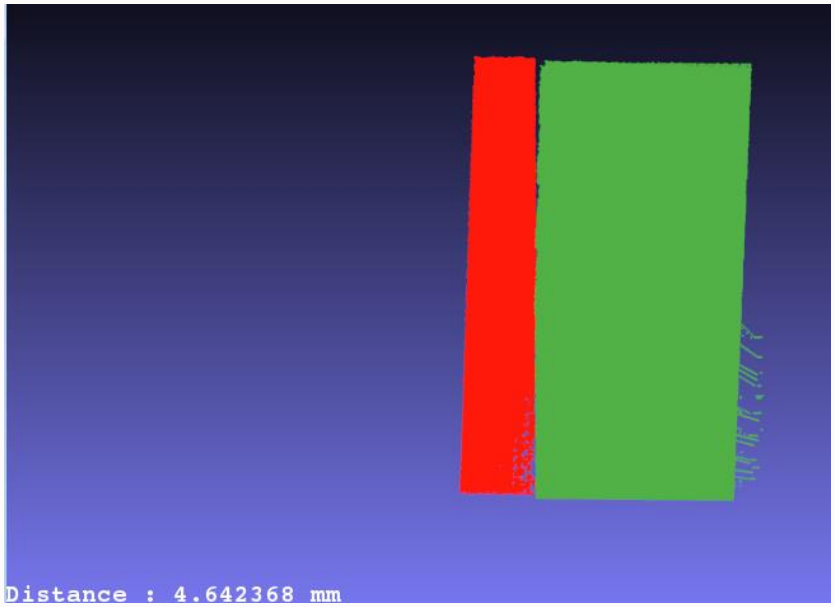
unit : mm

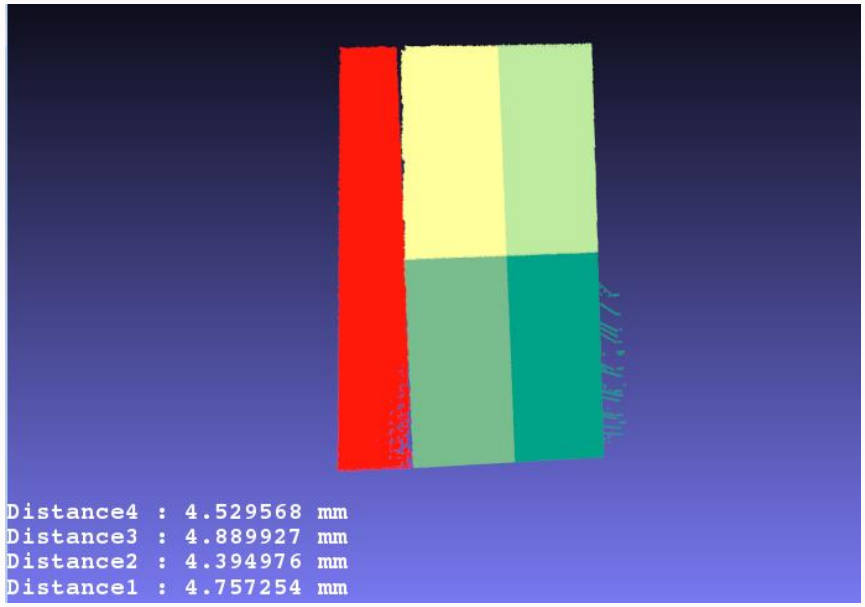
Processing	Center		Quadrant	
	Value	error	Value	error
neighbor value(front point to base plane)	4.611349	-0.388651	q1. 4.429819	-0.570181
			q2. 4.870867	-0.129133
			q3. 4.350430	-0.64957
			q4. 4.797889	-0.202111
neighbor value(base point to front plane)	5.270999	0.270999	q1. 5.231933	0.231933
			q2. 5.396667	0.396667
			q3. 5.155178	0.155178
			q4. 5.297791	0.297791

Active Stereo Vision

Experimental results

❖ Experimental results (filling method – interpolation)



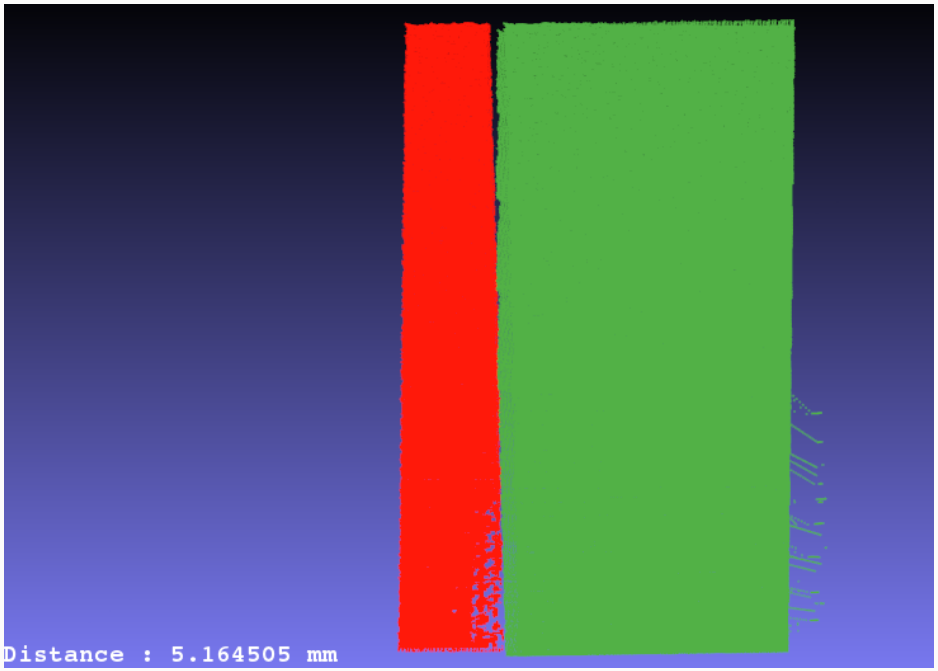


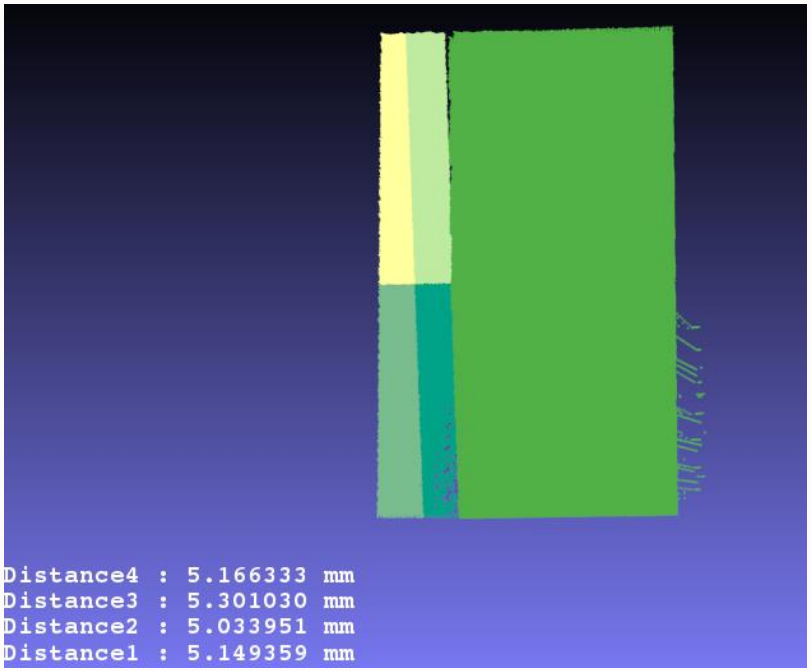
Front point to base plane

Active Stereo Vision

Experimental results

❖ Experimental results (filling method – interpolation)





Base point to front plane

Active Stereo Vision

Experimental results

❖ **Experimental results (filling method – interpolation)**

q1	q2
q3	q4

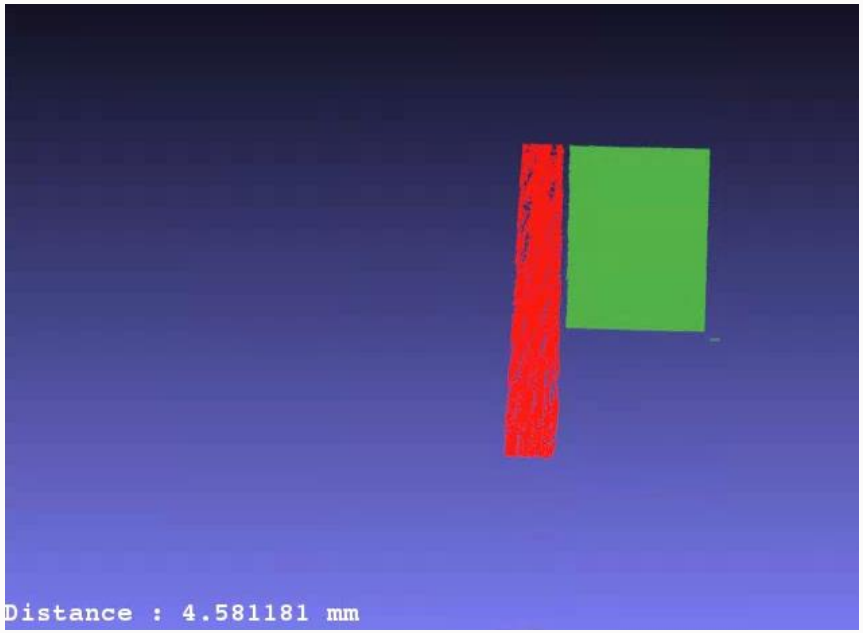
unit : mm

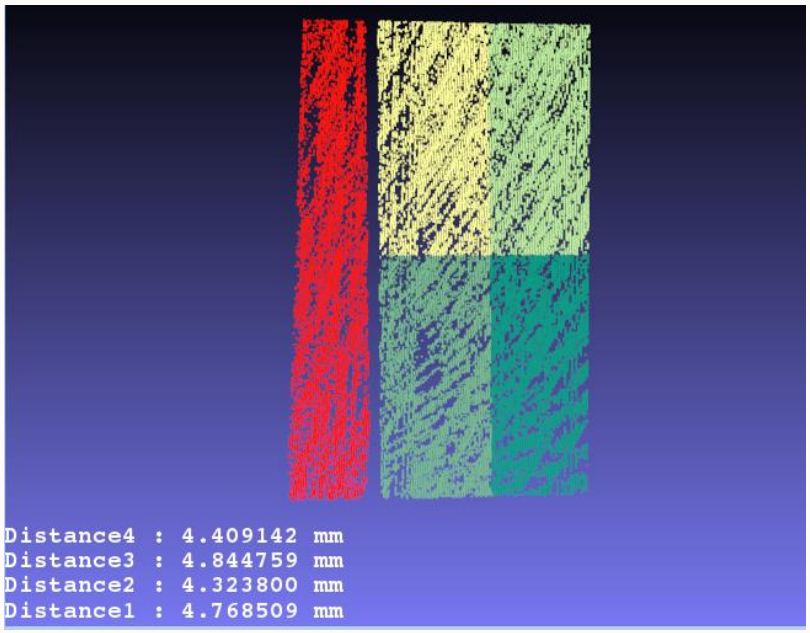
Processing	Center		Quadrant	
	Value	error	Value	error
interpolation (front point to base plane)	4.642368	-0.357632	q1. 4.529568	-0.470432
			q2. 4.889927	-0.110073
			q3. 4.394976	-0.605024
			q4. 4.757254	-0.242746
interpolation (base point to front plane)	5.164505	0.164505	q1. 5.166333	0.166333
			q2. 5.301030	0.301030
			q3. 5.033951	0.033951
			q4. 5.149359	0.149359

Active Stereo Vision

Experimental results

❖ Experimental results (residual error filtering)



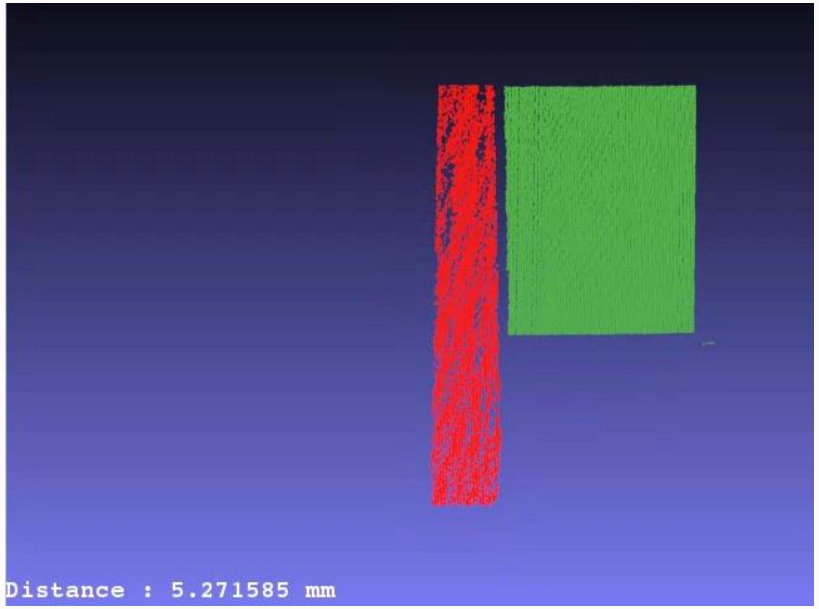


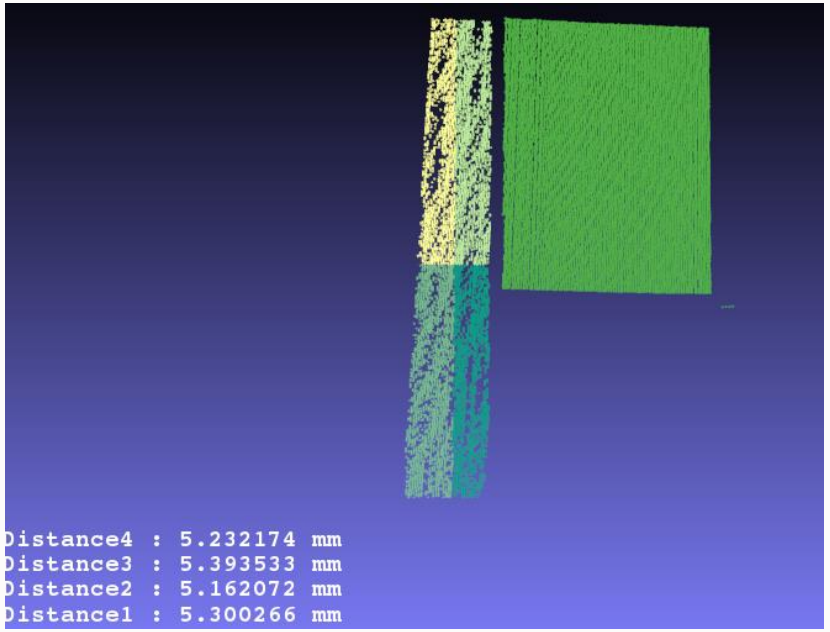
Front point to base plane

Active Stereo Vision

Experimental results

❖ Experimental results (residual error filtering)





Base point to front plane

Active Stereo Vision

Experimental results

❖ Experimental results (residual error filtering)

q1	q2
q3	q4

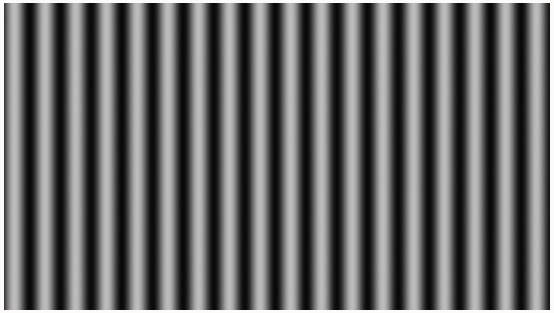
unit : mm

Processing	Center		Quadrant	
	Value	error	Value	error
residual filtering (front point to base plane)	4.581181	-0.418819	q1. 4.409142	-0.590858
			q2. 4.844759	-0.155241
			q3. 4.323800	-0.6762
			q4. 4.768509	-0.231491
residual filtering (base point to front plane)	5.271585	0.271585	q1. 5.232174	0.232174
			q2. 5.393533	0.393533
			q3. 5.162072	0.162072
			q4. 5.300266	0.300266

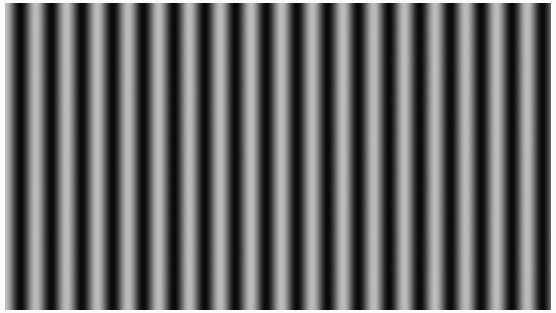
Active Stereo Vision

Experimental results

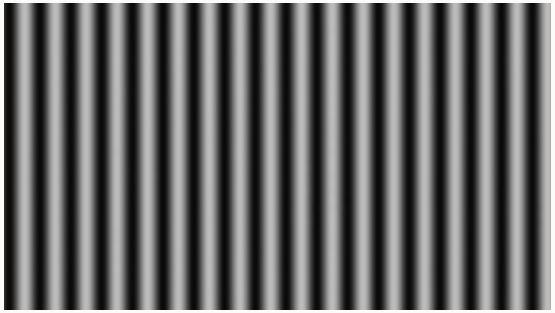
❖ Experimental results (phase shifting)



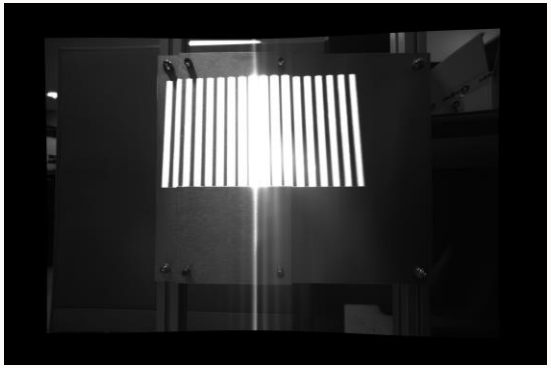
$I_1(-\frac{2\pi}{3})$

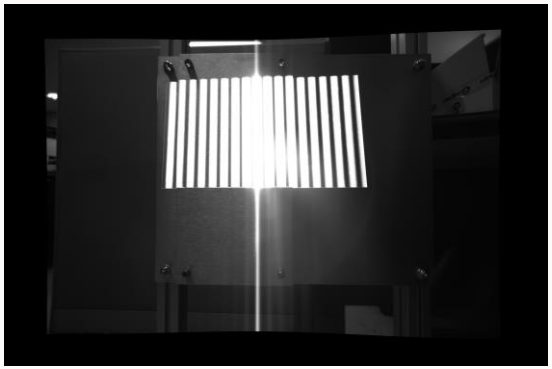


I_2



$I_3(+\frac{2\pi}{3})$

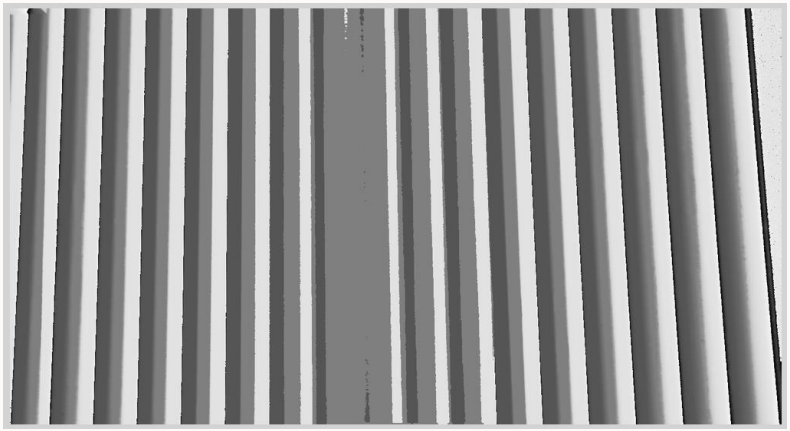




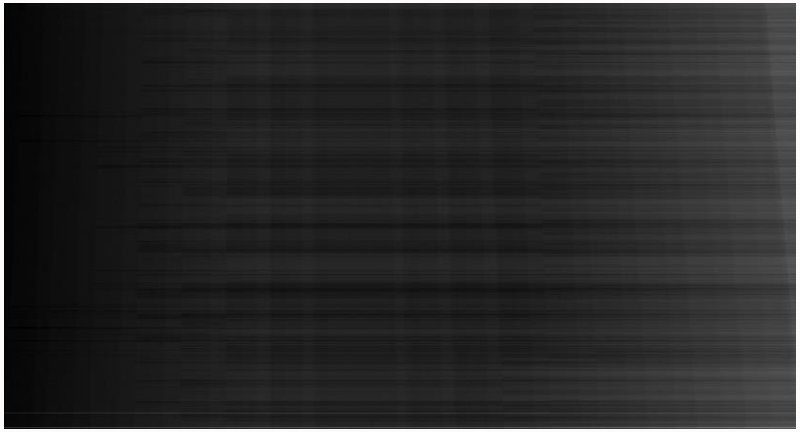
Active Stereo Vision

Experimental results

❖ Experimental results (phase shifting)



Phase image

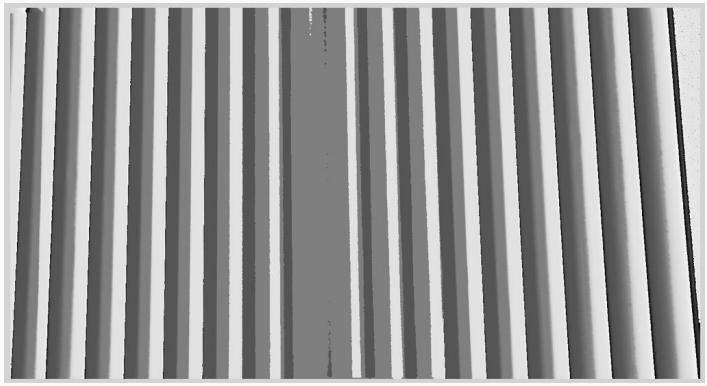


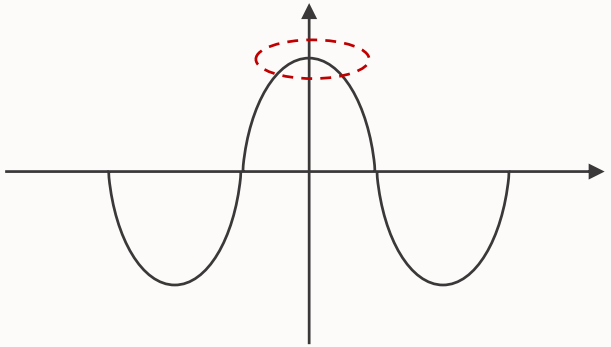
Phase image(unwrapped)

Active Stereo Vision

Experimental results

❖ Experimental results (phase shifting)





Conclusion

- Measure the 5mm thick object
- Fill the empty disparity region (neighbor value, interpolation)
- Perform the filtering large residual error data set
- Phase shifting algrithm

Q & A

Thank You!!!

Active Stereo Vision

Experimental results

❖ Experimental results (average error)

unit : mm

Processing	front point to base plane	base point to front plane
	average error	average error
no processing	-0.4355076	0.248027
neighbor value	-0.3879292	0.2705136
interpolation	-0.3571814	0.1630356
residual filtering	-0.4145218	0.271926