Analysis strategy

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Outline – Analysis strategy

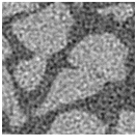
Introduction

Introduction

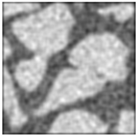
The past lectures we have learnt how to

- Acquire
- Process
- Extract information

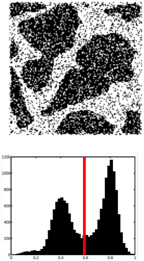
Aquisition



Enhancement

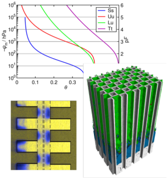


Segmentation



Post processing

Evaluation



Define questions

A number of questions are of high importance

- How can I plan my experiment to make the analysis easier?
- Is my original question too general?
- How can I transfer the original question into the vocabulary of image analysis?
- How much a priori information about the sample do I have? Can it be used for the analysis?

Data reduction through processing

Filtering

- Spatial data
- Gray levels
- Large data

Segmentation

- Spatial data
- Few levels
- Large data
- Reduction 2-10

Measurements

- Item data
- Positions, shape
- Small data
- Reduction 10-1000

Statistics

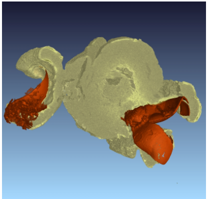
- class descriptions
- Tiny data
- Reduction 10^6 and more.

Workflow

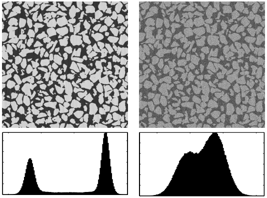
Visualization – Exploring the data

Getting a new data set, it is a good idea to explore it first. . .

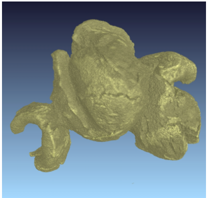
Cutting



Histograms



Iso-surface



Rendering

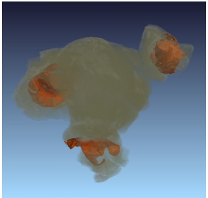


Image quality

The feasibility of the analysis depends on

Resolution

Is the resolution sufficient to detect relevant features or phenomena?

- Known feature size → select resolution for required level of detail.
- Unknown feature size → make a test acquisition.

Contrast

Can features be separated by intensity?

- Difference in attenuation
- Number of gray levels

Noise

The SNR can be improved by

- Change resolution
- Increase acquisition time

are these changes possible?

Technical limitations

Assuming the instrument can acquire the data...

Data size

- Does all data fit in primary memory?
- How to store
- How to transfer

Computing

- With 3D and 4D data it is important to find algorithms with complexity $< O(N^2)$.
- What hardware will solve the task?

Define chain of operations

- Select processing tools
  - Filters
  - Segmentation
  - Measurements
- Implement
- Evaluate performance
- Process the experiment data
- Evaluate statistics
- Presentation of data

Selecting the right tool

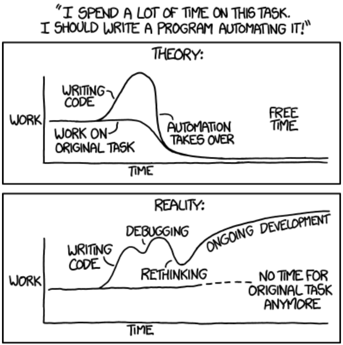
Criteria

- How many similar samples?
- How complex is the sample?
- Is human interpretation needed?
- What is the end product?
- Are there methods/tools available?
- Will there be more similar data sets?

The choice

There is no golden recipe.

- Interactive tools
- Scripting using existing toolboxes
- Development of new algorithms



xkcd.com

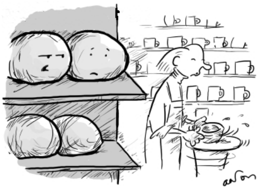
Verifying performance

Verify the correctness of the method

"Data massage"

Processing manipulates the data. . .

. . . avoid too strong modifications otherwise you may invent new image features!!!



Watch that man, he'll make mugs of us all!

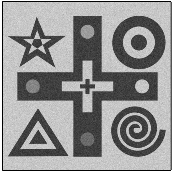
Verify the validity your method

- Visual inspection
- Difference images
- Use degraded phantom images in a "smoke test"

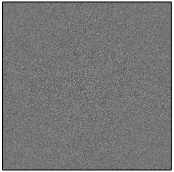
Verification using difference images

Compute pixel-wise difference between image f and g

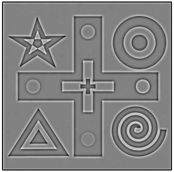
Noisy image



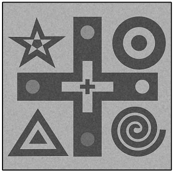
Ideal filter



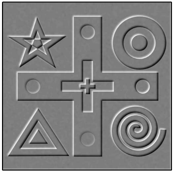
Over smoothing



Intensity scaling



Geometric shift



Difference images provide first diagnose about your processing performance

Performance evaluation – "Smoke test"

Aim of the evaluation

To identify the operating range of a proposed analysis method

- Noise sensitivity
- Feature sizes/characteristics
- Break-down point

How to make the evaluation

1. Build a set of phantoms representing variations in the features.
2. Add noise.
3. Process noisy phantom data.
4. Repeat 2–3 for different noise levels and contrasts.
5. Repeat 2–4 for different processing parameters N times for better stats.
6. Plot results and identify the stable operating range.

Metrics

An evaluation procedure need a metric to compare the performance

Mean squared error

$$MSE(f,g) = \sum_{p \in \Omega} (f(p) - g(p))^2$$

Structural similarity index

$$SSIM(f,g) = \frac{(2\mu_f \mu_g + C_1)(2\sigma_{fg} + C_2)}{(\mu_f^2 + \mu_g^2 + C_1)(\sigma_f^2 + \sigma_g^2 + C_2)}$$

μ_f, μ_g Local mean of f and g.

σ_{fg} Local correlation between f and g.

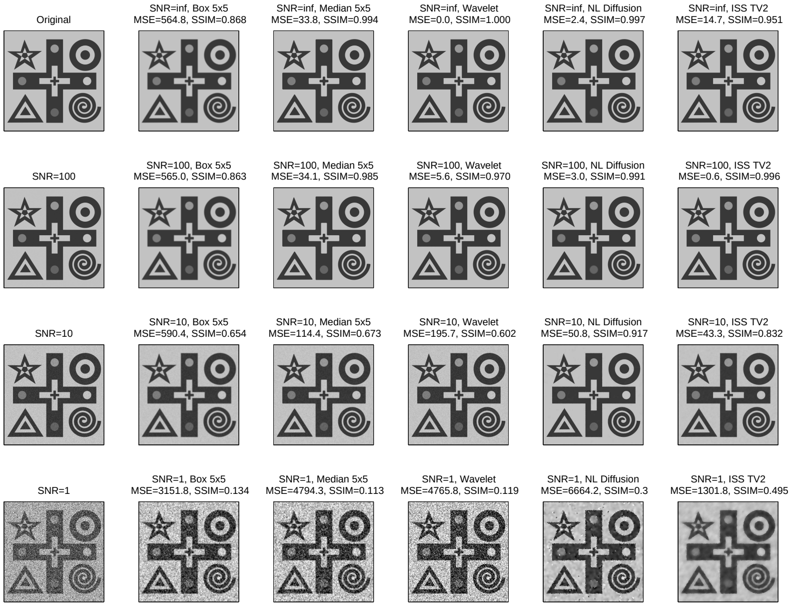
σ_f, σ_g Local standard deviation of f and g.

C_1, C_2 Constants based on the image dynamics (small numbers).

$$MSSIM(f,g) = E[SSIM(f,g)]$$

Wang and Bovik (2009); Bovik (2009)

Demonstrating metrics in filter evaluation



Classification metrics

Confusion matrix

Count pixels into the categories

- **a** True positive (correct)
- **b** False positive
- **c** False negative
- **d** True negative (correct)

Can be extended to more classes

Confusion matrix		***Target***			
		Positive	Negative		
Model	Positive	a	b	Positive Predicitve Value	a/(a+b)
	Negative	c	d	Negative Predicitve Value	d/(c+d)
		Sensitivity	Specificity	**Accuracy** =(a+d)/(a+b+c+d)	
		a/(a+c)	d/(b+d)		

Dice score

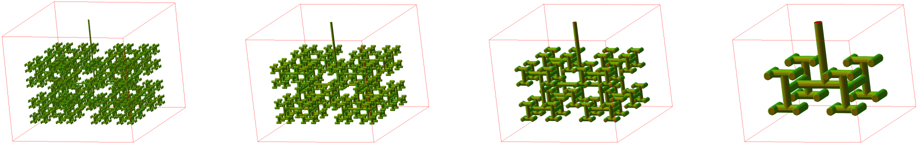
The Dice score compares two images X (ground truth) and Y (predicted)

$$DSC = \frac{2\#(X \cap Y)}{\#X + \#Y} = \frac{2\,a}{2\,a + b + c}$$

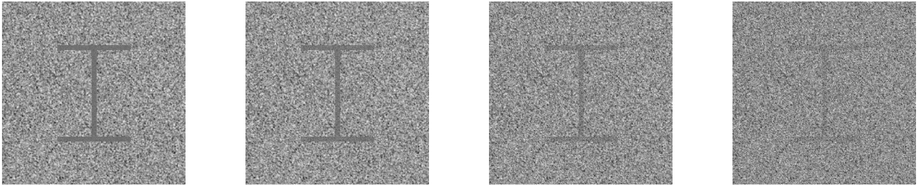
...and many more.

Test run example

Build phantoms



Add noise



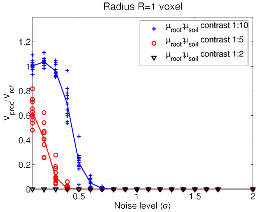
Process

Run the analysis method with different parameters.

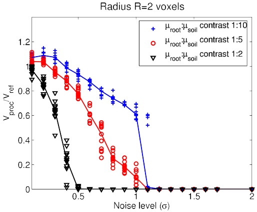
Results from smoke test

Metric: Ratio of voxels connected to the seed and voxels in reference structure.

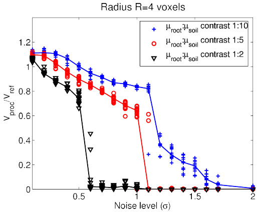
Radius 1 voxel



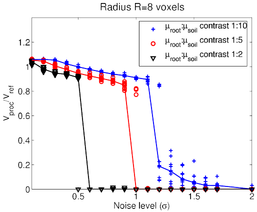
Radius 2 voxels



Radius 4 voxels



Radius 8 voxels



Summary

Today's lecture

- Think before acting. . .
- Get to learn you data
- Set up a process
- Verify operating range

Summary

All lectures

You have be introduced to the

- Main building blocks of image processing
  - Images and noise
  - Filters for denoising and feature enhancement
  - Segmentation
  - Morphological operations
  - Feature characterization to identify and quantify the contents of you images
  - Verification strategies
- Exercises to apply the concepts from the lectures

Your Questions

- Do you have any unclear details from the lectures to clear up?
- Questions related to your current projects?

Thesis topics

Topics

- Neutron imaging
- Bimodal imaging
- Image processing
- Materials science
- Porous media

Check our web page https://www.psi.ch/en/lns/teaching-and-education or contact me directly.

References I

Bovik, A., editor (2009). *The Essential Guide to Image Processing*. Elsevier.

Kaestner, A., Schneebeli, M., and Graf, F. (2006). Visualizing three-dimensional root networks using computed tomography. *Geoderma*, 136(1–2):459–469.

Wang, Z. and Bovik, A. (2009). Mean squared error: Love it or leave it? – a new look at signal fidelity measures. *IEEE Signal Processing Magazine*, January:89–117.