(Digital) Image processing

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The materials are based on the earlier lecturer prof. Árpád BARSİ

- Part 1: (6/12/2022) „Theory” of image processing
- Part 2: (13/12/2022) Practice with software examples
• Basic terms
• Image descriptions
• Image acquisition
• Resolutions
• Storage & software
• Manipulations: LUT, morphology, histogram operations
• Image filterings
• Color models
• Geometric manipulations
• Basic measurements
• Machine Learning Basics

Content
Is it interdisciplinary?

- Photography
- Mathematics
- Physics, optics
- Signal processing, electronics
- IT
- ...
- Application fields
Application fields

• Photography, documentation (from holiday to events)
• Cinema
• Design, marketing, advertisements
• Medicine, biology
• Industrial applications: robots, QA/QC, transportation...
• Physics, astronomy, measurement technologies
• Military applications
• Remote sensing, GIS
• And many more...

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• Detection and recognition of known objects
• Obtaining geometric models of unknown objects
• Computing position and orientation of objects
• Measurement of spatial properties of objects (distances, sizes, etc.)
• Measurement of object motion
• Measurement of surface texture and color

Goals of image processing
Levels

- Image processing
  - E.g. image enhancement

- Image analysis
  - E.g. feature extraction

- Image understanding
  - E.g. semantics
Image and pixel

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Image coordinate systems
Image acquisition procedure

1. Reality
2. Projection (optics)
3. Sampling
4. Quantization
5. Digital image
Image acquisition procedure
• An image is a function $f(x,y,b,t)$
• Resolution: geometric, radiometric, spectral, temporal
• Cut-off/mask: regular, arbitrary (ROI, AOI)
• Storage formats (color and BW; lossy and lossless)
• Features: descriptive data, statistics, histogram, sections
Geometric resolution

Original resolution  
1/4 of original

1/8 of original  
1/16 of original
Radiometric resolution

64 gray levels
16 gray levels
8 gray levels
4 gray levels
Spectral resolution
Temporal resolution
• Trigger (to have a single image not a video)
• Detector:
  • Single point – really fast
  • Small area (APD arrays)
  • Camera (CCD, CMOS)
• Photons → Electrons → Voltage → Dig. Number
• Parameters: Noise / Range / TimeFrame

Image acquisition
• Paper of A4 with 600 dpi
  • $210 \times 297$ mm
  • $4961 \times 7016$ pixel = $34\,806\,376$ pixel
  • à 24 bit (1 byte) = $99.6$ MB
• Aerial image with 7 μm pixel size
  • $230 \times 230$ mm
  • $32\,857 \times 32\,857$ pixel = $1\,079\,582\,449$ pixel
  • à 24 bit = $3.02$ GB
• Efficient algorithms to store information
  • Lossy or lossless methods

Image storage
• Graphics software:
  • PhotoShop, PhotoPaint, PaintShopPro, Kai, Photo DeLuxe, Gimp...

• General purpose development environments:
  • Khoros, **Matlab Image Processing Toolbox**, AVS, Image Vision Library, Halcon, ImageMagick, Rapidminer...

• Special application software:
  • ImageStation Imager, Erdas Imagine, GRASS, ImagePro Plus, Ilwis, **ImageJ**, Fiji, SNAP...
Software examples

Kai’s Power Tools

PhotoShop

GIMP

ILWIS

ImageJ
• Free Java based image processing software
• Download from: http://imagej.nih.gov/ij/
• Clear menu structure
• Numerous medical/biologic function
• Add-on possibility (plug-in)
• Well-documented (help, tutorials, videos)
- Classification
- Semantic segmentation
- Object detection
- Object localization


Image processing tasks
Wide variety of:
- Viewpoint
- Illumination
- Deformation
- Occlusion
- Clutter
- Intraclass Variation

• Transformation (Translation, Rotation, Cut, Resize, Denoise, Contrast enhancement, morphological transformations)
• Segmentation
• Registration (e.g. to fuse multiple images to the same CS)
• DICOM – Digital Imaging and Communication in Medicine
• Copyright at NEMA – National Electrical Manufacturers Association
• First standard: NEMA + Americal College of Radiology (1985)
• DICOM Standard Committee
• Providers: e.g. Agfa, Philips, Siemens, Zeiss...
• Users: e.g. American Academy of Ophthalmology, European Society of Cardiology, Deutsche Roentgengesellschaft...
• Other members: e.g. IT companies, health industry companies...
## Quick Links To Popular Programs

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**DICOM support**

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DICOM example

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• Descriptive data
  • #rows, #columns, capture date, exposition time...
• Statistics
  • Max, min, mean, median...
• Histogram
• Sections

Image features

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Once more about histograms
Look-Up Table (LUT)
LUT cases

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Binarization

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Morphology

Erosion

Dilatation

Opening

Closing
Skeletonize

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Opening & closing with 5 pixel radius STREL

Grayscale morphology
Histogram stretch
Brightness functions

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Contrast function
Image filtering

- Convolution
  - Smoothing
  - Edge detection
- Non-convolution
  - Special effects
- Filtering in frequency domain
  - Periodic noise removal
Convolution
Smoothing filter (mean)
Median-filter
Mean vs median filter
Laplace filtering

- $N=4, n=4$
- $N=4, n=5$
- $N=8, n=8$
- $N=8, n=9$
Find edges = Sobel filtering
• Additive models
  • E.g. RGB

• Subtractive models
  • E.g. CMY

Color models
RGB model
CMYK model
RGB model vs. Perceptual color model
Geometric manipulations
Basic measurements
• Traditional processing:
  
  Data + Program → Computation → Output

• ML driven processing:
  
  Data + Desired Output → Training → Program (The Model) → Output

New Data

Machine Learning

https://xkcd.com/1838/
AI - Artificial Intelligence: Anytime we use the Computer for something more than just processing the prewritten code
ML - Machine Learning: Adapting to a task, based on previous information, looking for patterns in a massive amount of data.
DL = ML + NN (Deep Neural Network)
Machine learning in ImageJ
Machine learning in Ilastik

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Machine learning in Ilastik

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2022
Deep learning in ImageJ

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Source: https://www.biorxiv.org/content/10.1101/799270v3.full.pdf
Thanks for your attention!

To be continued...
The materials are based on the earlier lecturer prof. Árpád BARSİ, the references for his materials:

- Jähne, B.: Digital Image Processing
- Epstein, L.C.: Introduction to the Mathematics of Medical Imaging
- Suetens, P.: Fundamentals of Medical Imaging
- dicom.nema.org
- http://www.olympusmicro.com/

References for the extensions:

- https://commons.wikimedia.org/wiki/User:Datumizer
- https://vas3k.com/blog/machine_learning/
- https://imagej.net/plugins/tws/
- https://www.biorxiv.org/content/10.1101/799270v3.full.pdf