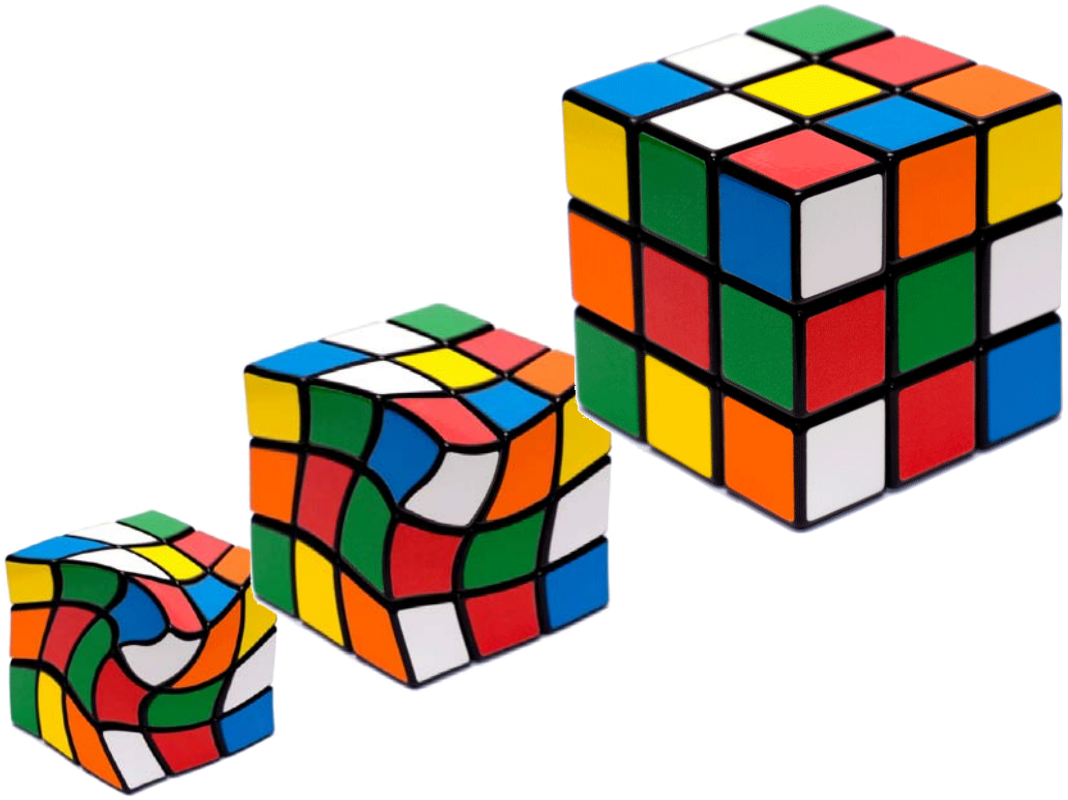
Image Registration in Biology



Overview

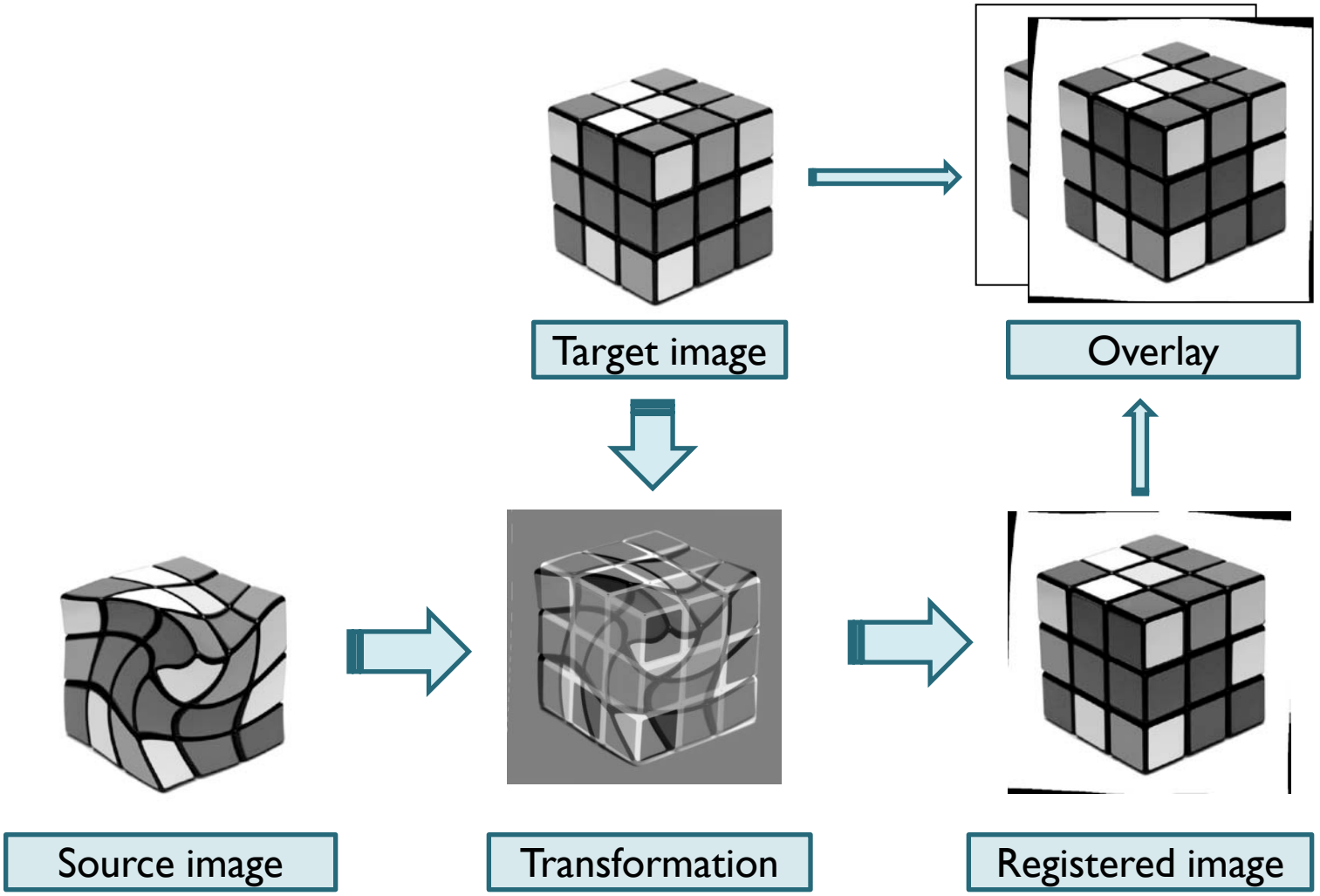
- Introduction
- Applications
- Types of Transformations
- Methods and Algorithms
- Resampling of Images
- Registration via Landmarks
- Registration in 3D
- Software

Introduction

- **Image registration** is the process of transforming different sets of data into one coordinate system.
- One image is aligned "registered" to a target image
- Datasets are taken under different conditions: Different timepoints, viewpoints, animals
- Common Features are aligned, differing Features become visible

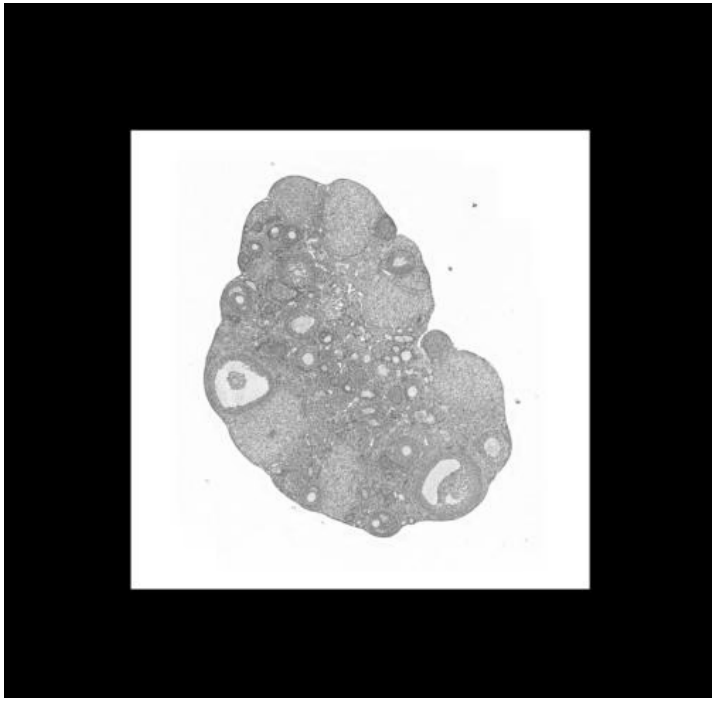
Introduction

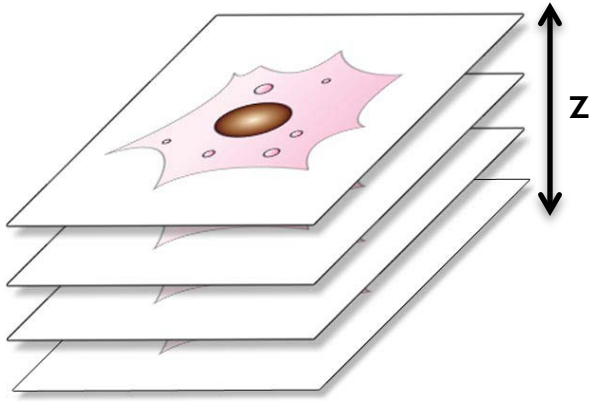
Workflow of Image Registration



Applications

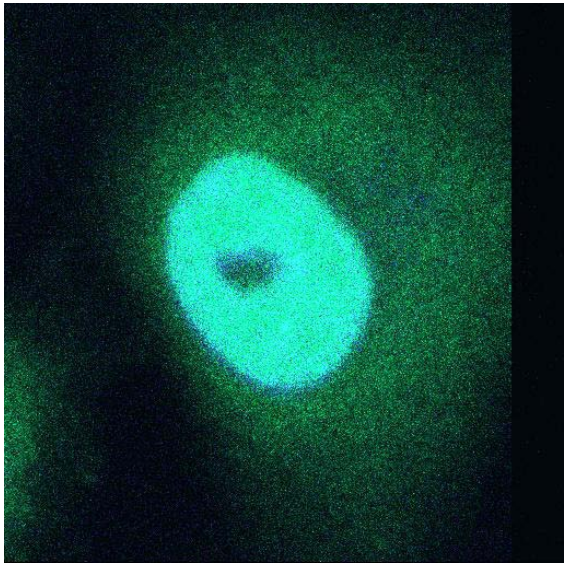
- Stack alignment

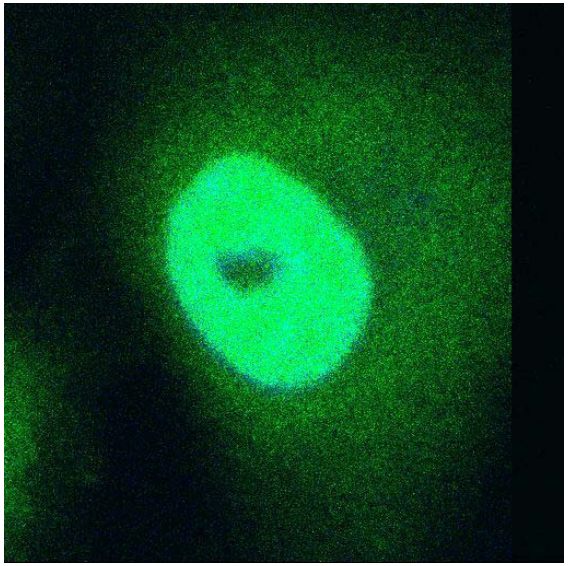


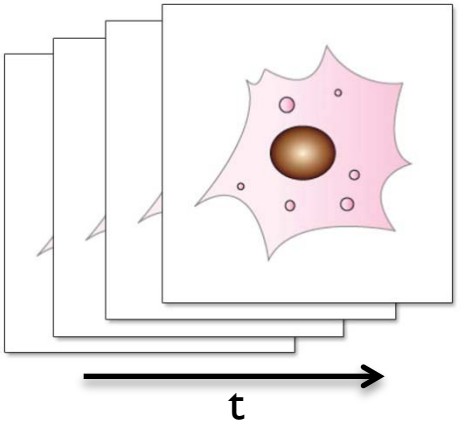


Applications

- Different timepoints

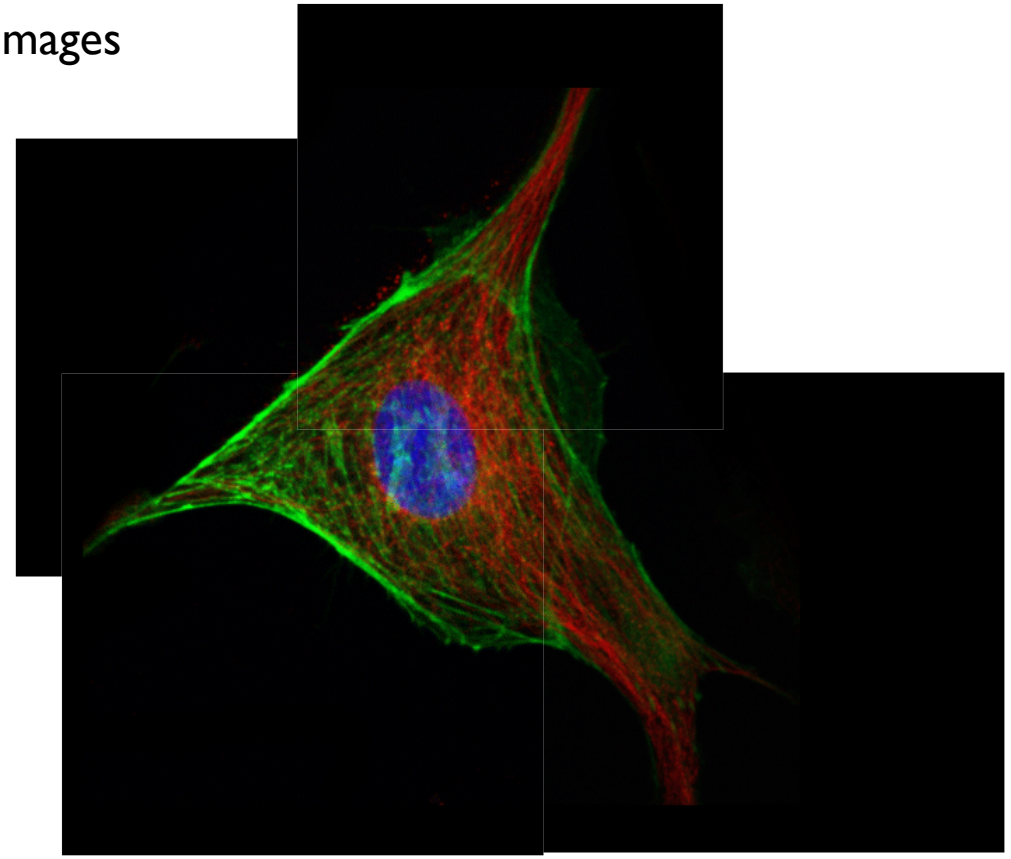






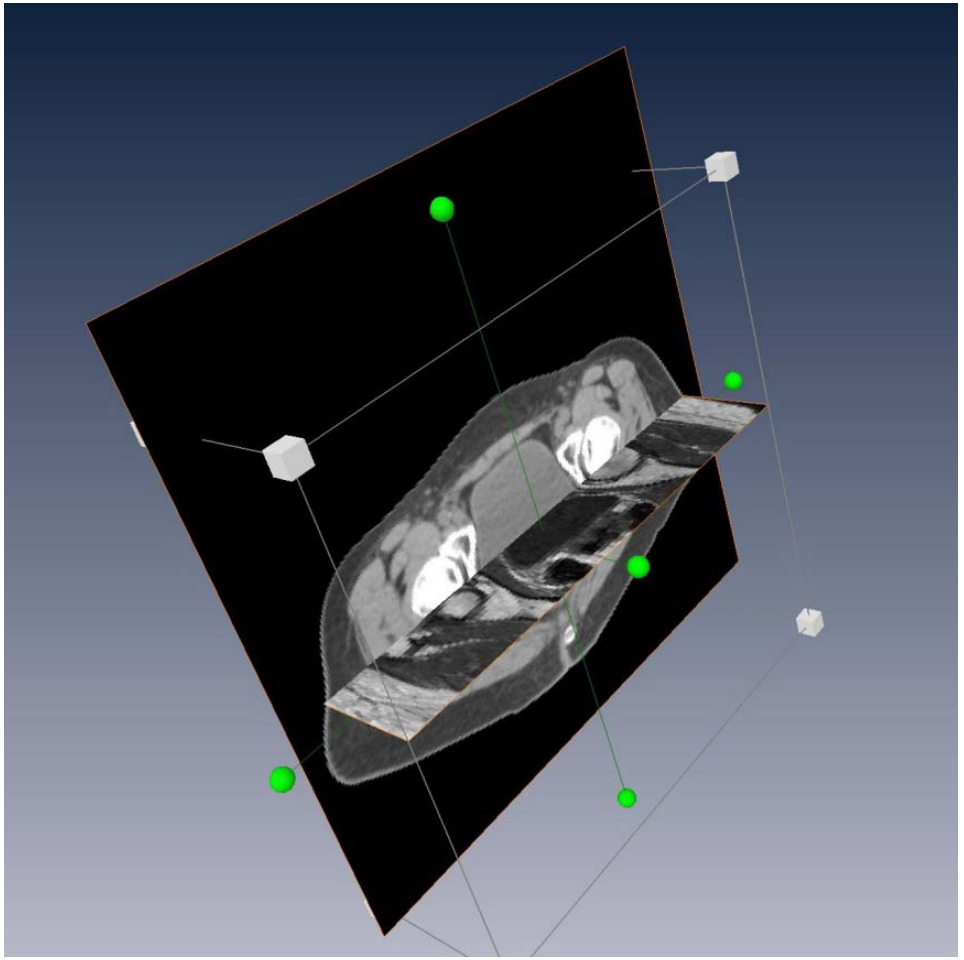
Applications

- Stitching
  - Arrangement of tiles
  - Satellite images



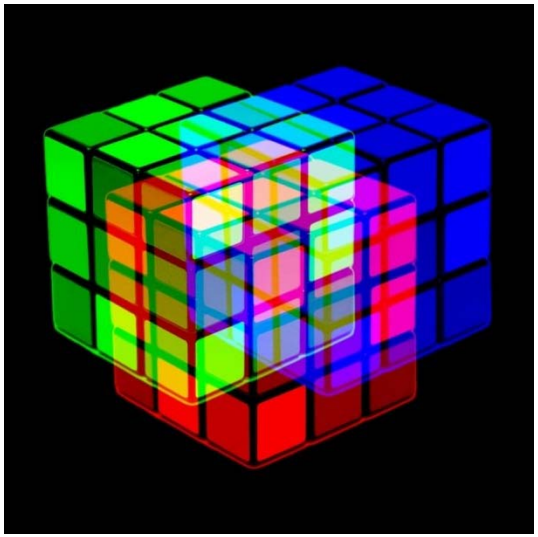
Applications

- 3D
  - Volume registration



Rectification

- Correction for distortions and misalignments during image acquisition



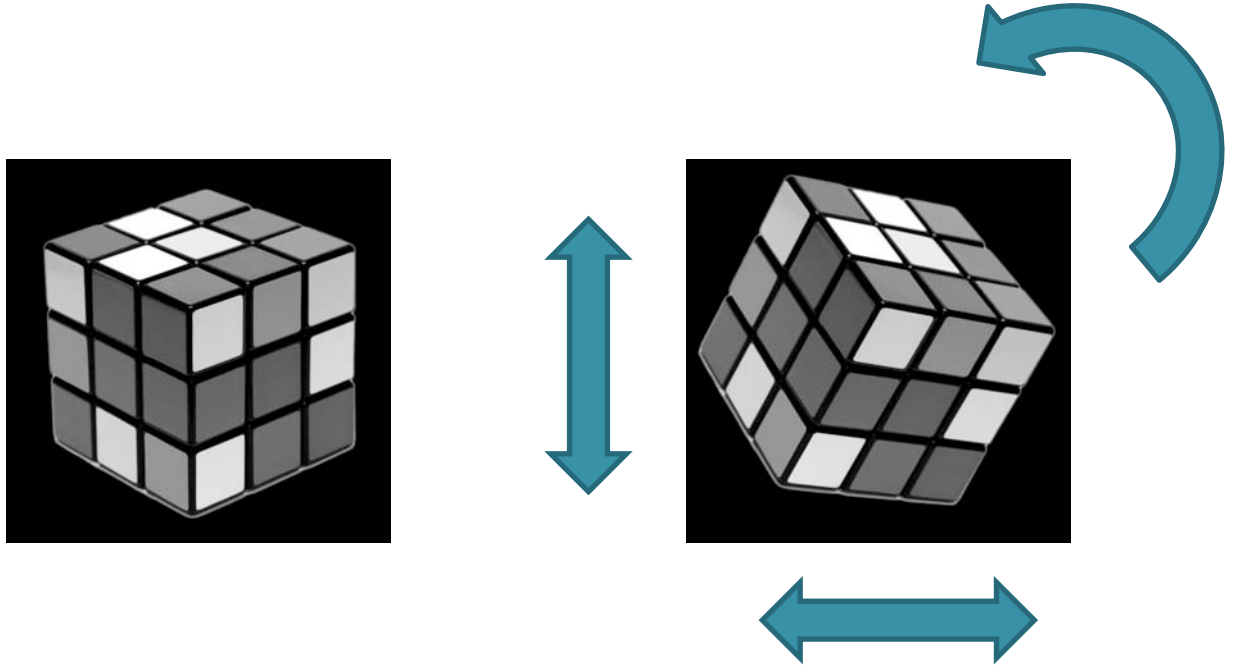
Types of transformations

There are different possibilities to transform images for alignment:

- Rigid transformations
  - Rotation
  - Translation
- Nonrigid transformations
  - Scaling
  - Affine transformation
  - Piecewise affine
  - Projective transformation
  - Elastic transformation

Types of transformations

- Rigid transformations
  - Only rotation and translation of image
  - The distance between any two points is conserved



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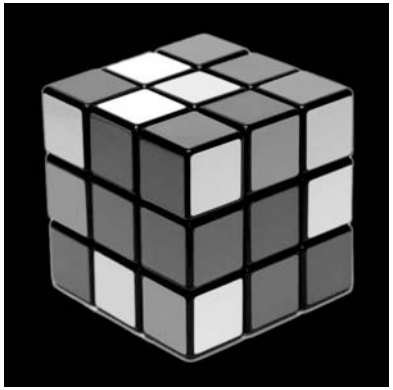
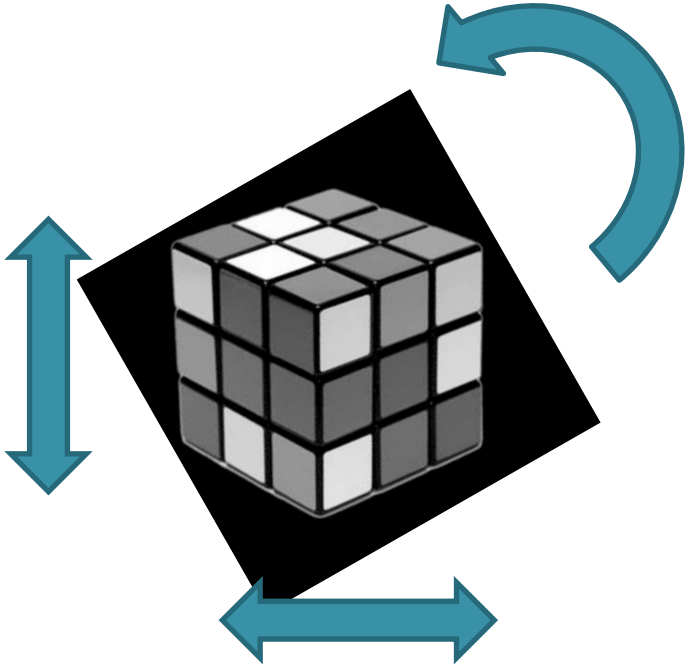
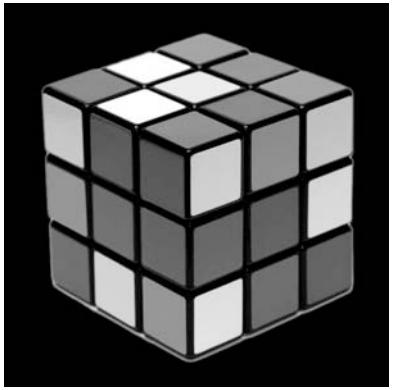
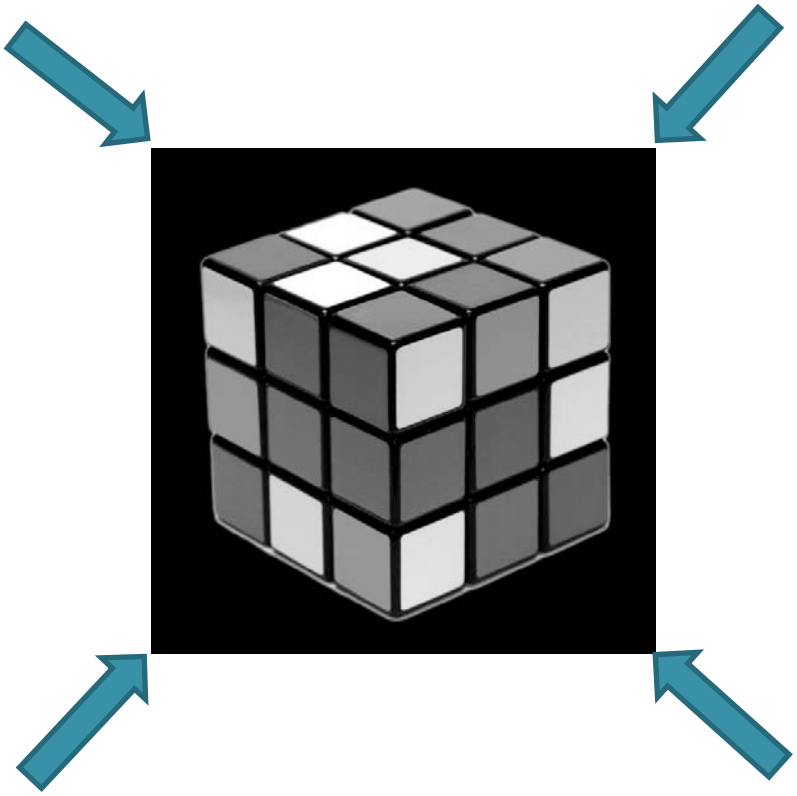




Types of transformations

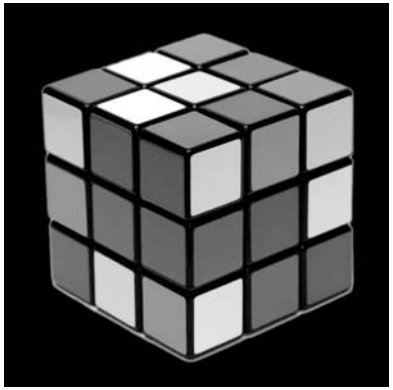
- Nonrigid transformations
  - Scaling
    - Lines and Angles are preserved

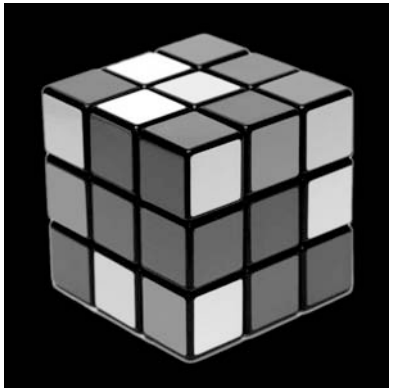




Types of transformations

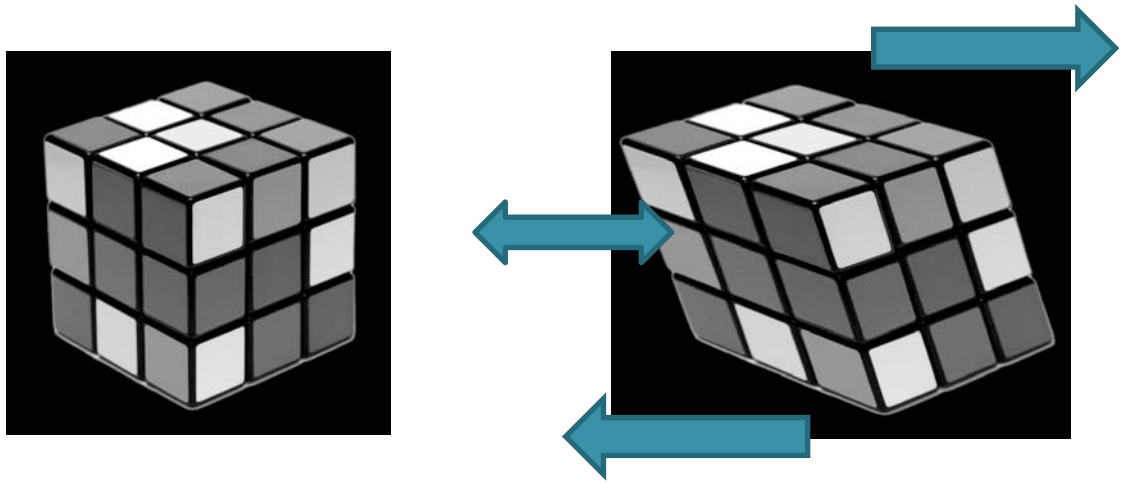
- Nonrigid transformations
  - Scaling
    - Straight lines and Angles are preserved





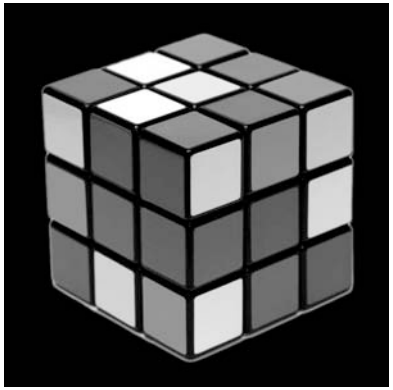
Types of transformations

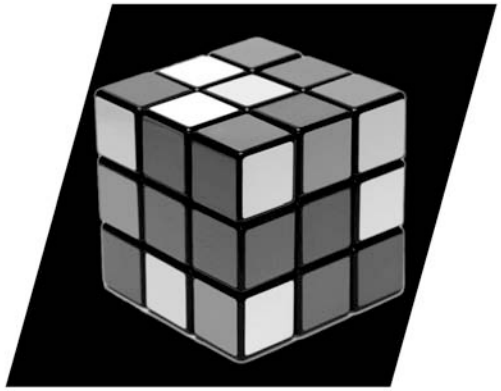
- Nonrigid transformations
  - Affine Transformation
    - Straight lines and parallelity are preserved



Types of transformations

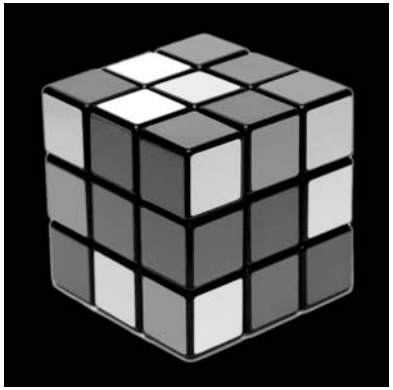
- Nonrigid transformations
  - Affine Transformation
    - Straight lines are preserved





Types of transformations

- Nonrigid transformations
  - Projective Transformation
    - Straight lines are preserved



Types of transformations

- Nonrigid transformations
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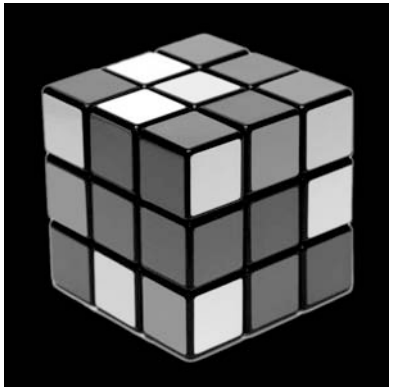
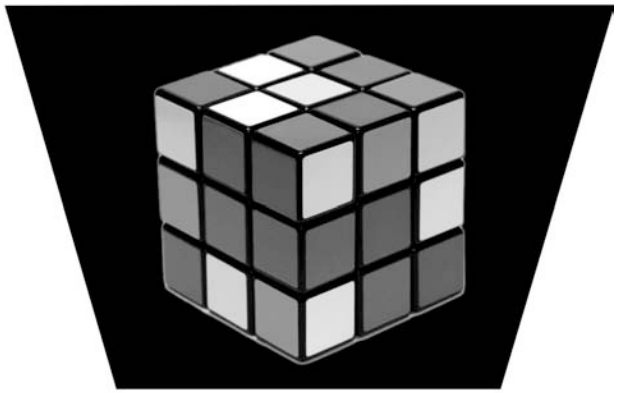
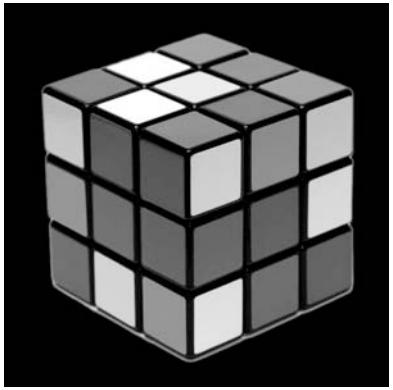
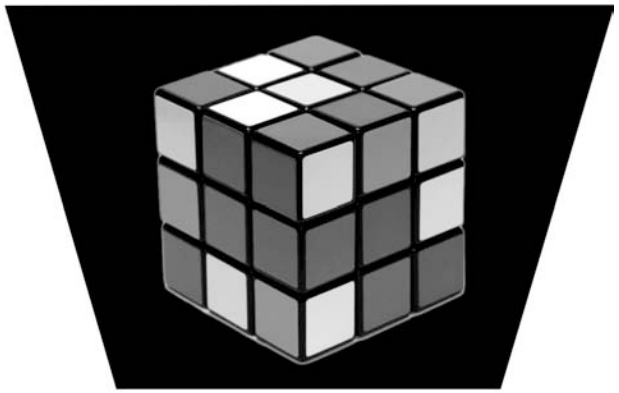




Types of transformations

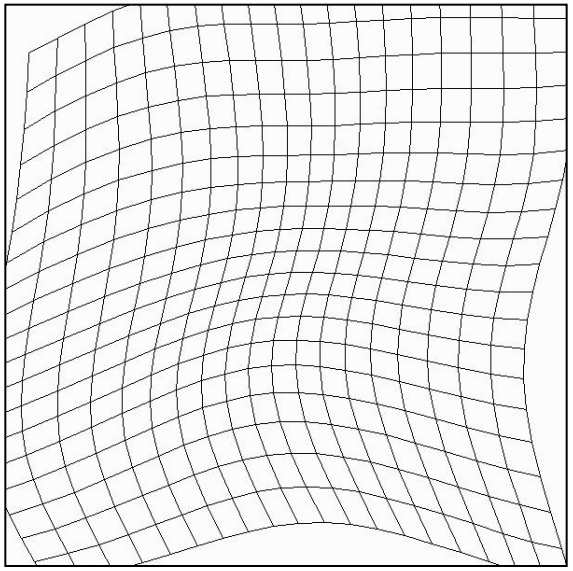
- Nonrigid transformations
  - Piecewise Affine - partas

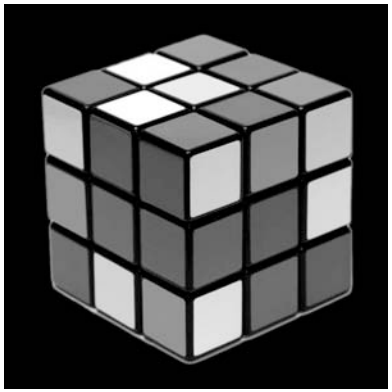


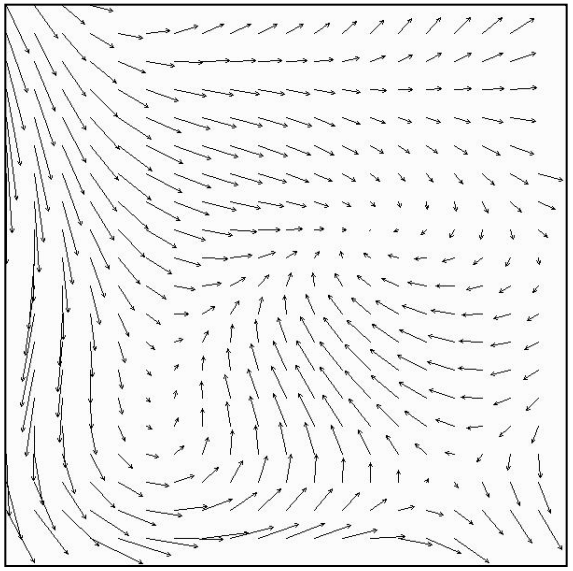


Types of transformations

- Nonrigid transformations
  - Elastic (curved) transformations
    - Spline



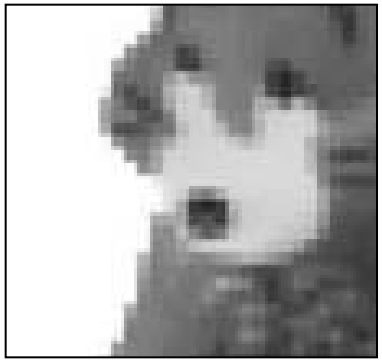




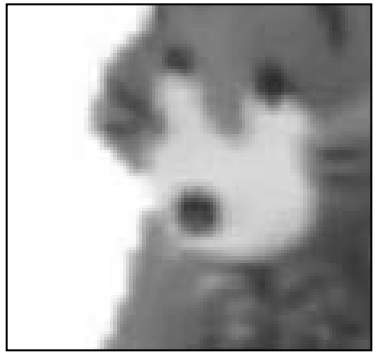
Resampling of registered Image

- Registered Image has to be „rebuilt“ - resampled
- Different interpolation Algorithms give different results
- Tradeoff between accuracy and computational costs

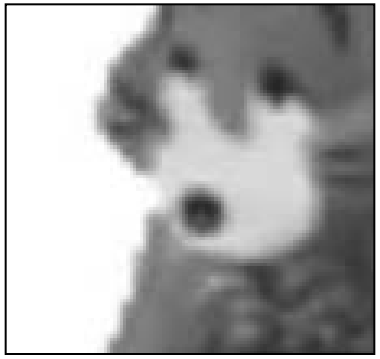
Original



Nearest neighbour



bilinear



bicubic

Methods and Algorithms

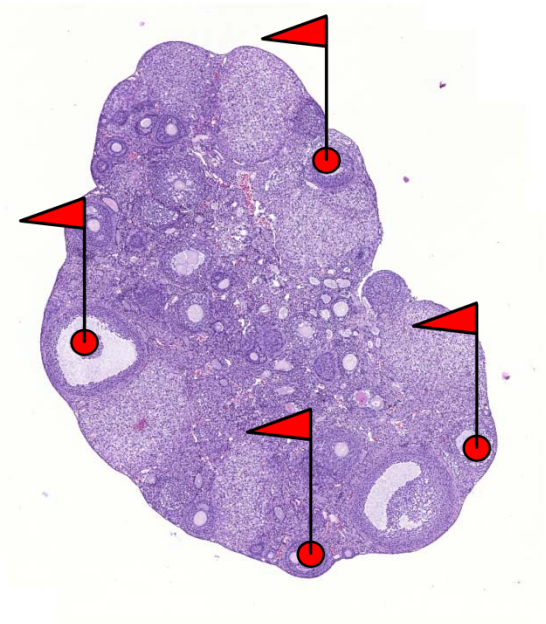
There is a huge variety of registration algorithms

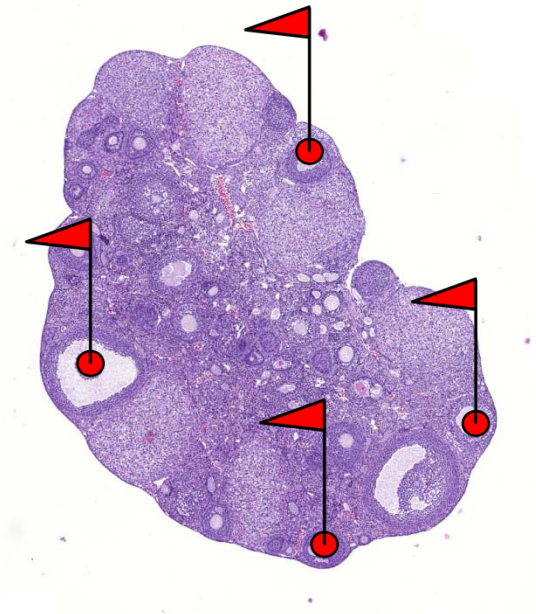
3 important categories are:

- Point based algorithms (Landmarks)
  - Scale Invariant Feature Transform (SIFT)
- Intensity based
  - Mutual information based techniques
- Fourier based

Registration via Landmarks

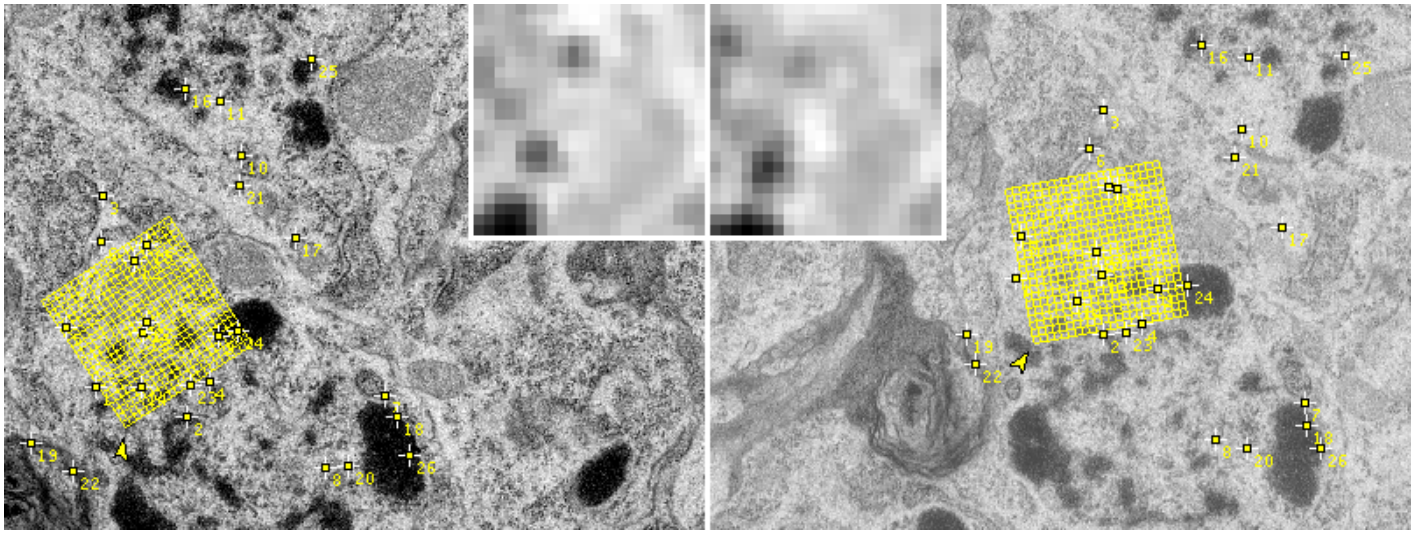
- Fiducial points, distinct features of the image can be located manually or by different detection algorithms
- Can be used as Landmarks aligned by transformation algorithms
- Fiducial points can also be added to a sample (e.g. Beads)





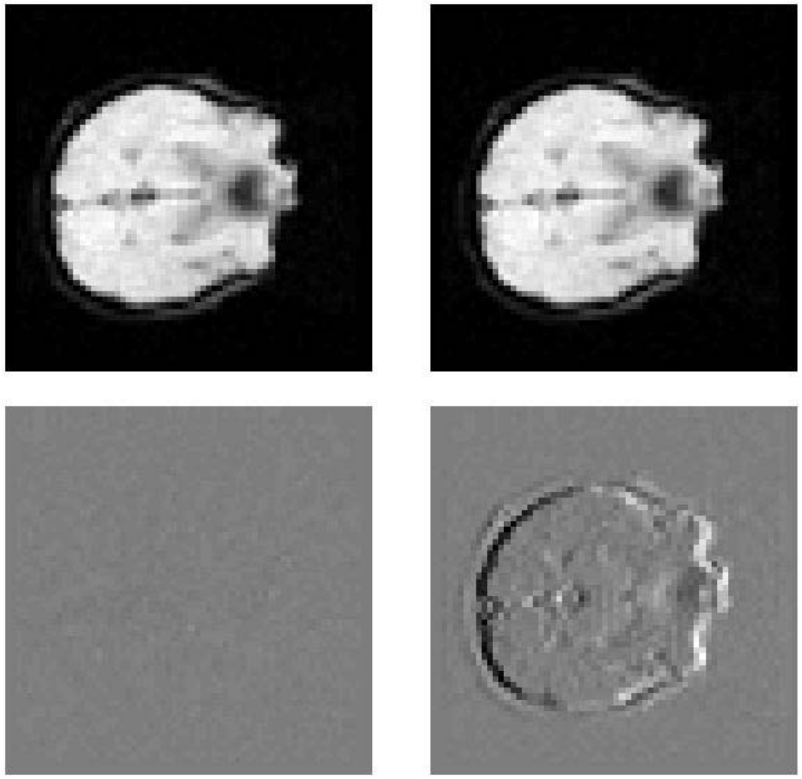
Registration via Landmarks

- SIFT – Scale Invariant Feature Detection
- Automatic detection of fiducial points via distinct patterns in the image



Intensity-based methods

- Mutual information based techniques:
  - The „difference image“ should give the lowest amount of information
  - Through iterative processing one gets closer and closer to the best fit.



aligned one pixel off

Fourier-based methods

- Fourier based correlation
  - Images are transferred to fourier space, rotation is determined, then the „real image“ is rotated by that angle
  - Fast algorithm
  - Only for rigid registrations, Images have to be very similar

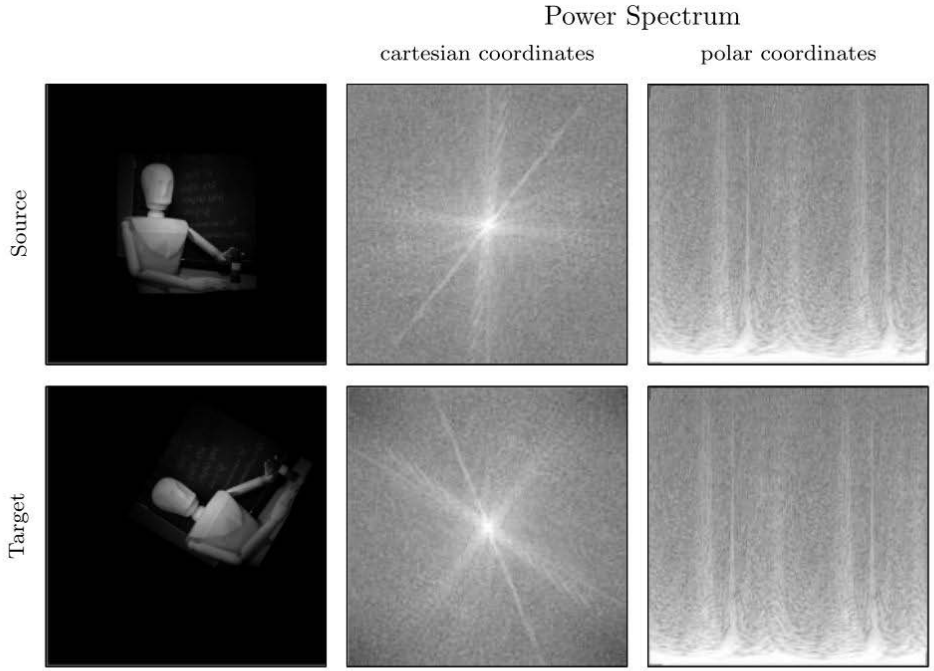
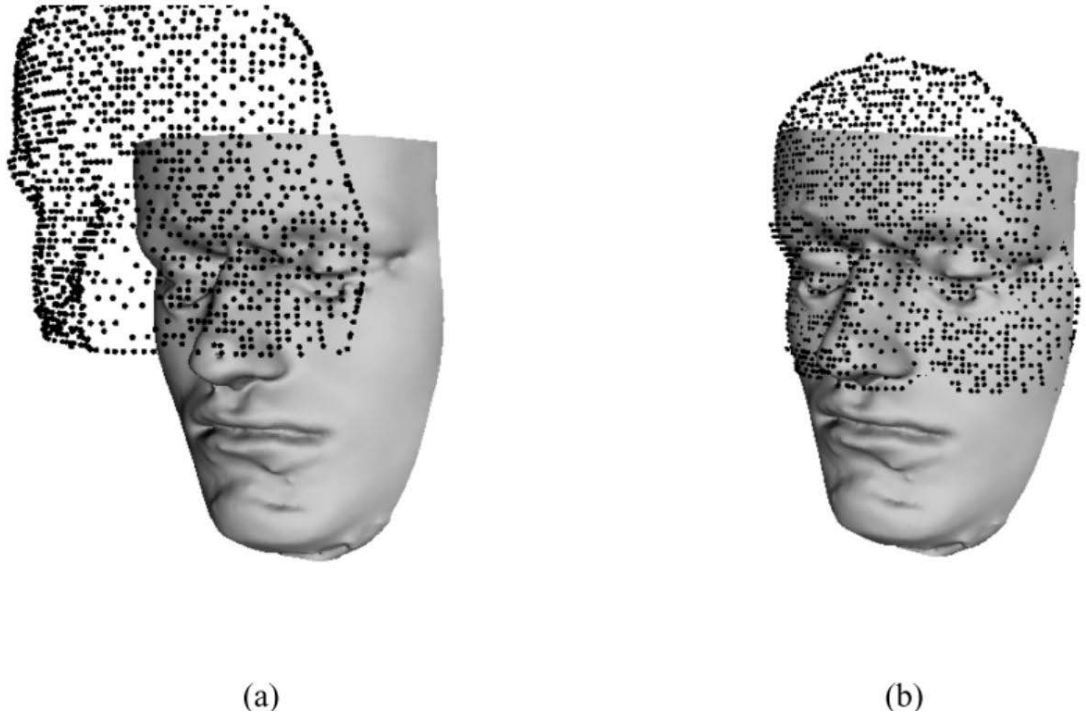


Figure 5. By considering the power spectra, translations vanish. Furthermore, in polar coordinates, rotations become translations.

Image Registration in 3D

- Surface based registration in 3D



(a) (b)

Applications

- Stack alignment (optical or physical sections)
- Different timepoints (growing or moving structures)
- Different viewpoints (e.g. stitching of images)
- Different sources (NMR, CT etc.)
- Scene to model registration
- Rectification

Software

- ImageJ/FIJI
- Bitplane Autoaligner
- Amira

Software

- Bitplane Autoaligner
  + Optical Sections work better
  + Fluorescent Images
  + Same file format as Imaris
  + Automated and manual alignment possible

  - Physical sections – if distorted, folded or torn
  - Brightfield – works better wen inverted
  - Only rigid transformation

Software

- Amira
  + Automatic and manual alignment of 3D – Stacks.
  + Manual setting of Landmarks in 3D
  + Alignment of 3D Data from different sources (e.g. MRI and CT)
  + Also elastic alingment possible

  - Sections – only manual alignment via landmarks
  - Only rigid transformation in 2D

Software

- ImageJ Plugins:
  - bUnwarpJ
  - SIFT registration
  - Stackreg
  - TrakEM2
  - Turboreg

Things to consider

- Stack registration
  - Images have to be in the right order (numbered_filename)
  - Right orientation (no flipped images)
  - Good contrast (filtering might help)
  - Bright on dark often works better (invert images)

- Image data is changed during the alignment and resampling process – Special caution with nonrigid transformations!!!

Sources

- www.wikipedia.org
- http://fiji.sc
- P. Kostelec et al.: Image Registration for MRI
- Barbara Zitova, Jan Flusser: Image registration methods: a survey
- Michal Irani, Shmuel Peleg: Improving Resolution by Image Registration
- David G. Lowe: Distinctive Image Features from Scale-Invariant Keypoints