Medical Image Processing for Diagnostic Applications

Iterative Closest Point Algorithm – Basics

Online Course – Unit 69

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Topics

Registration of ToF and CT Data

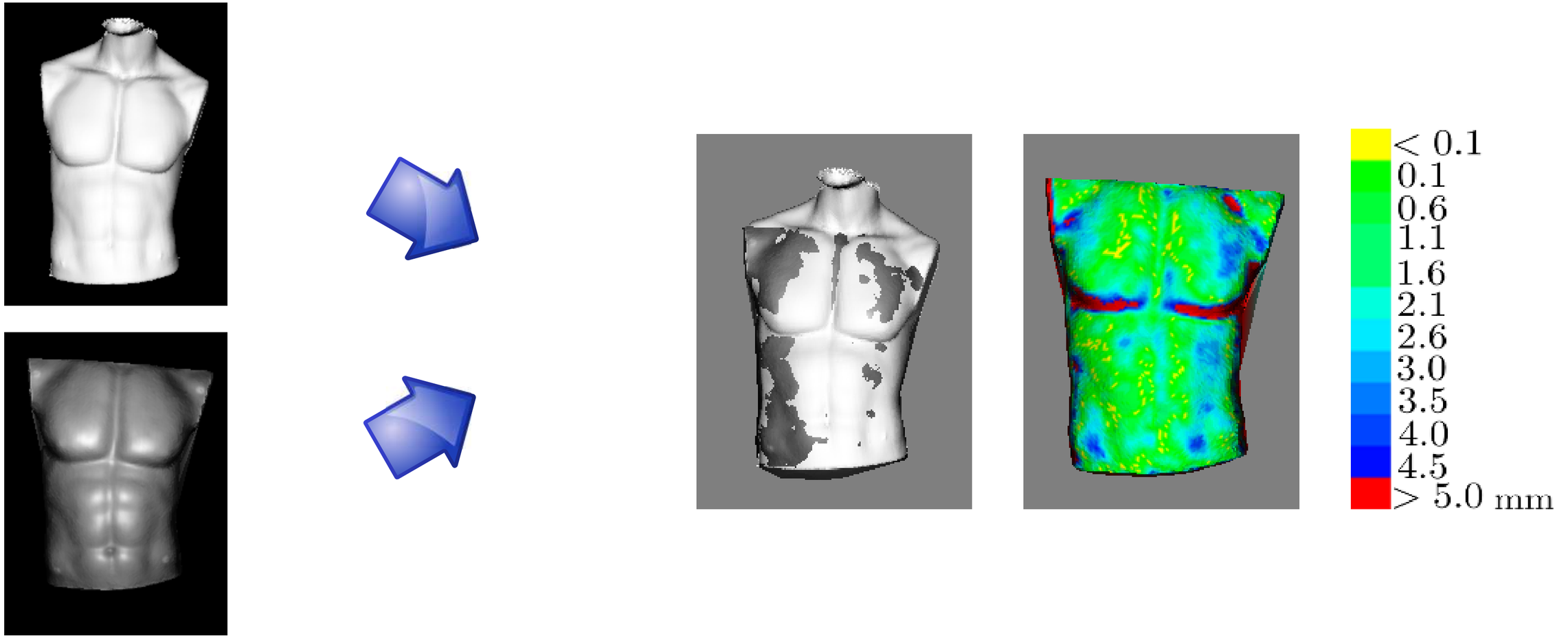
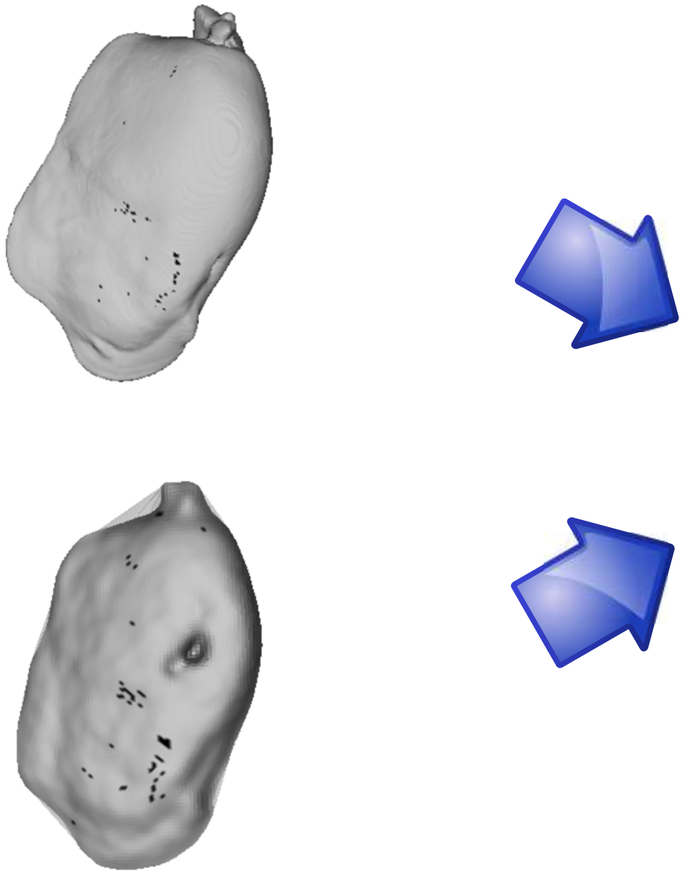
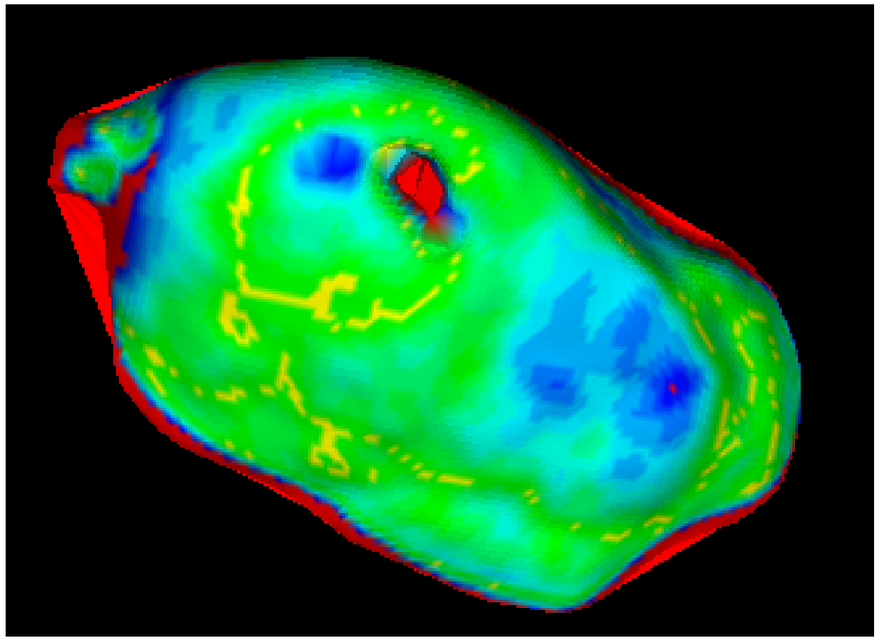


Figure 1: Images courtesy of Kerstin Müller [3]

Registration of ToF and CT Data





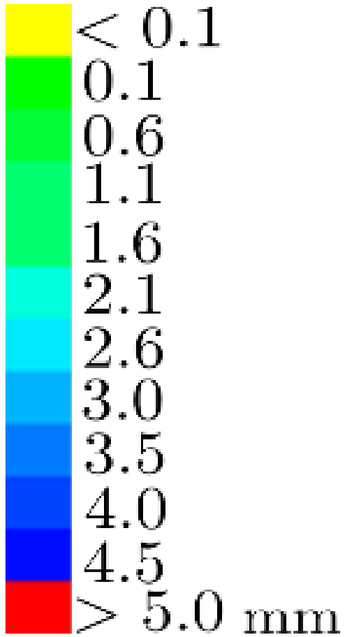


Figure 2: Images courtesy of Kerstin Müller [3]

Registration of Range Images

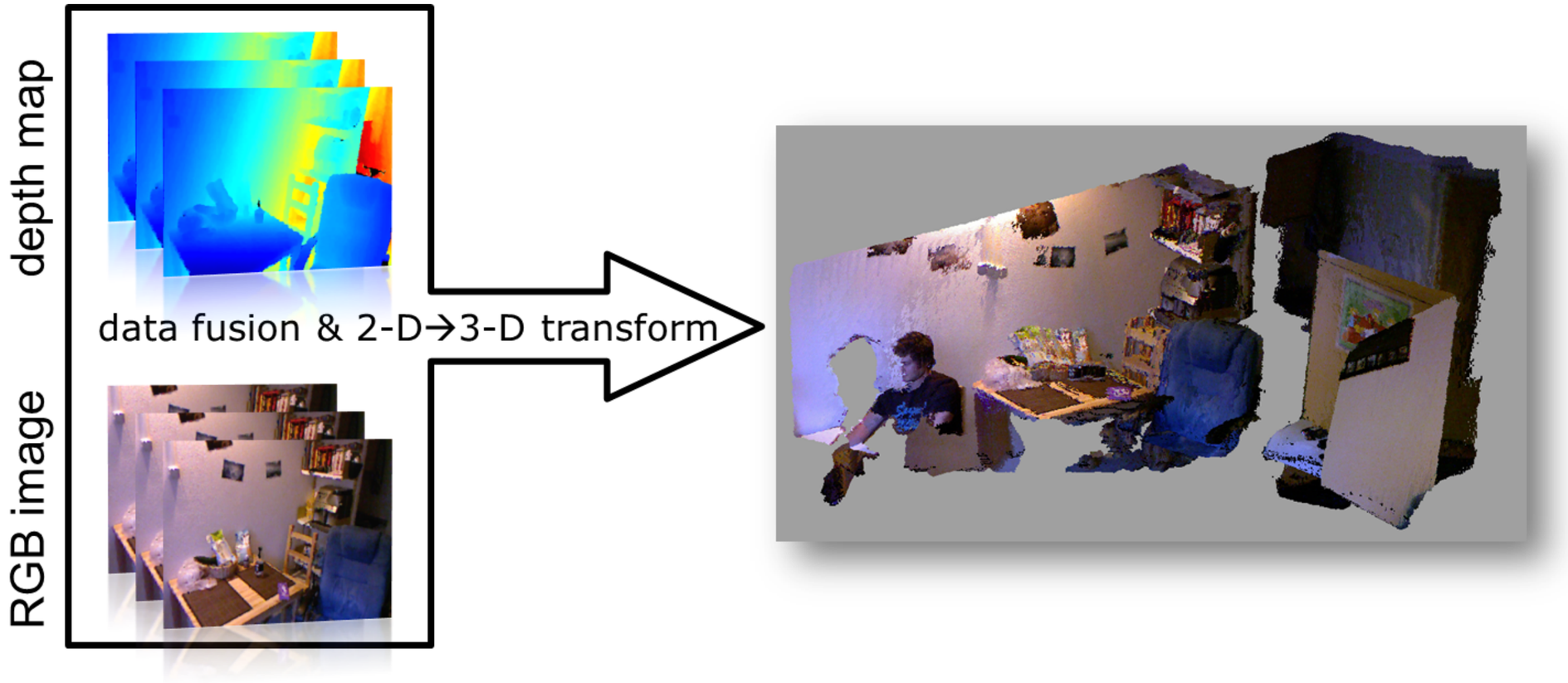


Figure 3: Images courtesy of Felix Lugauer [5]

Problem

- Input: meshes Q, P
- Output: rotation $\boldsymbol{R}$, translation $\mathbf{t}$

$$\hat{Q} = \boldsymbol{R}Q + \mathbf{t}$$
$$\min\left(\text{dist}\left(\hat{Q}, P\right)\right)$$

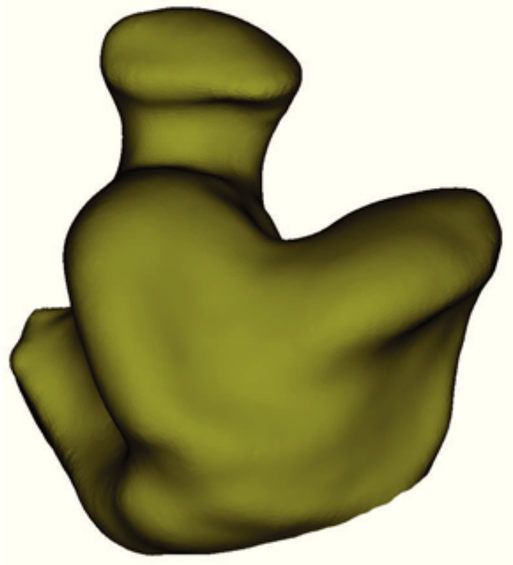


Figure 4: Images courtesy of Konrad Sickel [6]

Problem

- Input: point clouds Q, P
- Output: rotation $\boldsymbol{R}$, translation $\mathbf{t}$

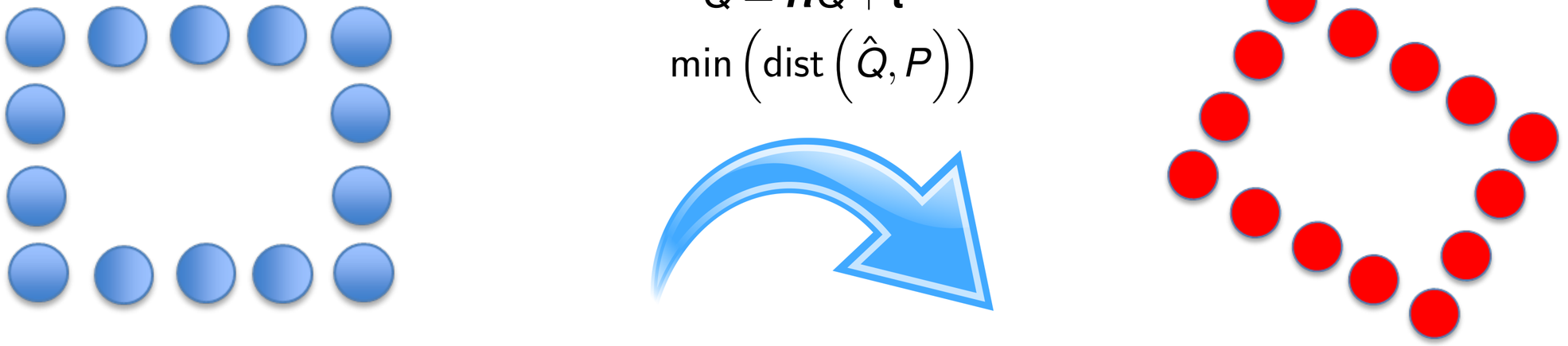


Figure 5: Scheme of a point cloud registration

Problem

- Input: point clouds Q, P
- Output: rotation $\boldsymbol{R}$, translation $\mathbf{t}$

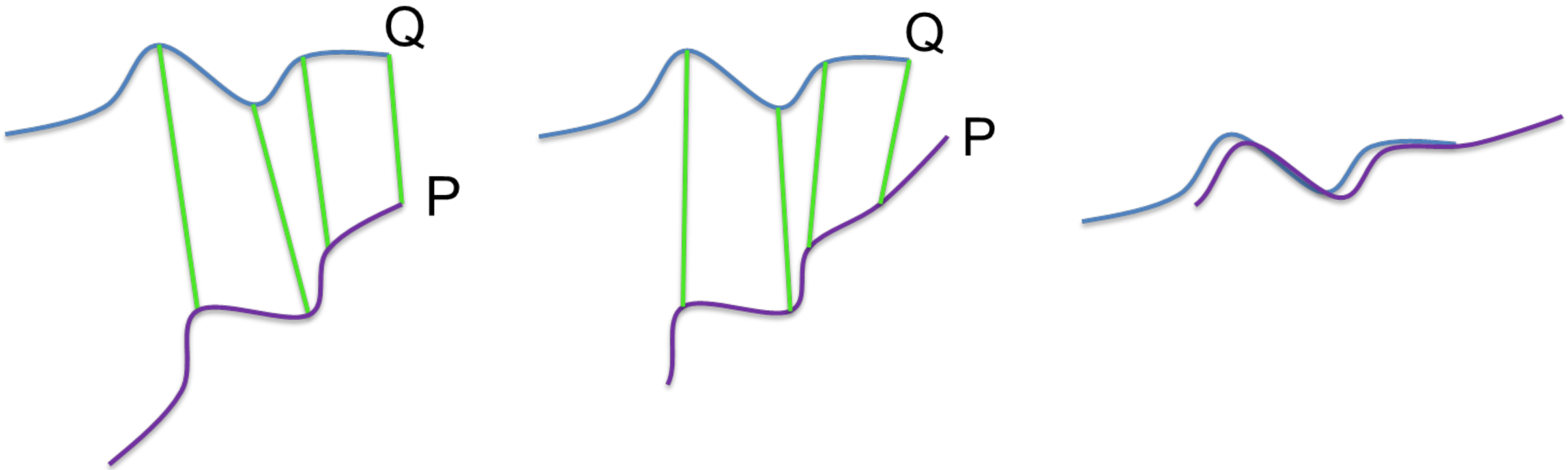
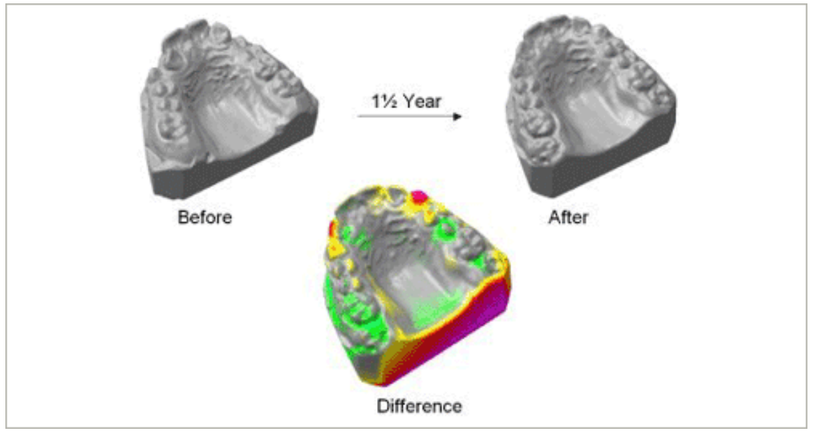


Figure 6: Curve alignment

Basics of Matching

1. Transformations:
   - rigid (rotation, translation)
   - affine (scaling)
   - projective (perspective distortion)
   - elastic (local deformation)

2. Applications of matching:
   - multi-modal (different modalities)
   - temporal (different time points)
   - viewpoint (different perspectives)



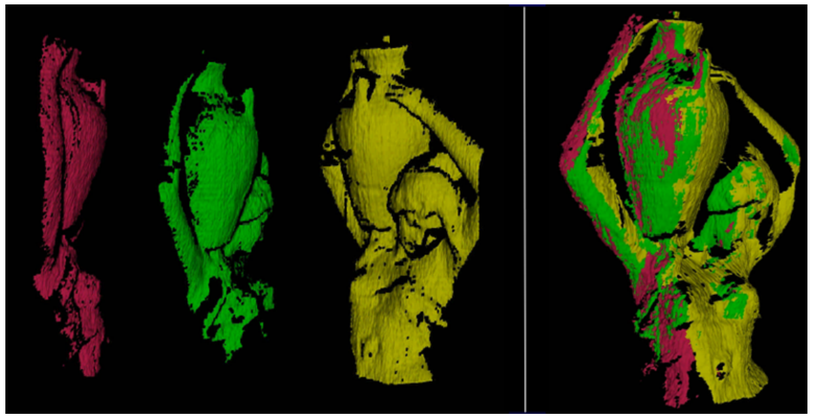


Figure 7: Images courtesy of Wilhelm Nagel [4]

Original Work

ICP was originally applied to scan-matching tasks in the early 1990s.

There were three independently published papers:

- Besl and McKay [1]:
  registration of point clouds using point-to-point error metric,
- Chen and Medioni [2]:
  working with range data for object modeling and point-to-plane error metric,
- Zhang [7]:
  robust method of outlier rejection in the selection phase of the algorithm.

Geometric Data

ICP can be used with the following representations of geometric data [1]:

- point sets,
- line segment sets (polylines),
- implicit curves,
- parametric curves,
- triangle sets (faceted surfaces),
- implicit surfaces,
- parametric surfaces.

Basic Concept

ICP computes the registration by iterating the following steps [6]:

1. computation of correspondences between two point clouds,
2. computation of a transformation which minimizes the distance between the corresponding points.

Topics

Take Home Messages

- There are a lot of applications for registration of point clouds, and simple concepts for matching are desired.
- ICP supports a lot of different geometric data.
- ICP is an iterative algorithm that is based on the minimal distance of points at each iteration step.

Further Readings

[1] Paul J. Besl and Neil D. McKay. “A Method for Registration of 3-D Shapes”. In: *IEEE Transactions on Pattern Analysis and Machine Intelligence* 14.2 (Feb. 1992), pp. 239–256. DOI: 10.1109/34.121791.

[2] Yang Chen and Gérard Medioni. “Object Modeling by Registration of Multiple Range Images”. In: *Proceedings of the 1991 IEEE International Conference on Robotics and Automation, Sacramento, California*. IEEE, Apr. 1991, pp. 2724–2729. DOI: 10.1109/ROBOT.1991.132043.

[3] Kerstin Müller. “Multi-modal Organ Surface Registration using Time-of-Flight Imaging”. Diploma Thesis. Erlangen: Pattern Recognition Lab, Friedrich-Alexander-Universität Erlangen-Nürnberg, Sept. 2010.

[4] Wilhelm Nagel. “Matchen und Mergen von 3D Punktwolken”. Seminararbeit, Universität Karlsruhe. 2002/2003.

[5] Dominik Neumann et al. “Real-time RGB-D Mapping and 3-D Modeling on the GPU using the Random Ball Cover Data Structure”. In: *2011 IEEE International Conference on Computer Vision Workshops (ICCV Workshops)*. IEEE, Nov. 2011, pp. 1161–1167. DOI: 10.1109/ICCVW.2011.6130381.

[6] Konrad Sickel. “Computerized Automatic Modeling of Medical Prostheses”. PhD Thesis. Erlangen: Pattern Recognition Lab, Friedrich-Alexander-Universität Erlangen-Nürnberg, Apr. 2013.

[7] Zhengyou Zhang. “Iterative Point Matching for Registration of Free-form Curves and Surfaces”. In: *International Journal of Computer Vision* 13.2 (Oct. 1994), pp. 119–152. DOI: 10.1007/BF01427149.