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

Original image → feature extraction → Pixel Features

- Polarity
- Anisotropy
- Texture contrast
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.
Scale Selection Terminology

- Gradient of the L* component (assuming that the image is in the L*a*b* color space) : $\nabla \mathbf{I}$

- Symmetric Gaussian: $G_{\sigma} (x, y) = G_{\sigma} (x) * G_{\sigma} (y)$

- Second moment matrix: $M_{\sigma} (x, y) = G_{\sigma} (x, y) * (\nabla \mathbf{I})(\nabla \mathbf{I})^{T}$

Notes: $G_{\sigma} (x, y)$ is a separable approximation to a Gaussian.

- $\sigma$ is the standard deviation of the Gaussian $[0, .5, ... 3.5]$.  
- $\sigma$ controls the size of the window around each pixel $[1, 2, 5, 10, 17, 26, 37, 50]$.  
- $M_{\sigma}(x,y)$ is a 2X2 matrix and is computed at different scales defined by $\sigma$.  

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 $M\sigma$ is computed.

- **Edge:** polarity is close to 1 for all scales $\sigma$
- **Texture:** polarity varies with $\sigma$
- **Uniform:** polarity takes on arbitrary values
Scale Selection (continued)

- \( \mathbf{n} \) 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:

\[
\mathbf{n} = [1 \ 1]
\]

\[
\mathbf{x} = [1 \ .6]
\]

\[
\mathbf{x'} = [-1 \ -.6]
\]
Scale Selection (continued)

- Texture scale selection is based on the derivative of the polarity with respect to scale $\sigma$.
- Algorithm:
  1. Compute polarity at every pixel in the image for $\sigma_k = k/2$, $(k = 0,1...7)$.
  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 $\sigma$ 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) : \( p = p_{o^*} \)
  - Anisotropy : \( a = 1 - \frac{\lambda_2}{\lambda_1} \)
    \( \lambda_1 \) and \( \lambda_2 \) denote the eigenvalues of \( M_o \)
    \( \frac{\lambda_2}{\lambda_1} \) measures the degree of orientation: when \( \lambda_1 \) is large compared to \( \lambda_2 \) 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

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

Original image in PGM (Portable Gray Map) format
Application to Protein Crystal Images

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Original image in PGM (Portable Gray Map) format
Application to Outdoor Objects

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Original image in JPEG (Joint Photographic Experts Group) format
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References
