CSANG: CONTINUOUS SCALE ANISOTROPIC GAUSSIANS FOR ROBUST LINEAR STRUCTURE EXTRACTION

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CONTRIBUTION: FAST EDGE DETECTION WITH CSANG

- We use an adaptive robust structure tensor (ARST) method [1] where the local adaptation process uses spatially varying adaptive Gaussian kernel that is initialized using the total least-squares.
- Adaptation and continuous scale anisotropic Gaussian (CSANG) kernel changes for local orientation estimation helps us to obtain robust edge and junction features.
- Graphical processing unit (GPU) implementation which obtained 30× speed improvement over traditional CPU computations.
- Robust edge detections and comparison with other edge detectors shows that our approach obtains better quality edge maps [2].

ADAPTIVE ROBUST STRUCTURE TENSOR (ARST) ESTIMATION

Let $\mathbf{v}(\mathbf{x})$ be the true (latent) gradient of an image patch $\Omega(\mathbf{y})$, centered at pixel $\mathbf{x}$. To estimate $\mathbf{v}$, we minimize an robust error functional $\rho(\|\mathbf{e}(\mathbf{x}, \mathbf{y})\|^2)$ integrated over the image patch Ω ,

$$e_\rho(\mathbf{x}) = \int_{\Omega} \rho(\|\mathbf{e}(\mathbf{x}, \mathbf{y})\|^2) W(\mathbf{x}, \mathbf{y}) d\mathbf{y}, \quad \rho(\|\mathbf{e}(\mathbf{x}, \mathbf{y})\|) = \frac{\|\mathbf{e}(\mathbf{x}, \mathbf{y})\|^2}{m^2 + \|\mathbf{e}(\mathbf{x}, \mathbf{y})\|^2} \quad (\text{Geman-McClure}) \quad (1)$$

where $\|\mathbf{e}(\mathbf{x}, \mathbf{y})\| = \|\mathbf{g}(\mathbf{y}) - (\mathbf{g}^T(\mathbf{y}) \mathbf{v}(\mathbf{x})) \mathbf{v}(\mathbf{x})\|$ is the error vector between the estimated gradient $\mathbf{g}(\mathbf{y})$ at location $\mathbf{y}$ and $\mathbf{v}(\mathbf{x})$.

- We utilize the continuous scale anisotropic Gaussian kernels $W_i(\mathbf{x}, \mathbf{y})$ (Figure 1),

$$W_i(\mathbf{x}, \mathbf{y}) = K e^{-(\frac{1}{2} (\mathbf{y}-\mathbf{x})^T \mathbf{U}_{i-1}^T \Lambda_i^{-2} \mathbf{U}_{i-1} (\mathbf{y}-\mathbf{x}))} \quad \text{with} \quad \Lambda_i = \begin{bmatrix} \sqrt{2}R_i^1 & 0 \\ 0 & \sqrt{2}R_i^2 \end{bmatrix}, \quad (2)$$

where K is a scaling factor.

- Differentiating e_ρ , with respect to $\mathbf{v}$, and setting it to zero gives,

$$\mathbf{J}(\mathbf{x}, \mathbf{v}_i, W) \mathbf{v}_{i+1} = \lambda \mathbf{v}_{i+1}, \quad \text{with} \quad \mathbf{J}(\mathbf{x}, \mathbf{v}, W) = \int_{\Omega} \frac{m^2}{(\mathbf{g}^T \mathbf{g} - \mathbf{v}^T (\mathbf{g} \mathbf{g}^T) \mathbf{v} + m^2)^2} (\mathbf{g} \mathbf{g}^T) W(\mathbf{x}, \mathbf{y}) d\mathbf{y}.$$

✓ This fixed-point functional iteration scheme for numerically solving $(\lambda, \mathbf{v})$ usually converges to a local minimum [1].

Figure 1. The first three steps of the adaptive tensor algorithm at an ideal edge [1].

GPU-ARST FOR FAST EDGE DETECTION

- We use CUDA-GPU implementation of the ARST to obtain the robust gradient estimation and orientations.
- We apply Canny post processing steps (non-maximal suppression, hysteresis thresholding) to obtain binary edge maps.

COMPARISON WITH CANNY EDGE DETECTOR

- Experiments on Berkeley segmentation data set (BSDS500) shows that our CSANG edge detection results are better than Canny edge detector.

- Quantitative comparisons with other gradient based edge detectors indicate that our CSANG is robust to noise and obtains superior quality edge maps [2]. Further applications to image smoothing and regularization are currently under consideration [3].

REFERENCES

- [1] S. Nath, K. Palaniappan. Adaptive robust structure tensors for orientation estimation and image segmentation. *ISVC*, Springer LNCS vol. 3804, pp. 445–453, 2005.
- [2] V. B. S. Prasath et al. Multiscale structure tensor for improved feature extraction and image regularization. *IEEE Transactions on Image Processing*, 2016. Submitted.
- [3] V. B. S. Prasath et al. Multiscale Tikhonov-total variation image restoration using spatially varying edge coherence exponent. *IEEE Transactions on Image Processing*, vol. 24, no.12, pp. 5220–5235, 2015.

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- CIVA Lab: <http://cell.missouri.edu>
- Download the poster @ figshare.com: <http://dx.doi.org/10.6084/m9.figshare.3175450>