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SPARSE DISPARITY ESTIMATION USING GLOBAL PHASE ONLY CORRELATION FOR STEREO MATCHING ACCELERATION

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1. Introduction

- Disparity candidates of stereo block matching

  Stereo block matching is a method to obtain distance by measuring local patch disparity of two stereo images.
  - Calculation order is $O(n \times d)$
    n: pixel number in image.
    d: searching disparity range.
    Disparity candidates selection can accelerate stereo BM.

- Our contribution can be summarized as follows:
  - Obtaining the global feature of disparities using Full-Image 2D POC.
  - Sparse block matching based on valid disparities selection from FIPOC.
  - High-efficiency calculation even when combined with naive SAD.

2. Phase Only Correlation

- Phase Only Correlation Diagram

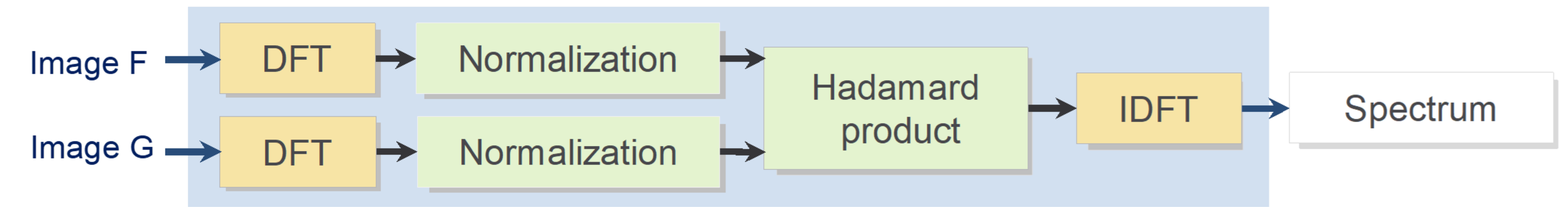


Figure: Diagram of Phase Only Correlation

1. The output of discrete Fourier transform of an image consists of amplitude and phase components.

$$DFT(f(x,y)) = F(k_x,k_y) = |F(k_x,k_y)| \exp(j\theta_F(k_x,k_y))$$

2. Normalized cross phase spectrum $\hat{C}(k_x,k_y)$ is obtained as follows:

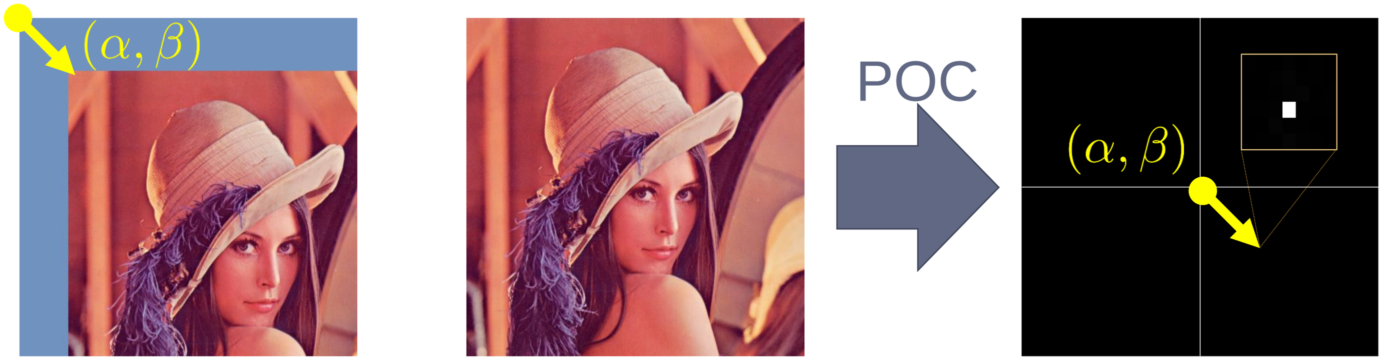
$$\hat{C}(k_x,k_y) = \frac{F(k_x,k_y)\overline{G(k_x,k_y)}}{|F(k_x,k_y)||\overline{G(k_x,k_y)}|} = \exp(j(\theta_F(k_x,k_y) - \theta_G(k_x,k_y))$$

3. IDFT is performed to obtain the output spectrum $\hat{c}(x,y)$

$$\hat{c}(x,y) = IDFT(\hat{C}(k_x,k_y))$$

The output spectrum has same size as the input image.

- The output spectrum of a shifted image → delta function



$f(x,y)$ $g(x,y)$ $\hat{c}(x,y) = \delta(x-\alpha, y-\beta)$

relation: $f(x-\alpha, y-\beta) = g(x,y)$ shift detection image matching

3. Our Disparity Reduction Strategy

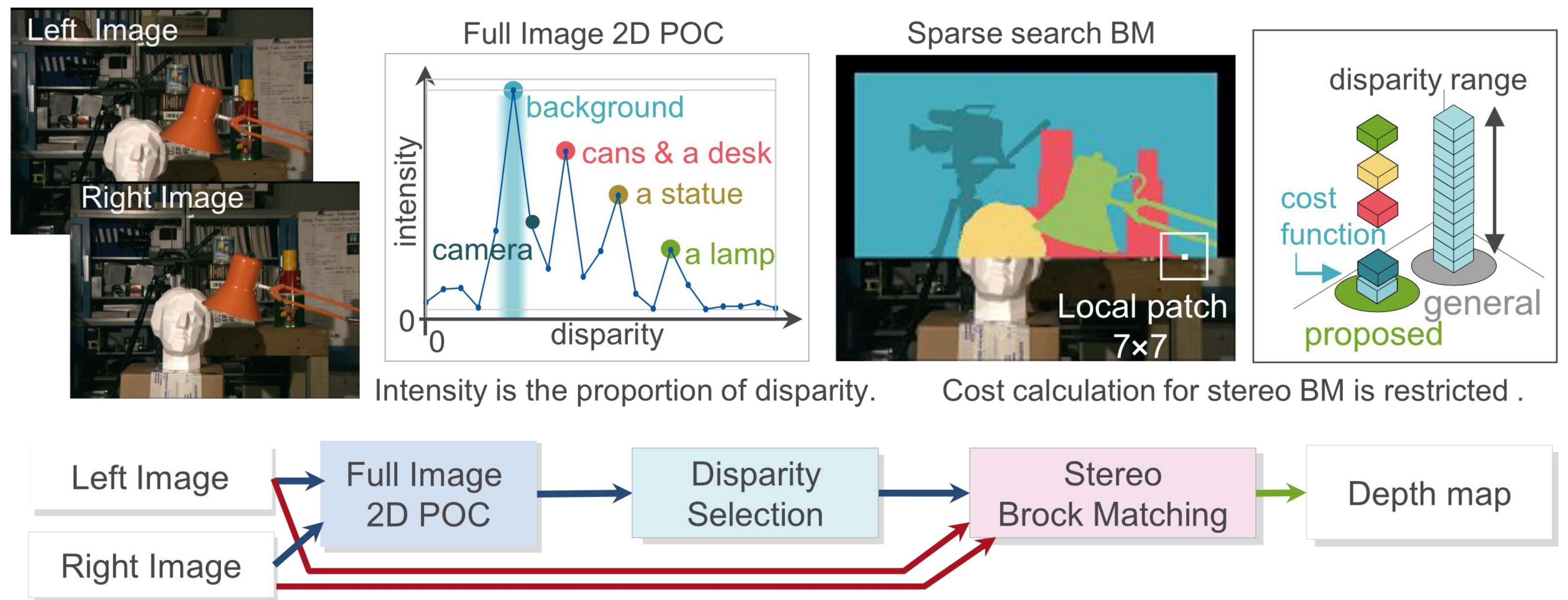
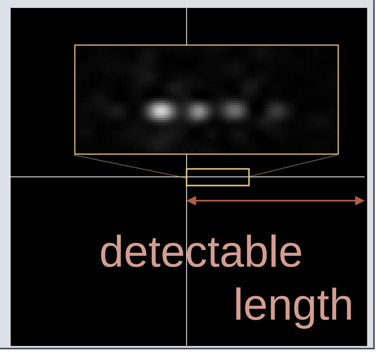


Figure: Outline of our disparity candidate reduction.

- Full image 2D POC to stereo image pair

  Output :Multi peak spectrum
  peak position : the disparity value of object
  peak intensity: the area width of object
  → can detect disparity distribution !! (<< 7 ms)



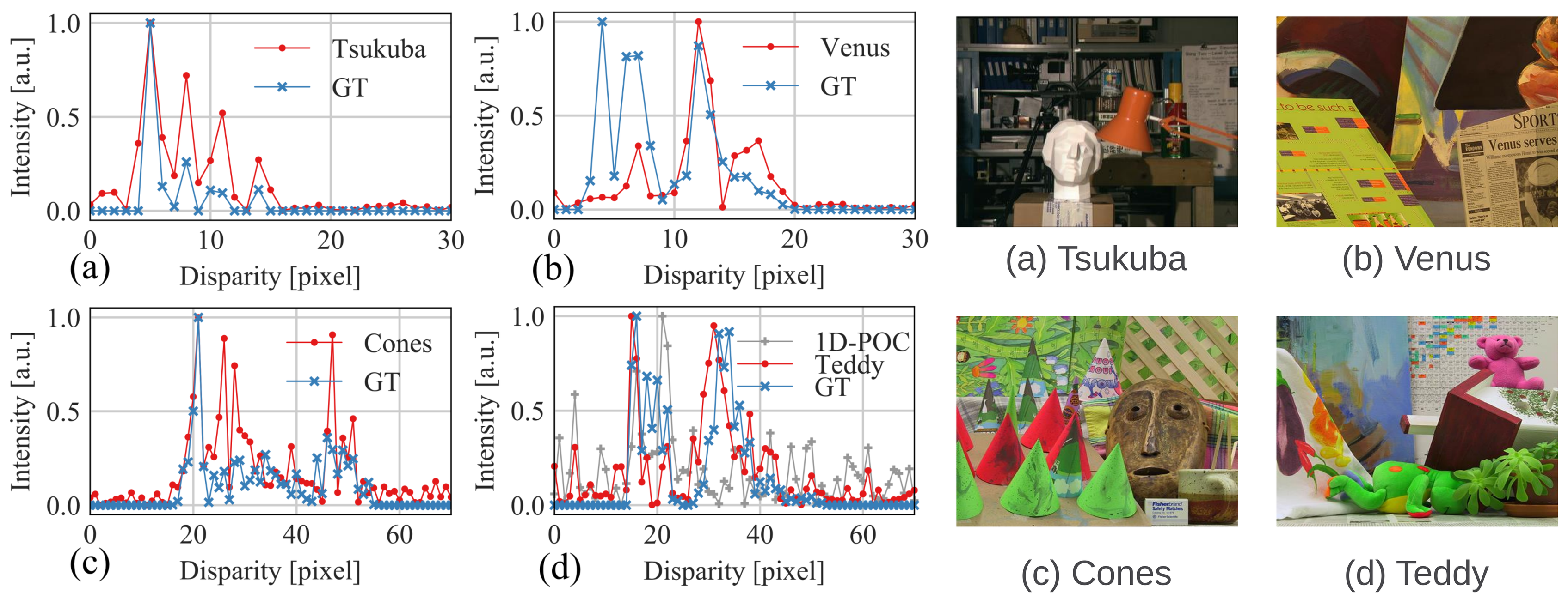
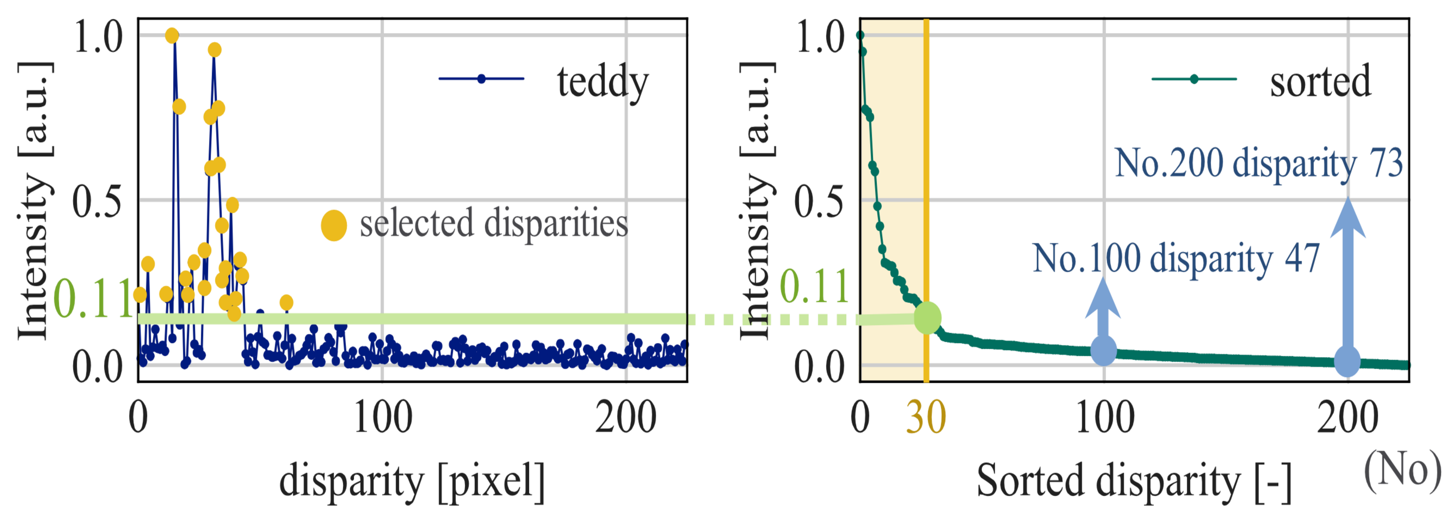


Figure: Photo images on the right are commonly used stereo benchmark image (Middlebury ver.2). The four graphs are the output spectrum of Full Image 2D POC and ground truth and 1D POC result. It is noted that our method is more effective than 1D POC in the accuracy/calculation cost.

- Disparity Candidate Reduction
  1. Sort output by intensity.
  2. Pick up the disparity candidate which have high intensity.
  3. Cost calculation using this disparity.

SAD cost function

$$\sum_{(x,y)\in\mu} |f(x-d,y) - g(x,y)|$$



4. Experimental Result

- The effect of disparity reduction

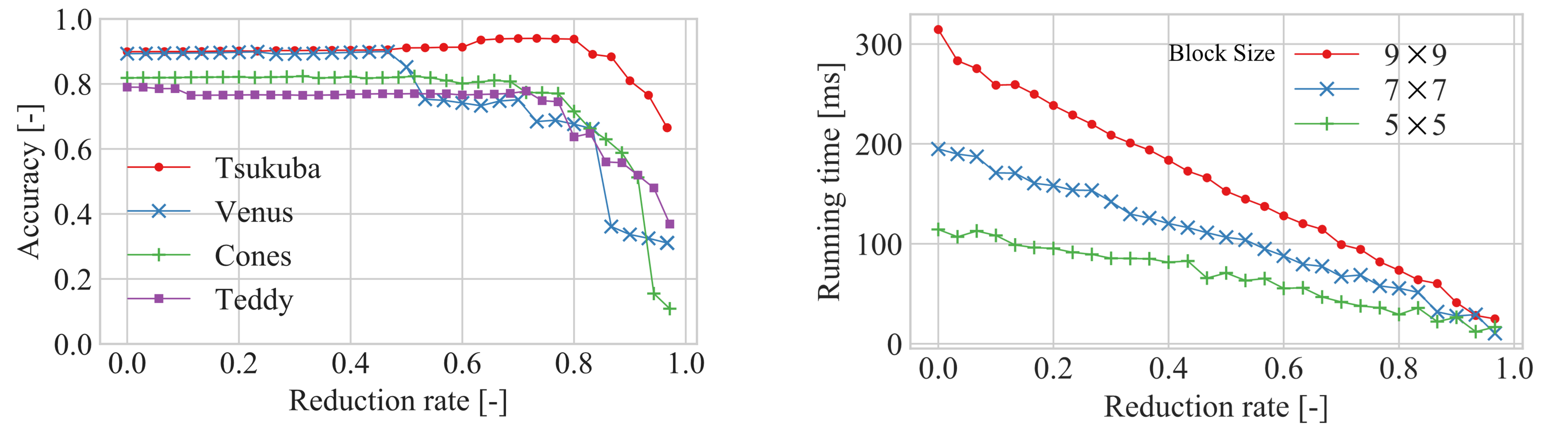
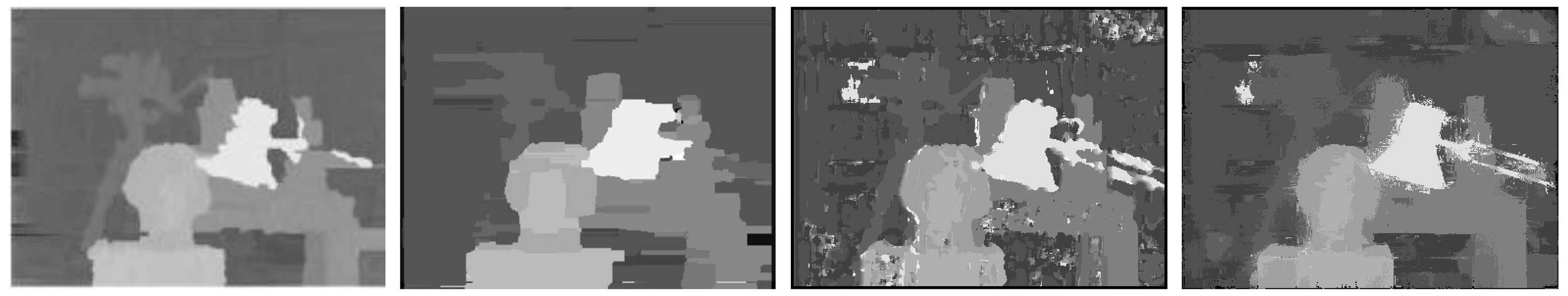


Figure: Our disparity reduction method was tested using Middlebury 4 stereo images. Our reduction rate is defined as below. All candidates : Tsukuba Venus: 30, Cones Teddy 70.

$$Reduction\ rate = \frac{n(Reduced\ candidates)}{n(All\ candidates)}$$

- Comparison with other methods

Algorithm	t(ms)	W×H (disp)	Mde/s	CLK	normalized Mde/s*	Avg.Acc(%)	Tsukuba(%)
ProfShape	16	384×288(16)	110.5	2.8(GHz)	126.29	78.04	90.42
SNCC	140	450 ×375(60)	77.1	3.0(GHz)	82.24	93.01	93.92
Naive SAD	180	384×288(30)	18.4	2.7(GHz)	21.81	77.26	86.06
Ours+SAD	70	384×288(192)	**302.8**	2.7(GHz)	**358.87**	76.69	90.42
Ours+SAD+WM	175.6	384×288(192)	120.9	2.7(GHz)	**143.29**	81.82	93.99



SNCC[1] Profile Shape[2] Ours SAD Ours SAD + WM

Table and Figure: Table shows Comparison with other real time stereo algorithms. Figures are disparity estimation result of Tsukuba image. WM is weighted median filter, which we use as post filter. Mde/s is block matching efficiency index and defined as follows :

$$Mde/s = \frac{W \times H \times D}{t \times 10^6}$$

5. Conclusion

- Our experiments show that our method can estimate global disparity distribution and it can run much faster than stereo BM.
- Using this distribution, reduction of stereo cost calculation without dropping accuracy. →Effective
- Our SAD BM implementation can achieve high efficiency compared with the current real-time stereo method.

References

[1] Nils Einecke, et al. A two-stage correlation method for stereoscopic depth estimation," in *Digital Image Computing: Techniques and Applications (DICTA)*,2010.
[2] Beau J Tippetts, et al."Dense disparity real-time stereo vision algorithm for resource-limited systems," *IEEE Transactions on Circuits and Systems for Video Technology*, vol. 21, no. 10, pp. 1547–1555, 2011.