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COMPUTER SCIENCE

ON THE ANISOTROPY OF IMAGES. A BRIEF NOTE

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Many physical systems, known as highly dependent on direction, are called anisotropic. Anisotropy is characterized by different properties, measured along each axis in different directions. For understanding physical phenomena, a model of anisotropic materials is useful. Patterns of the anisotropy of images with heterogeneities and anisotropies offer significant information, to be used for image analysis [3]. The literature of the field provides numerous definitions for the anisotropy of images. This article provides a brief presentation of the different approaches applied for the definition of the anisotropy of images, as well as a critical discussion of one of these methods.

A method for the local estimation of anisotropy was developed by Kass and Witkin. For the analysis of oriented patterns with multiple axes of anisotropy, they proposed the decomposition of the problem into two parts: field flow (magnitude of anisotropy) analysis, describing the direction of anisotropy and the independent pattern of the change of flow direction [2]. The anisotropic process is highlighted by the local power spectrum of the image. To compute the direction and strength of anisotropy (coherence) in the first step, the image is convolved with the isotropic portion of the filter bandpass, after which the angle of anisotropy and coherence are computed using formulas below [2]:

$$\varphi(x, y) \approx \tan^{-1} J_1^*(x, y); J_2^*(x, y))/2 \qquad (1)$$

$$\chi(x, y) = (J_1^*(x, y)^2 + J_2^*(x, y)^2)^{\frac{1}{2}} / J_3^*(x, y) \qquad (2)$$

where: $J_i^*(x, y),\ i = \overline{1,3}$ represent the gradient vectors convolved with a weighing function $W(x, y)$; $\varphi(x, y)$ is the angle of anisotropy and $\chi(x, y)$ is coherence.

The advantage of this method is that the intrinsic images obtained by decomposition of the original image are simpler, facilitating the analysis and description of the pattern.

Nguyen *et al*. [4] proposed a method which uses simultaneously brightness and connectivity for finding cracks in road pavement. For connecting crack segments, the CTA (Conditional Texture Anisotropy) and FFA (Free Form Anisotropy) methods were compared, the last one providing better results.

The CTA index of a pixel *l* was defined as [4]:

$$CTA(1) = \frac{\max_j\{p(x_j^l|1 \in w_1)\} - \min_j\{p(x_j^l|1 \in w_1)\}}{\max_j\{p(x_j^l|1 \in w_1)\}} \quad (3)$$

where x_j^l is a set of n texture features computed along the orientation *j*; $p\left(x_j^l|1 \in w_1\right)$ is the probability for pixel 1 to be a pixel without defect along the orientation *j*. CTA provides good results for 0°, 45°, 90°, 135° orientations, however, for other orientations, only large defects were detected, while the thin defects were suppressed.

The FFA method eliminates the CTA limitations; the features are calculated for each path. The FFA index of each pixel *l* was defined as [4]:

$$FFA(1) = \frac{\max_j\{h(\pi_j, \pi_{bgd})\} - \min_j\{h(\pi_j, \pi_{bgd})\}}{\max_j\{h(\pi_j, \pi_{bgd})\}} \quad (4)$$

where *j* is global orientation.

The FFA method is able to remove the background for different types of textures and to provide results with very low noise. It can be used in other types of images with fine structure.

Brunet-Imbault *et al*. [1] describe a FFT-based method to obtain anisotropy indices on bone radiographs. They selected manually the spreading angles of the longitudinal and transversal part of bone density and computed the degree of anisotropy index (DA) using formula:

$$DA = \frac{180}{(DLI + DTI)} \quad (5)$$

where DLI and DTI are the Dispersion Longitudinal, respectively, Transverse Indices. They used the FFT to evaluate the bone structure, highlighting the preferred directions of the anisotropic structure where the texture is strongly anisotropic.

Lehoucq *et al*. [3] attempted at identifying the maximum scale of anisotropy on different patterns using an inertia tensor. The image is divided into boxes with predefined shapes (ellipse, circle, square), which contained the signal, then the direction in which the signal is more intense is determined and the inertia tensor is measured in each box. The inertia tensor measures local anisotropy and is useful for statistical description of anisotropy of 2D or 3D patterns, in which individual objects cannot be easily distinguished.

Another analysis method able to detect local anisotropy in the texture of the image was proposed Wirjadi *et al*. [6], who applied anisotropic convolution filters (anisotropic Gaussian convolution filters) to detect images structure, and used a second order orientation tensor for quantitative interpretations of direction.

In order to define anisotropy, Teodorescu proposed some methods related to derivatives and directional filtering [5]. The anisotropy index was defined with formula:

$$\alpha = \sqrt{\sum_{i=1}^{N}\left(h_x\left(x_i\right) - h_y\left(y_i\right)\right)^2} \tag{6}$$

where $h_x(x_i)$ and $h_x(y_i)$ are the projection functions on the axes.

Another index of anisotropy related to the edges is presented in [5], where anisotropy was computed based on the correlation of the projection functions:

$$\alpha = \frac{1}{N}\frac{\max\limits_{m}\left|Cor_{h_x,h_y}(m)\right| - \min\limits_{m}\left|Cor_{h_x,h_y}(m)\right|}{\max h_x \max h_y} \tag{7}$$

Essentially, this definition has much in common with that of [5], as both are based on some form of edges. Also, the definition given by Teodorescu is obviously connected to that based on spectra, specifically with asymmetry in the spectra in high frequency ranges. The relationship of the definition in [5] and the one in [3] is less obvious. The definition of asymmetry in [5] has the disadvantage that the results depend on the high-pass filter used in the detection of edges; therefore, this method is parametric in case of a filter with parameters (as Sobel). There is no indication in the definition in [5] on how to choose the filter. The advantage of the definition in [5] is that, computationally, it is somewhat less demanding, being possibly better correlated with the human way of asymmetry perception. However, another disadvantage of the definition is the lack of correlation with color: the edges determined by difference in colors would be equivalent with those determined by the gradient of brightness, which may be problematic. Also, the method proposed in [5] has the serious disadvantage that the result changes when the axes are rotated; an optimal direction of the axes is required, which is computationally costly.

In this note, we investigate the ability of the definition in [5] to determine the anisotropy in complex images. We are interested in finding the weaknesses of the method and to make recommendations for improvement. Three original images used in the study are shown in Figure 1.

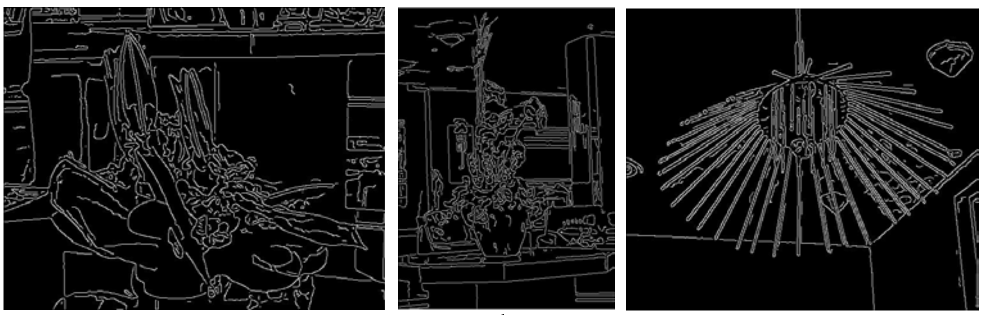
a b c

Fig. 1. Original images: a. Flowers 1; b. Flowers 2; c. Lamp

After converting the image in gray levels (Fig. 2) and applying the filter, the edge extraction produced the images shown in Figure 3.

a b c

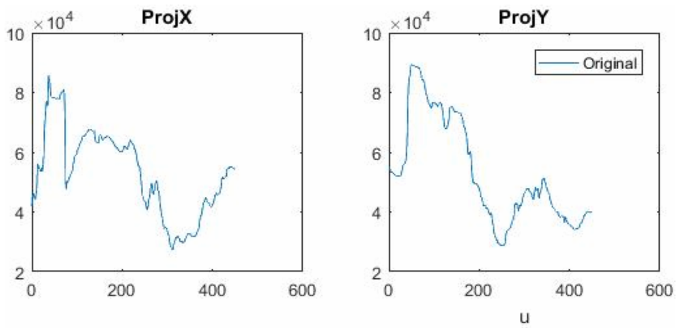
Fig. 2. Results of median filtering: a. Flowers 1; b. Flowers 2; c. Lamp.



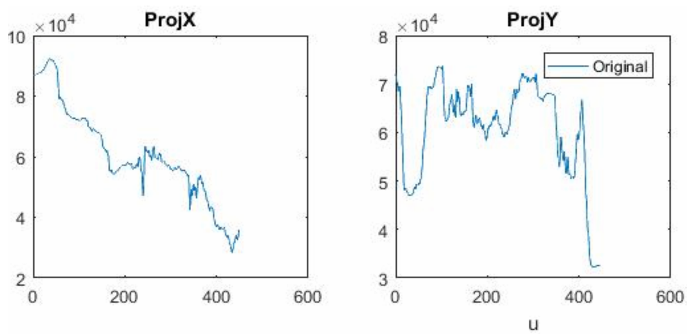
a b c

Fig. 3. Edges obtained by using the Canny edges detector: a. Flowers 1; b. Flowers 2; c. Lamp

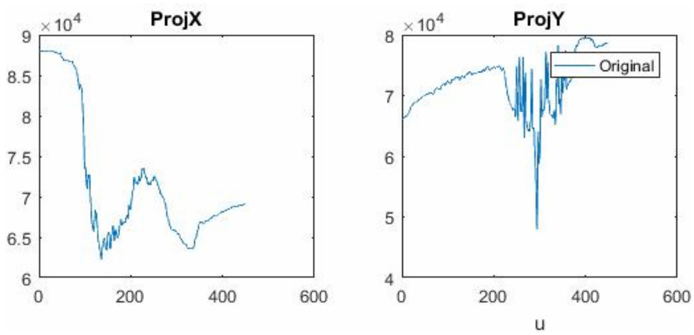
The corresponding projections of the edges on the two axes are shown in Figure 4.



a



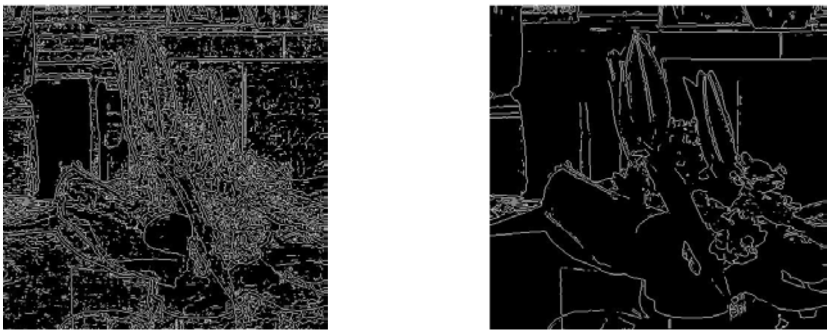
b



c

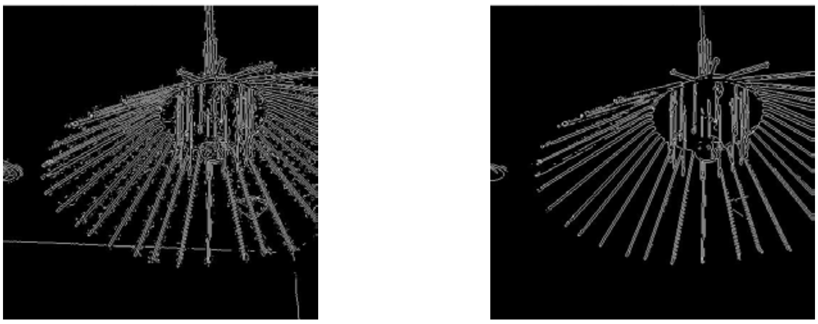
Fig. 4. Projections of the original image: a. Flowers 1; b. Flowers 2; c. Lamp

Observe the substantial difference in edges, as produced by a filter with different parameters, namely a Sobel filter with threshold factor 0.1 and 0.5, respectively (Fig. 5).



a

b

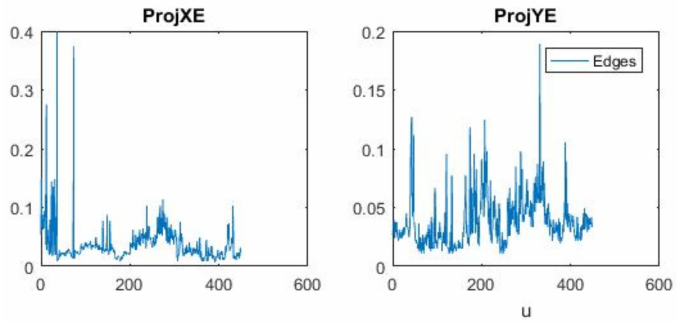


c

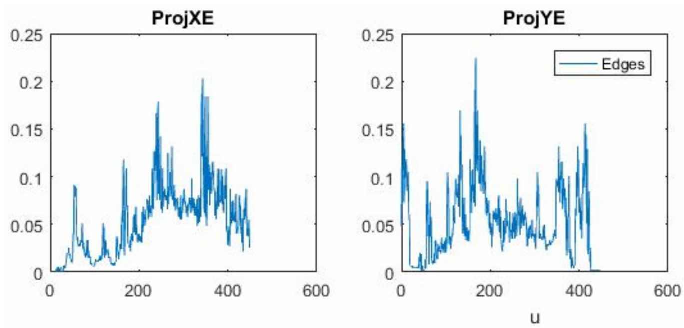
Fig. 5. Edge detection using Sobel filter with threshold factor 0.1 (left image), respectively 0.5 (right image): a. Flowers 1; b. Flowers 2; c. Lamp

Observe the important difference in the graphs of the projection functions in the case of the two filters. This would result in large differences in the anisotropy index defined in [5].

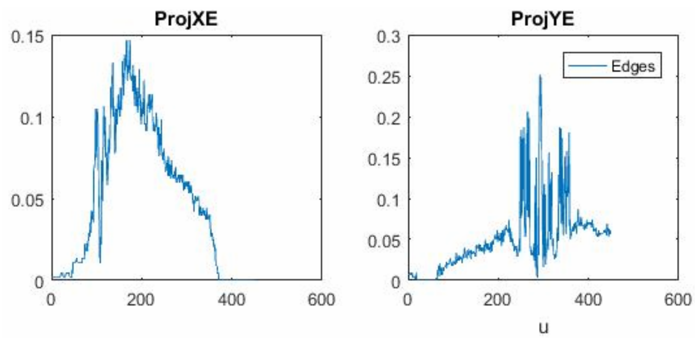
Concluding, the use of the method proposed in [5] may have some computational advantages, however it is problematic in the selection of parameters. Either the method is complemented with a fixed filter (and fixed parameter value) and with an automatic orientation for the largest distance between the projections on the axes, or the method is of limited use. Nevertheless, with suitable amendments, as indicated in this study, the method may have potential applications.



a



b



c

Fig. 6. Edges projections on the two axis: a. Flowers 1; b. Flowers 2; c. Lamp

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REFERENCES

1. BRUNET-IMBAULT B., LEMINEUR G., CHAPPARD C., HARBA R., BENHAMOU C.-L., *A new anisotropy index on trabecular bone radiographic images using the fast Fourier transform*, BMC Medical Imaging, 2005, **5** (4).
2. KASS, M., WITKIN, A., *Analyzing oriented patterns*, Computer Vision, Graphics, and Image Processing, 1987, **37** (*3*), 362–385.
3. LEHOUCQ R., WEISS, J., DUBRULLE B., AMON A., LE BOUIL A., CRASSOUS J, AMITRANO D., GRANER F., *Analysis of image vs. position, scale and direction reveals pattern texture anisotropy*, Front. Phys., 2015, **2** (84), 1–15.
4. NGUYEN T.S., BEGOT S., DUCULTY F., AVILA M., *Free-form anisotropy: A new method for crack detection on pavement surface images,* 18th IEEE Int. Conf. Image Processing, Bruxelles, Belgium, Sept. 2011.
5. TEODORESCU H.-N., DASCALESCU L., *Statistical characterization of images – Anisotropy*, in Applied Electronics (AE), 2016 International Conference, IEEE, 2016, 269–272.
6. WIRJADI O., SCHLADITZ K., RACK A., BREUEL T., *Applications of anisotropic image filters for computing 2d and 3d-fiber orientations. Stereology and image analysis*, ECS10 – Proc. 10th Eur. Congress ISS, (V. Capasso *et al*., Eds.), MIRIAM Project Series, ESCULAPIO Pub. Co., Bologna, Italy, 2009.