Image Analysis - Motivation

NewScientist

Dung beetle inspires night vision
Overview – image processing

1. **Noise reduction**
2. Anisotropic filtering
3. Application: low light video enhancement
4. Block matching and collaborative filtering
5. Deep learning architectures for image processing
6. Application: low light image processing using learning
Noisy image
Gaussian smoothing
Gaussian smoothing - blurs edges!
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Structure/Orientation Tensor

Construct the matrix

\[
M = \begin{bmatrix}
W_{xx} & W_{xy} \\
W_{xy} & W_{yy}
\end{bmatrix} = \begin{bmatrix}
(\frac{\partial f}{\partial x})^2 & G_b \\
(\frac{\partial f}{\partial x} \frac{\partial f}{\partial y}) & G_b \\
(\frac{\partial f}{\partial x} \frac{\partial f}{\partial y}) & G_b \\
(\frac{\partial f}{\partial y})^2 & G_b
\end{bmatrix}
\]

where \( G_b \) denotes the Gaussian function with parameter \( b \).

\[M\] - orientation tensor.

Note: We construct a matrix for every pixel.
Structure Tensor

The matrix $M$ has the following properties:

- **(Flat)** Two small eigenvalues in a region - flat intensity.
- **(Flow)** One large and one small eigenvalue - edges and flow regions.
- **(Texture)** Two large eigenvalues - corners, interest points, texture regions.

This can be used in algorithms for segmenting the image into (flat, flow, texture).
Rotate Gaussian kernels using eigenvectors of the structure tensor
Scale Gaussian kernels using a function of the eigenvalues of the structure tensor
Structure adaptive smoothing
Close-up comparison

Noisy input  Gaussian  Structure adaptive
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Low light enhancement

1. Amplify signal
   using eg scaling or histogram equalization
   Introduces noise

2. Anisotropic filtering of noise
Low light video enhancement

ADAPTIVE ENHANCEMENT AND NOISE REDUCTION IN VERY LOW LIGHT-LEVEL VIDEO
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Block matching
many structures are repeated at multiple locations in an image
Collaborative filtering
Do hard filtering on each set of similar matched blocks
BM3D
Uses two pass version of block-matching and filtering
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Autoencoders
U-net

input image tile

output segmentation map

conv 3x3, ReLU
copy and crop
max pool 2x2
up-conv 2x2
conv 1x1
Segmentation using U-net

Segmentation of Touching Objects of the Same Class

HeLa cells recorded with DIC microscopy

manual segmentation
(colors: different instances)

[Data provided by Dr. Gert van Cappellen, Erasmus Medical Center. Rotterdam. The Netherlands]

Olaf Ronneberger, University of Freiburg, Germany, 22.5.2015
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Low light image enhancement using a U-net

Results