

Image Processing for Physicists

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Maximum likelihood principle



Overview

- Likelihood
- Bayes' theorem
- Application
 - ML Classification
 - Deconvolution
 - Image registration

What is likelihood?

- A likelihood function is a probability distribution expressed as a function of its parameters, and evaluated for a given set of observations.

Maximum likelihood

Can easily be misunderstood...



Bayes' theorem

Maximum likelihood & optimization

- Goal: find the parameters that explain best the observed data.
 - Maximum likelihood
 - or
 - Maximum a posteriori (MAP)
- Very often more convenient to minimize $-\log()$.

Example: a biased coin

Example: Gaussian model

Example: Gaussian model

Image classification

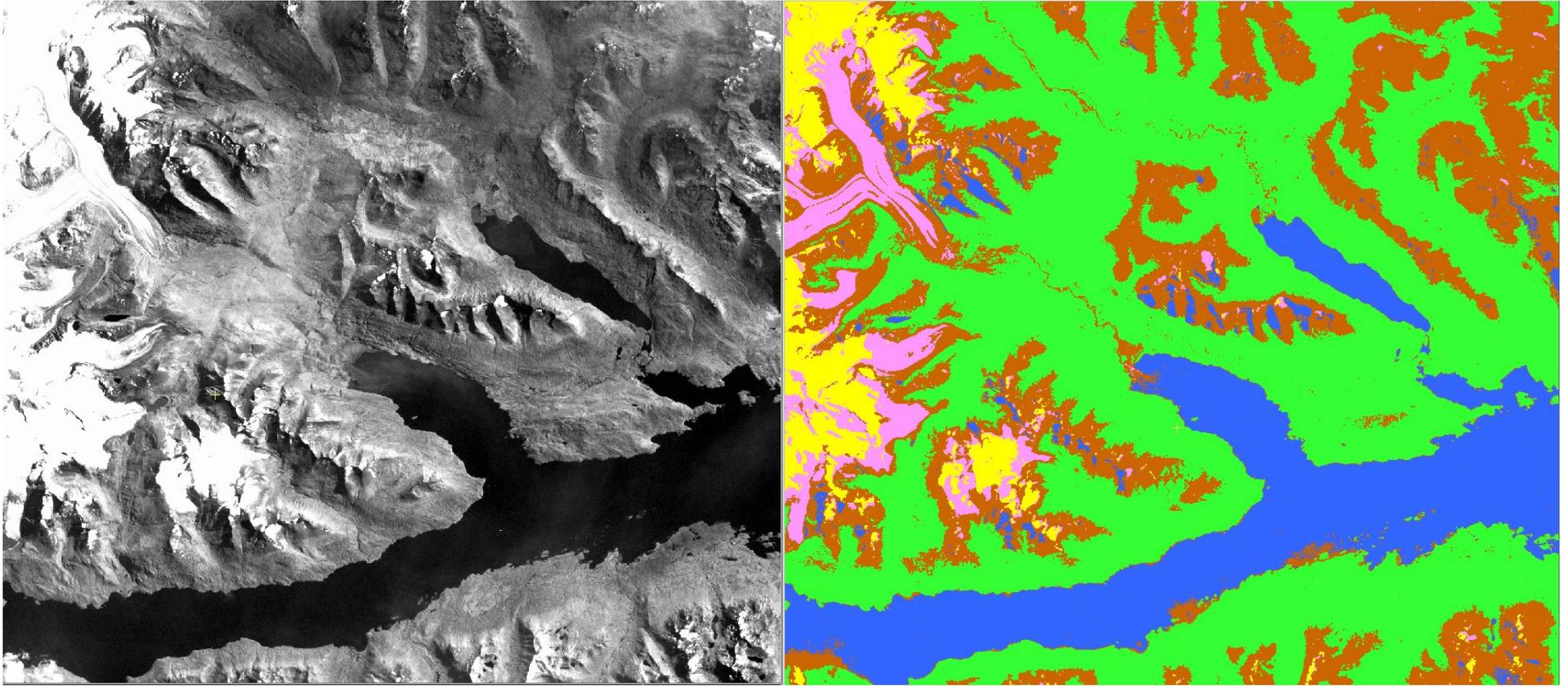


Image classification

Landsat 8-9 Operational Land Imager (OLI) and Thermal Infrared Sensor (TIRS)

| Bands | Wavelength (micrometers) | Resolution (meters) |
|-------------------------------------|-------------------------------------|--------------------------------|
| Band 1 - Coastal aerosol | 0.43-0.45 | 30 |
| Band 2 - Blue | 0.45-0.51 | 30 |
| Band 3 - Green | 0.53-0.59 | 30 |
| Band 4 - Red | 0.64-0.67 | 30 |
| Band 5 - Near Infrared (NIR) | 0.85-0.88 | 30 |
| Band 6 - SWIR 1 | 1.57-1.65 | 30 |
| Band 7 - SWIR 2 | 2.11-2.29 | 30 |
| Band 8 - Panchromatic | 0.50-0.68 | 15 |
| Band 9 - Cirrus | 1.36-1.38 | 30 |
| Band 10 - Thermal Infrared (TIRS) 1 | 10.6-11.19 | 100 |
| Band 11 - Thermal Infrared (TIRS) 2 | 11.50-12.51 | 100 |

Image classification

Supervised Maximum Likelihood Classification

1. Training: for each class, evaluate the probability distribution of the measurements.

Image classification

Supervised Maximum Likelihood Classification

2. Classification: for each pixel, compute the probability that it belongs to each class. The highest probability wins.

Image deconvolution

Image deconvolution

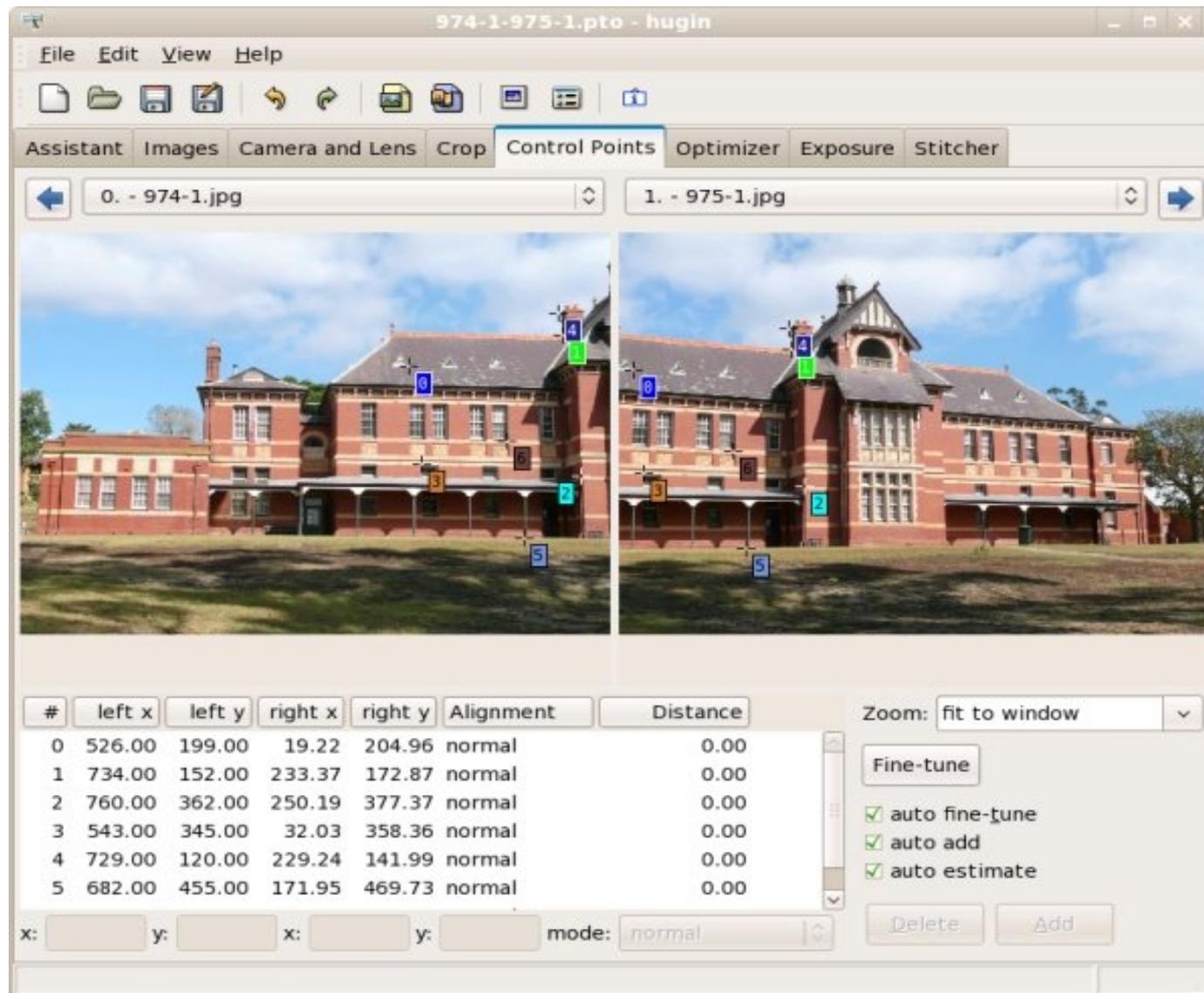
Image deconvolution

Image deconvolution

What is image registration?

- Geometric transformation of multiple images to make them match
- Transformations can be rigid or non-rigid
 - Rigid: translation, scale, rotation
 - Non-rigid: shear, perspective, ...
- Optimization can be done on the transformed images or on a set of control points.
- In almost all cases, interpolation is required to remap images on a regular grid.

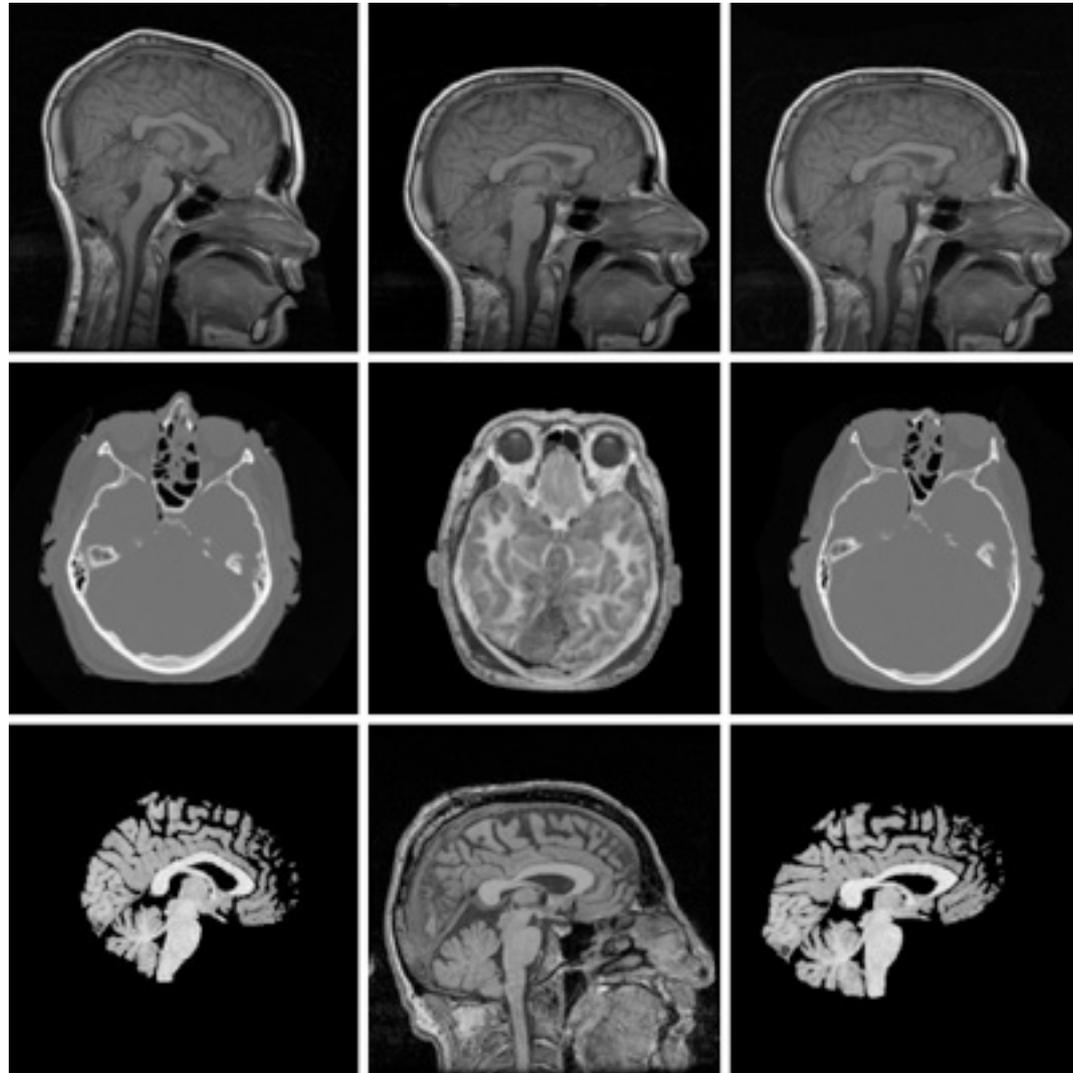
Control points for photo stitching



Source: <http://hugin.sourceforge.net/tutorials/two-photos/en.shtml>

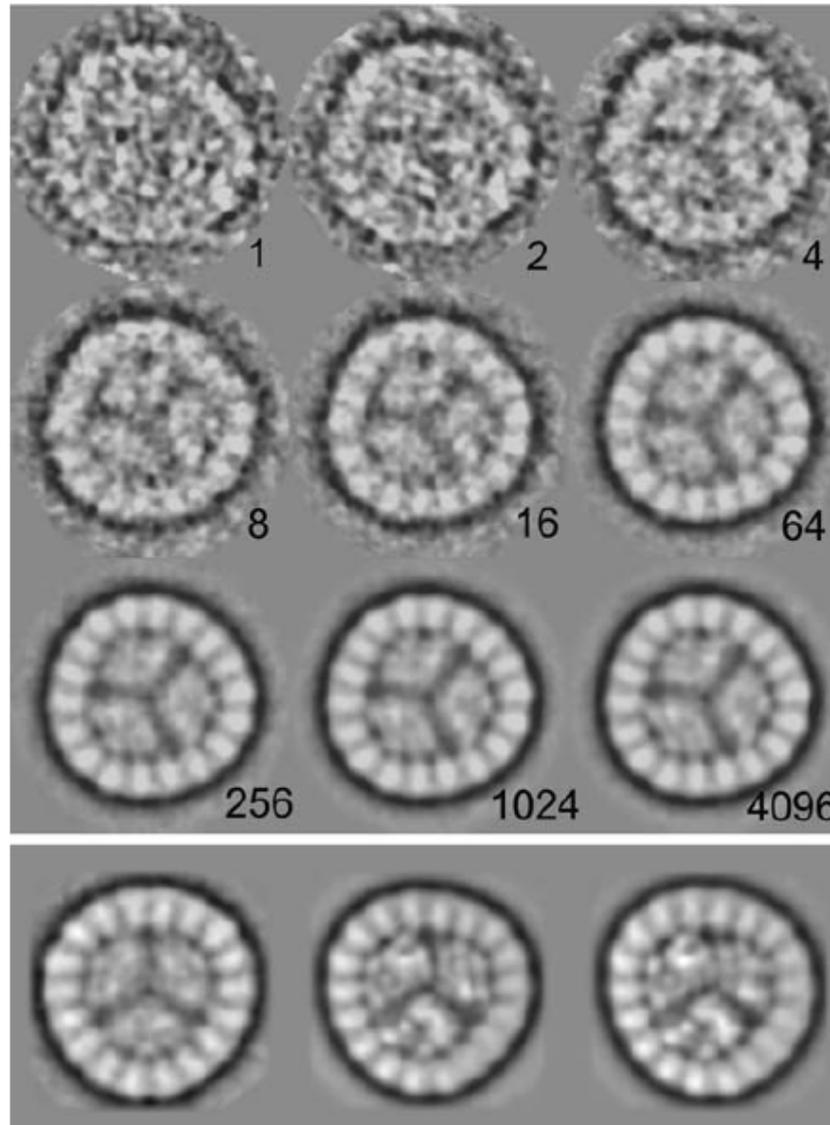
Image registration

Medical image registration



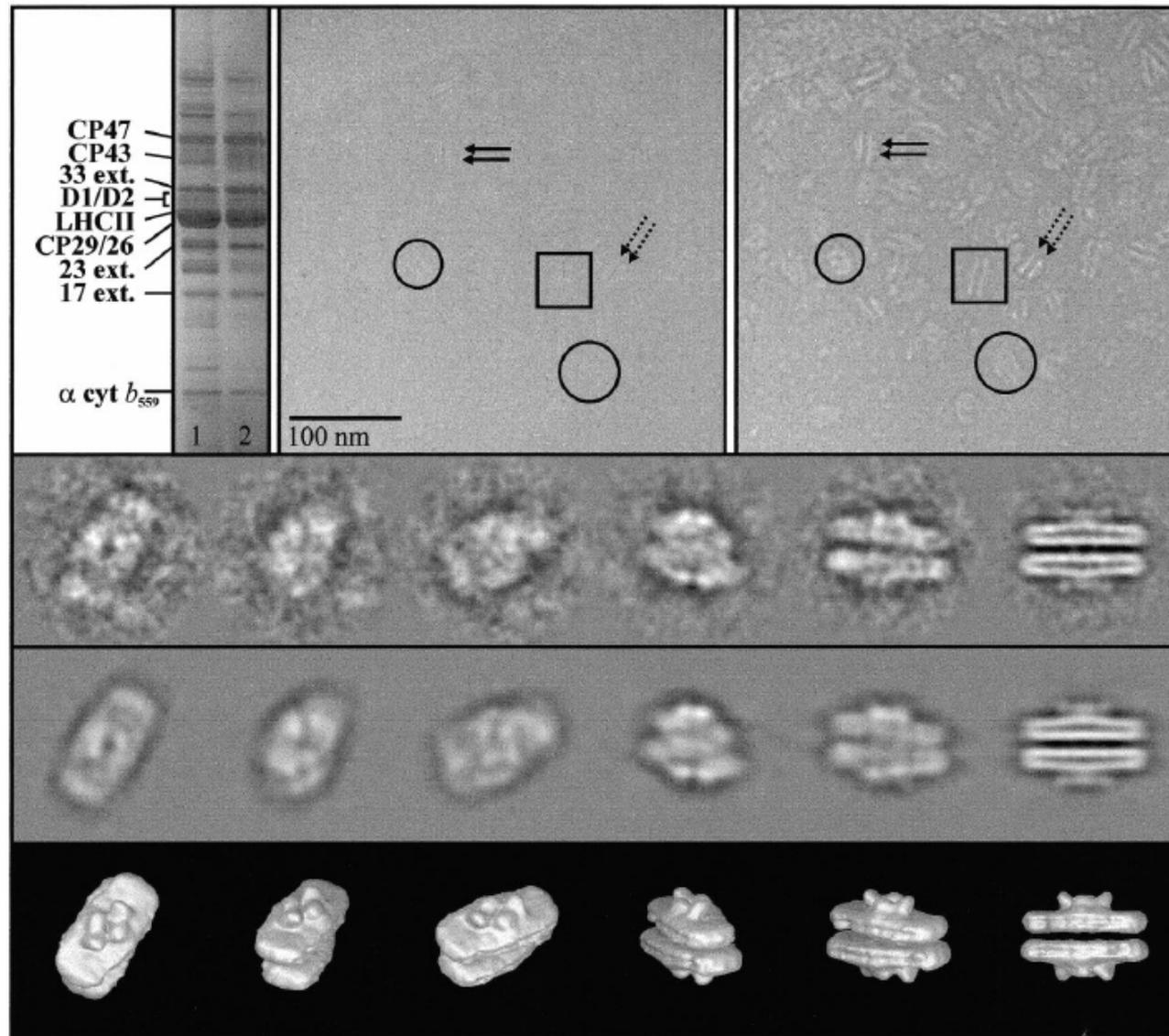
Source: http://www.cs.dartmouth.edu/farid/Hany_Farid/

Single particle analysis



Source: Boerkema *et al.* Photosynth. Res. **102**, 189-196 (2009)

Single particle analysis



Source: Nield *et al.* Nat. Struct. Bio. 7, 44-47 (2000)

Image registration



Maximum likelihood formulation

Maximum likelihood formulation

Summary

- Likelihood maximization: finding parameters that best fit an observation.
 - Powerful, but:
 - Can overfit, can misinterpret
- Maximum A Posteriori (MAP): include prior (probabilistic) knowledge
- Broad range of applications:
 - Classification, registration, enhancements, ...