Medical Image Processing for Interventional Applications

3-D Ultrasound

Online Course – Unit 38

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Topics

3-D Ultrasound

Interpolation Techniques

Summary

- Take Home Messages
- Further Readings

3-D Reconstruction

- 3-D reconstruction requires computation of relative positions and orientations of acquired 2-D ultrasound images.
- 3-D volume results from interpolation of voxel values.
- Adjustment of 2-D images:
  - Feature-based reconstruction
  - Intensity-based reconstruction

3-D Ultrasound: Principle

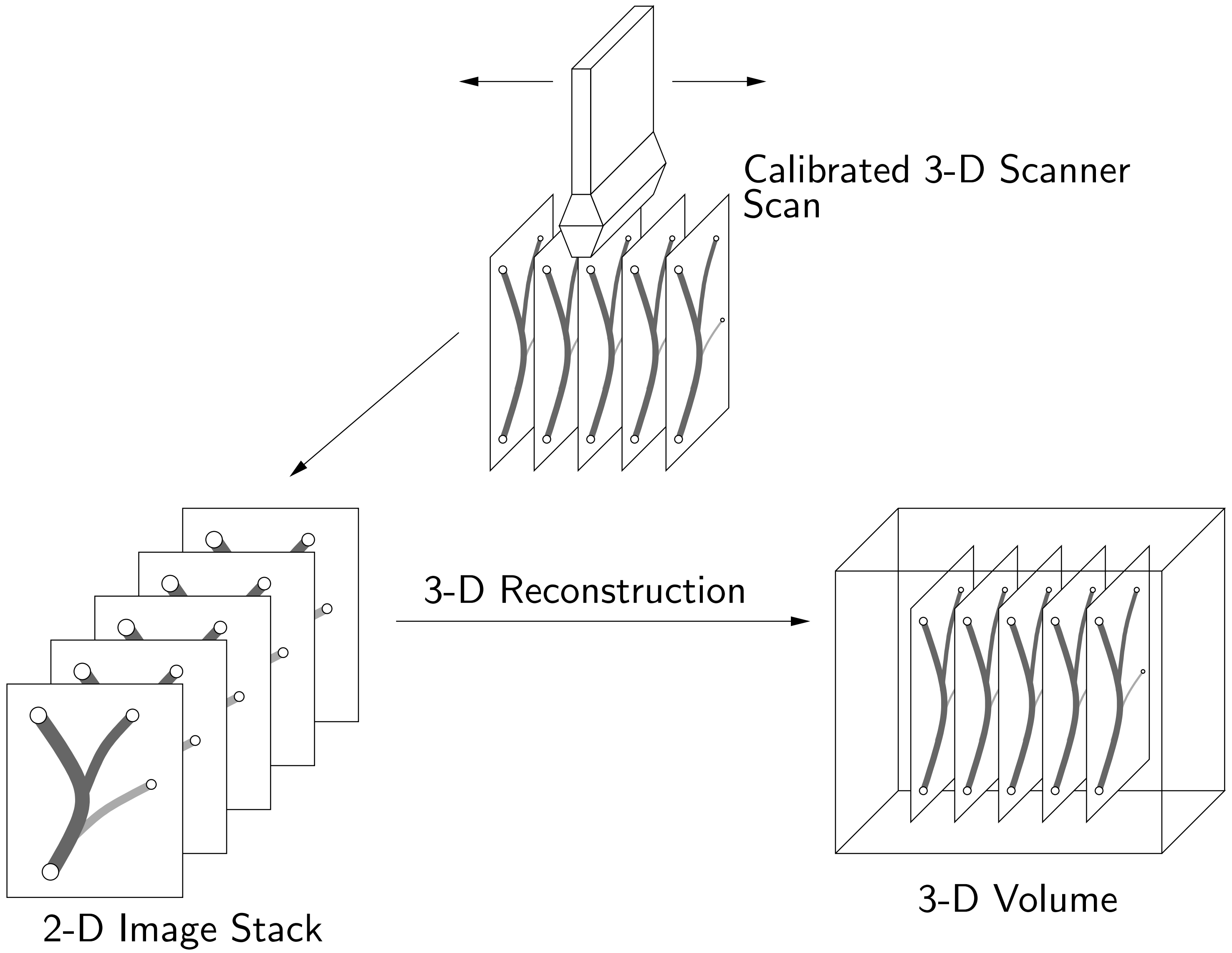

Figure 1: Ideal 3-D ultrasound acquisition

3-D Ultrasound: Principle

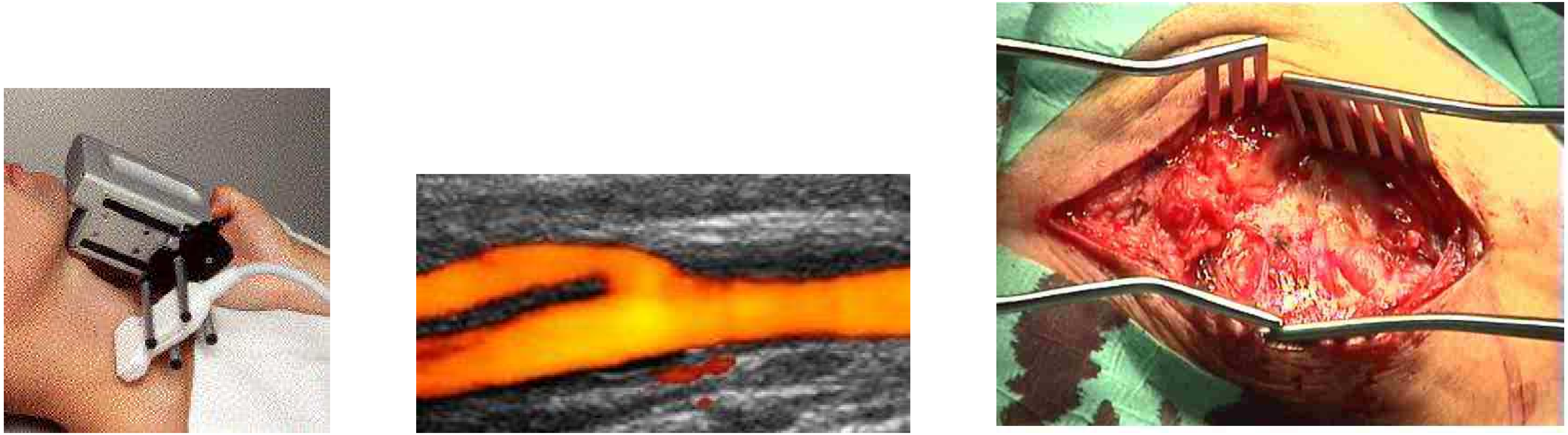

Figure 2: Special device for 3-D ultrasound acquisition (left) (image courtesy of A. Fenster & D. B. Downey), ultrasound image of carotis bifurcation (middle), surgery of carotis (right) (image courtesy of Schön Klinik Vogtareuth)

3-D Ultrasound: Principle

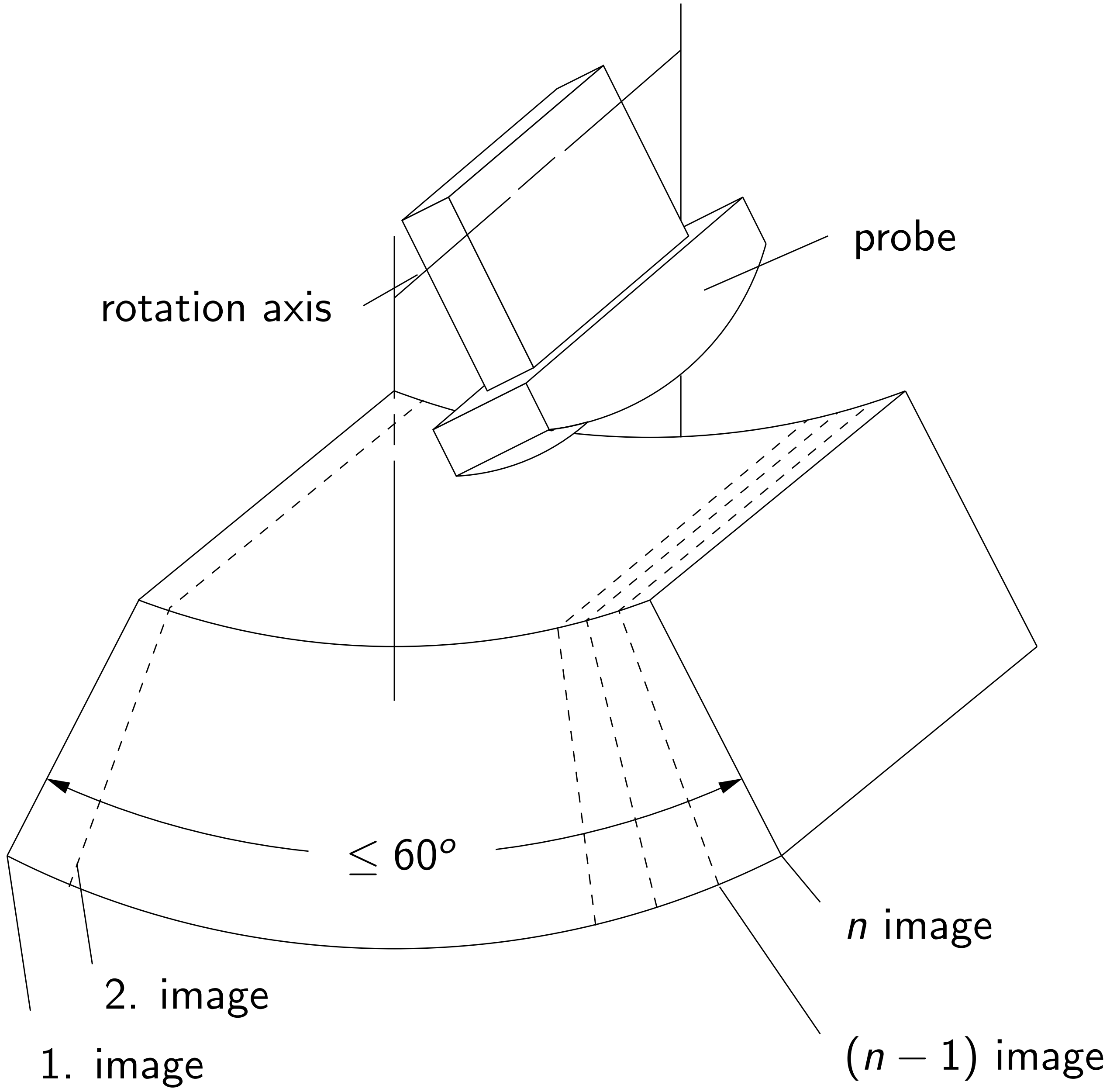

Figure 3: 3-D ultrasound acquisition

3-D Ultrasound: Principle

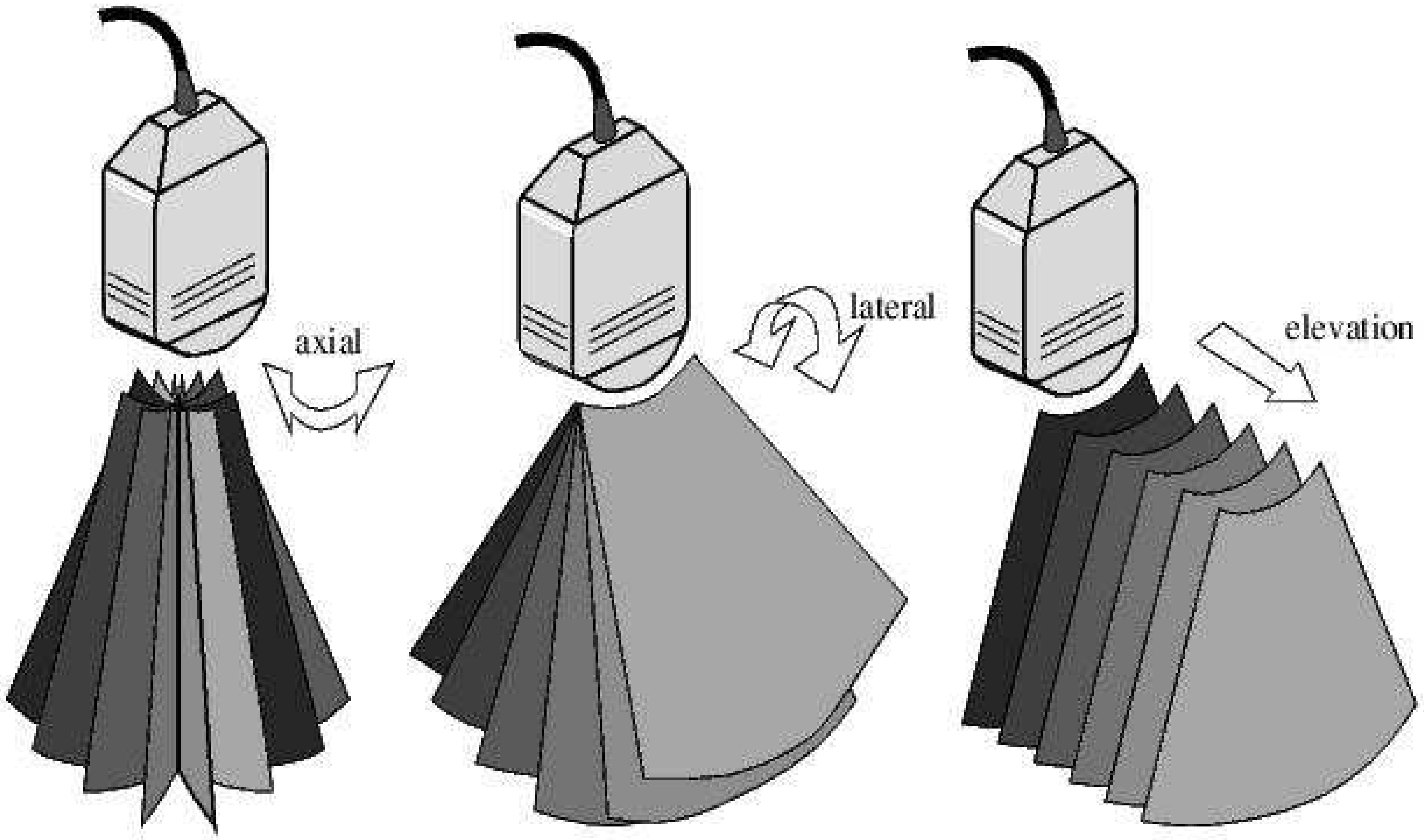

Figure 4: Mechanical sweep motion for 3-D US acquisition

3-D Ultrasound: Principle

Figure 5: Mechanical motion of the probe by a rotation device (left), a sweep device (middle), or a pullback device (right) (TOMTEC, Munich)

3-D Ultrasound: Principle

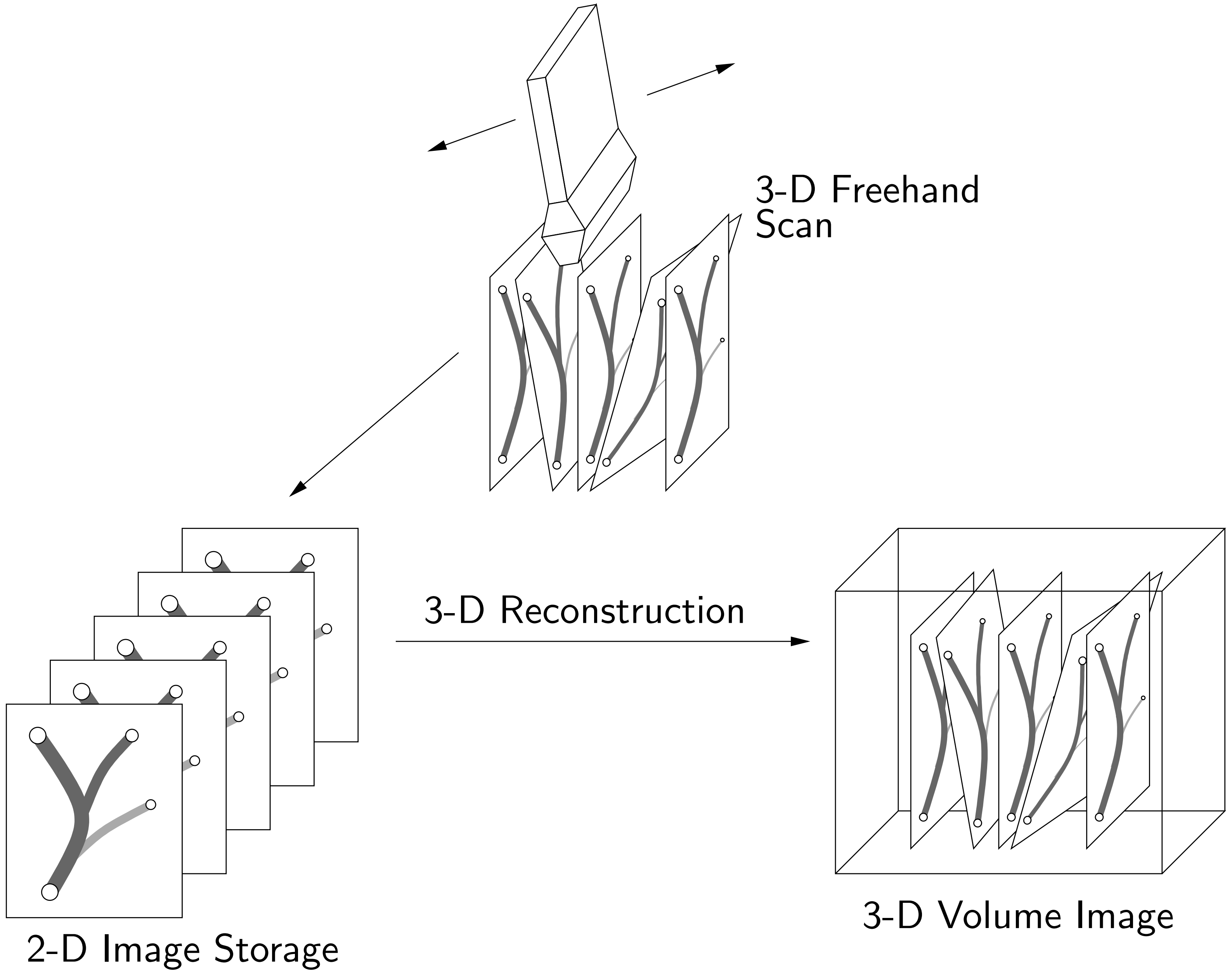

Figure 6: Freehand ultrasound 3-D acquisition

3-D Ultrasound: Principle

Figure 7: Markers for automatic pose estimation of the probe (left), stereo camera system (right)

Exercise: Describe an algorithm that computes the rotation and translation parameters between two different positions of the probe (use fundamental and essential matrix).

ECG Triggered US Reconstruction

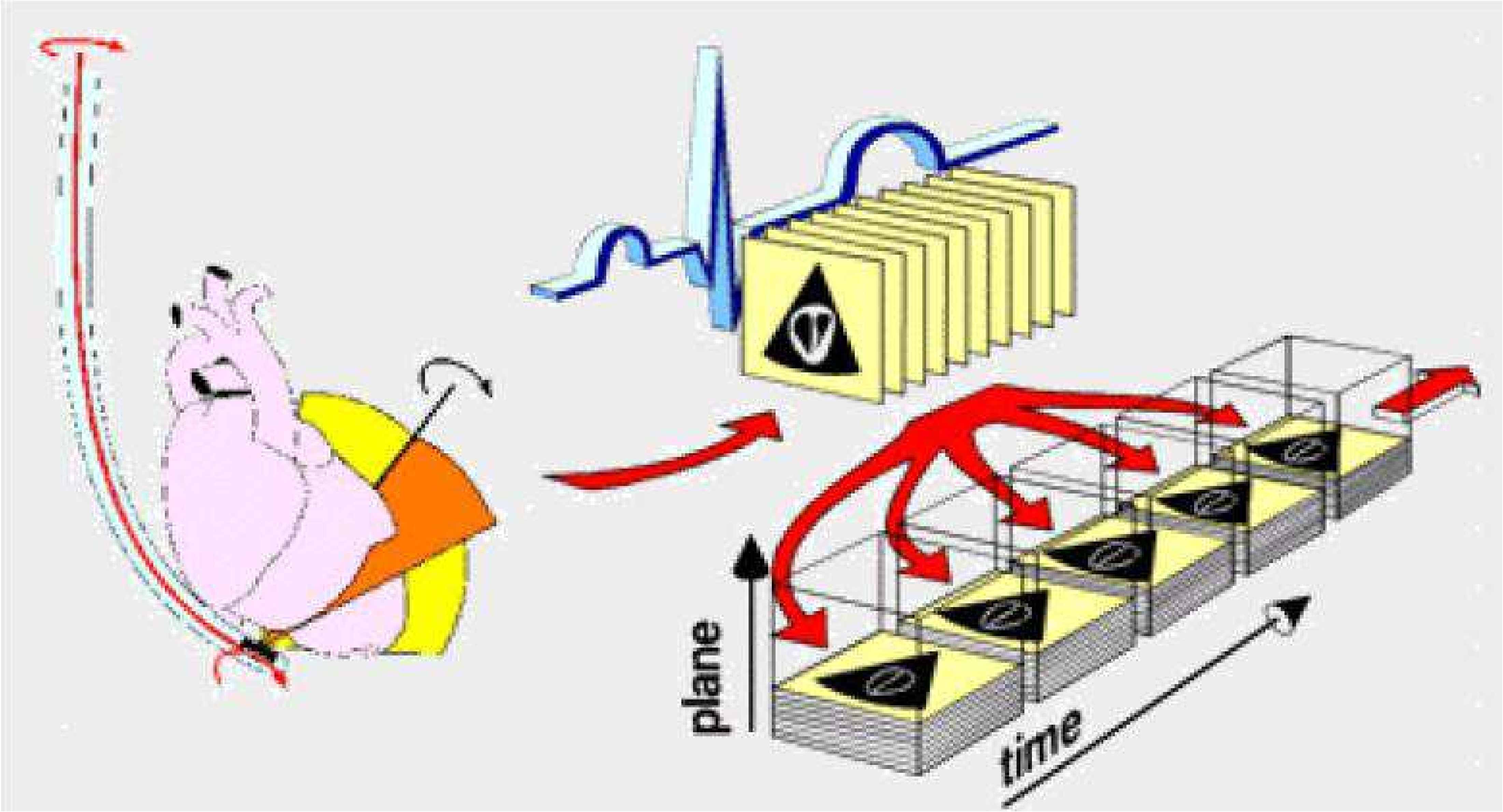

Figure 8: ECG triggered US reconstruction (TOMTEC, Munich)

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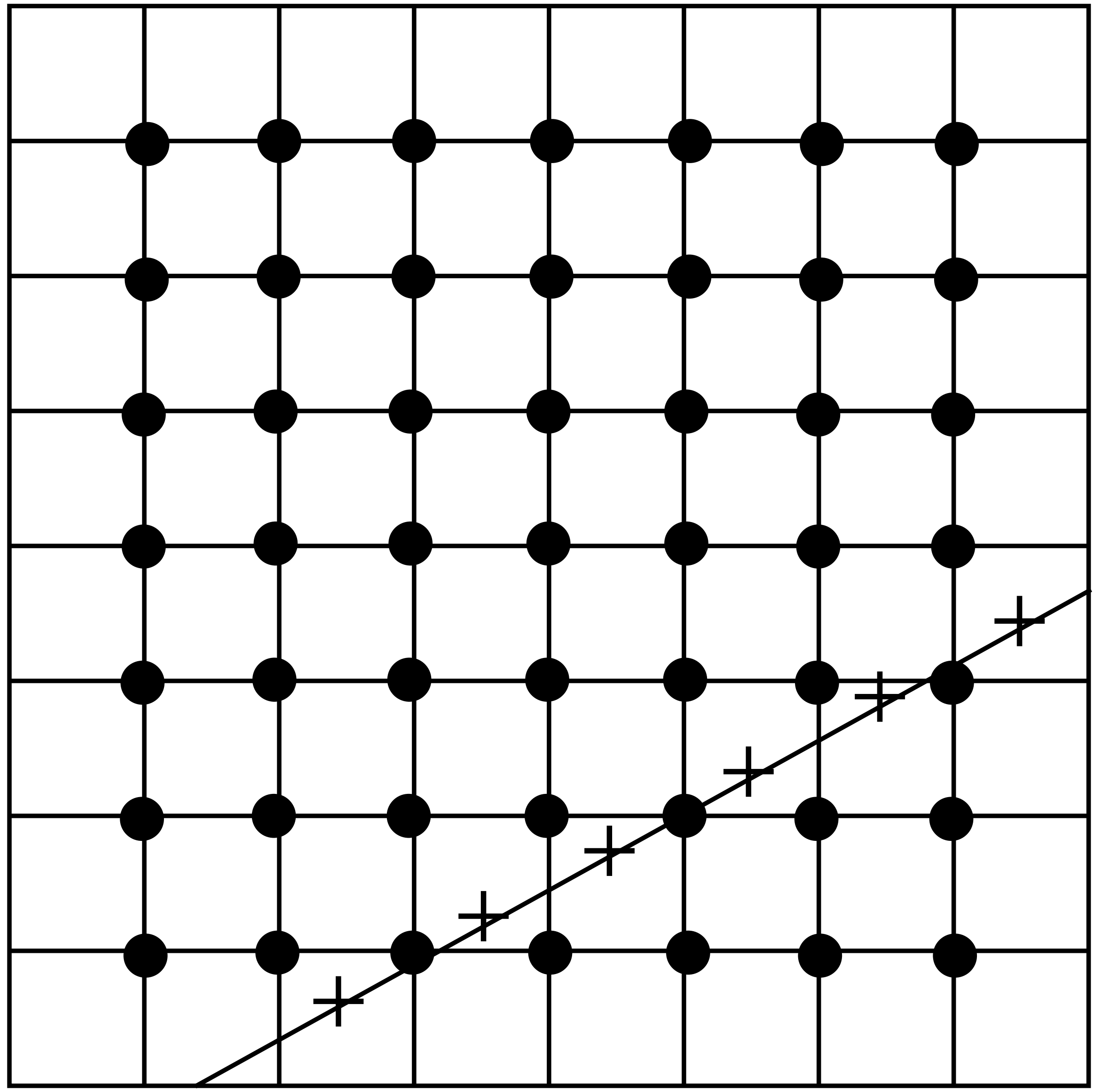

Figure 9: Interpolation

Interpolation Techniques

Voxel nearest neighbor:

- Assign voxel to nearest pixel.
- No parameterization is required.
- Avoid gaps in the reconstruction.

Interpolation Techniques

Nearest neighbor interpolation:

- Run through all pixels.
- Fill the nearest voxel with the intensity value.
- Multiple contributions are averaged or use maximum value alternatively.
- Gap filling is done in a second step.

Interpolation Techniques

Distance weighted interpolation:

- Sampling is done voxel by voxel.
- Voxel values are assigned the averaged sum of nearby voxels.
- For example, consider a spherical neighborhood centered around each voxel.

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Take Home Messages

- There are several ways to acquire US data for 3-D reconstruction, some of them even involve freehand acquisition.
- Implementing 3-D ultrasound reconstruction requires interpolation methods, where there is also a variety of methods to choose from (differing in runtime and accuracy).

Further Readings

- Carlo Tomasi and Takeo Kanade. "Shape and Motion from Image Streams Under Orthography: A Factorization Method". In: *International Journal of Computer Vision* 9.2 (Nov. 1992), pp. 137–154. DOI: 10.1007/BF00129684
- C. J. Poelman and T. Kanade. "A Paraperspective Factorization Method for Shape and Motion Recovery". In: *IEEE Transactions on Pattern Analysis and Machine Intelligence* 19.3 (Mar. 1997), pp. 206–218. DOI: 10.1109/34.584098
- Mei Han and Takeo Kanade. "A Perspective Factorization Method for Euclidean Reconstruction with Uncalibrated Cameras". In: *The Journal of Visualization and Computer Animation* 13.4 (2002), pp. 211–223. DOI: 10.1002/vis.290
- Peter Sturm and Bill Triggs. "A Factorization Based Algorithm for Multi-Image Projective Structure and Motion". In: *Computer Vision — ECCV '96: 4th European Conference on Computer Vision Cambridge, UK, April 15–18, 1996 Proceedings Volume II*. ed. by Bernard Buxton and Roberto Cipolla. Vol. 1065. Lecture Notes in Computer Science. Berlin, Heidelberg: Springer Berlin Heidelberg, 1996, pp. 709–720. DOI: 10.1007/3-540-61123-1_183