Blobworld Texture Features

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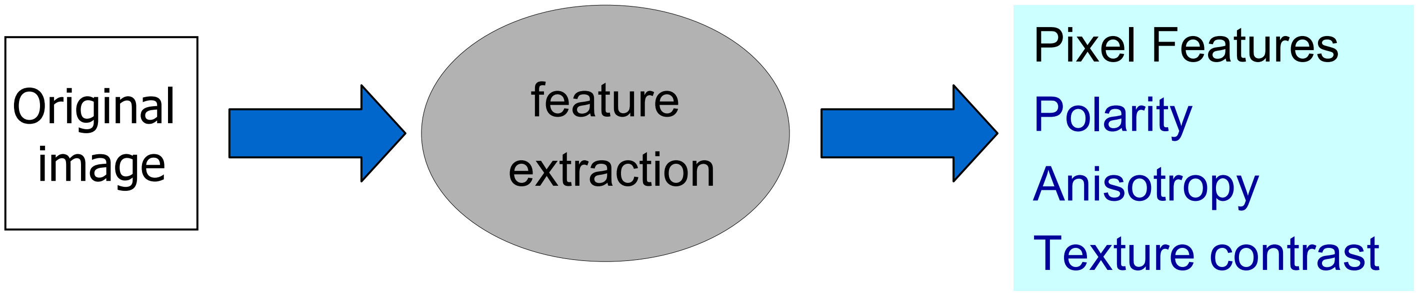
Feature Extraction

- Input: image
- Output: pixel features
  - Color features
  - Texture features
  - Position features
- Algorithm: Select an appropriate scale for each pixel and extract features for that pixel at the selected scale



Texture Scale

- Texture is a local neighborhood property.
- Texture features computed at a wrong scale would lead to confusion.
- Texture features should be computed at a scale which is appropriate to the local structure being described.

The white rectangles show some sample texture scales from the image.

Scale Selection Terminology

- Gradient of the L* component (assuming that the image is in the L*a*b* color space) : ∇I

- Symmetric Gaussian : $G\sigma(x, y) = G\sigma(x) * G\sigma(y)$

- Second moment matrix: $M\sigma(x, y) = G\sigma(x, y) * (\nabla I)(\nabla I)^T$

Notes: Gσ (x, y) is a separable approximation to a Gaussian.

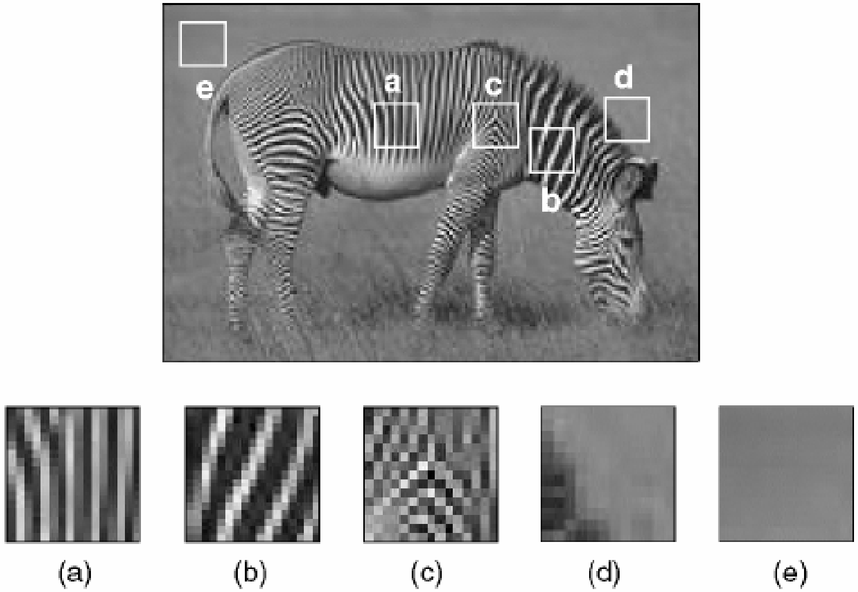
σ is the standard deviation of the Gaussian [0, .5, … 3.5].

σ controls the size of the window around each pixel [1 2 5 10 17 26 37 50].

Mσ(x,y) is a 2X2 matrix and is computed at different scales defined by σ.

Scale Selection (continued)

- Make use of polarity (a measure of the extent to which the gradient vectors in a certain neighborhood all point in the same direction) to select the scale at which Mσ is computed



Edge: polarity is close to 1 for all scales σ
Texture: polarity varies with σ
Uniform: polarity takes on arbitrary values

Scale Selection (continued)

$$p_\sigma = \frac{|E_+ - E_-|}{E_+ + E_-}$$

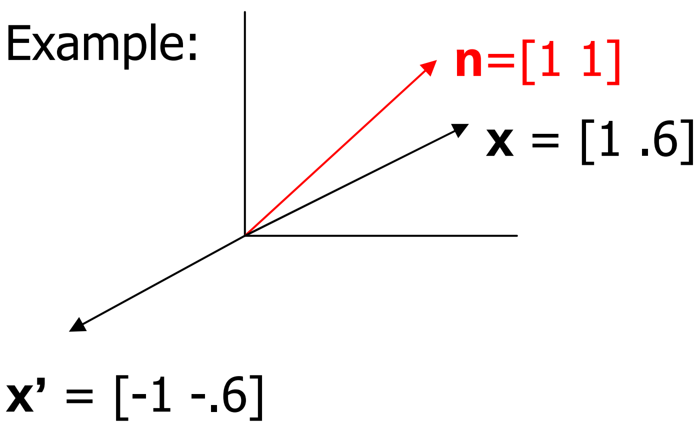
$$E_+ = \sum_{x,y} G_\sigma(x,y)[\nabla I \cdot \hat{n}]_+$$

$$E_- = \sum_{x,y} G_\sigma(x,y)[\nabla I \cdot \hat{n}]_-$$

- **n** is a unit vector perpendicular to the dominant orientation.
- The notation [x]+ means x if x > 0 else 0

  The notation [x]- means x if x < 0 else 0
- We can think of E^+ and E^- as measures of how many gradient vectors in the window are on the positive side and how many are on the negative side of the dominant orientation in the window.

Example:



σk

Scale Selection (continued)

- Texture scale selection is based on the derivative of the polarity with respect to scale σ.
- Algorithm:

1. Compute polarity at every pixel in the image for $\sigma_k = k/2$, ($k = 0,1\ldots7$).

2. Convolve each polarity image with a Gaussian with standard deviation 2k to obtain a smoothed polarity image.

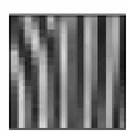
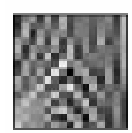
3. For each pixel, the selected scale is the first value of σ for which the difference between values of polarity at successive scales is less than 2 percent.

Texture Features Extraction

- Extract the texture features at the selected scale
  - Polarity (polarity at the selected scale) : $p = p_{\sigma^*}$
  - Anisotropy : $a = 1 - \lambda_2 / \lambda_1$

    λ_1 and λ_2 denote the eigenvalues of M_σ

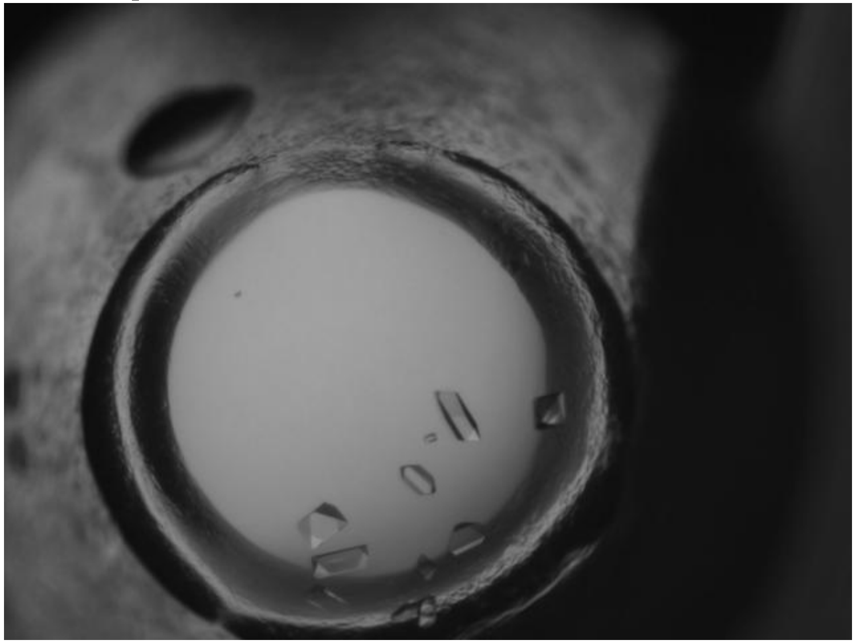
    λ_2 / λ_1 measures the degree of orientation: when λ_1 is large compared to λ_2 the local neighborhood possesses a dominant orientation. When they are close, no dominant orientation. When they are small, the local neighborhood is constant.

  - Local Contrast: $C = 2(\lambda_1+\lambda_2)^{3/2}$

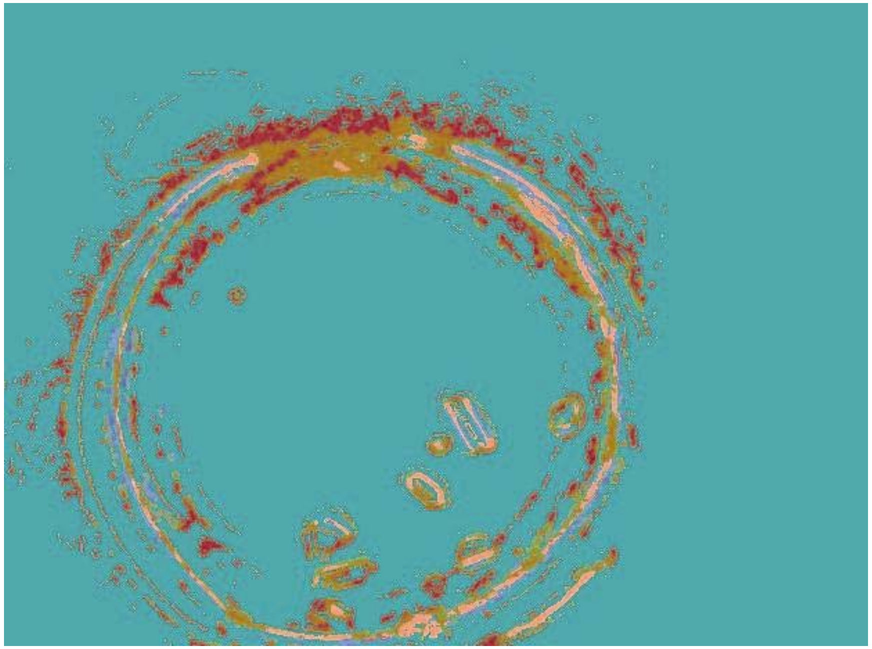
    A pixel is considered homogeneous if $\lambda 1+\lambda 2$ < a local threshold

Application to Protein Crystal Images



Original image in PGM (Portable Gray Map) format

- K-mean clustering result (number of clusters is equal to 10 and similarity measure is Euclidean distance)
- Different colors represent different textures



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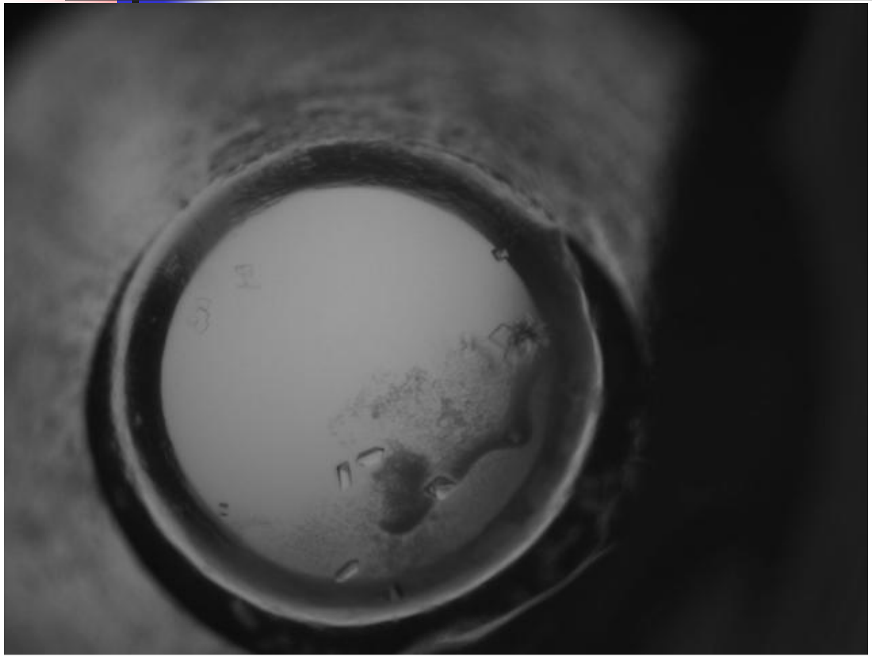

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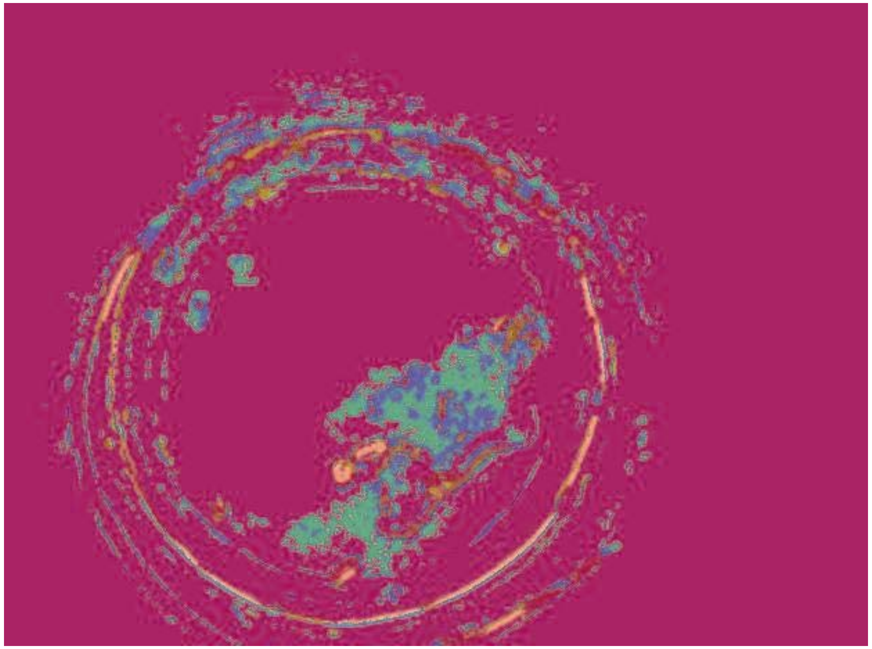

Application to Outdoor Objects

Original image in JPEG (Joint Photographic Experts Group) format

- K-mean clustering result (number of clusters is equal to 10 and similarity measure is Euclidean distance)
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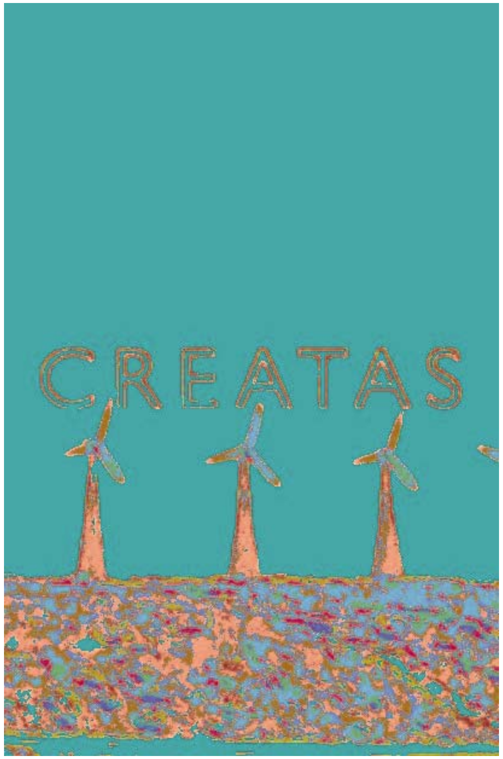
Application to Outdoor Objects

Original image in JPEG (Joint Photographic Experts Group) format



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References

- Chad Carson, Serge Belongie, Hayit Greenspan, and Jitendra Malik. "Blobworld: Image Segmentation Using Expectation-Maximization and Its Application to Image Querying." IEEE Transactions on Pattern Analysis and Machine Intelligence 2002; Vol 24. pp. 1026-38.

- W. Forstner, “A Framework for Low Level Feature Extraction,” Proc. European Conf. Computer Vision, pp. 383-394, 1994.