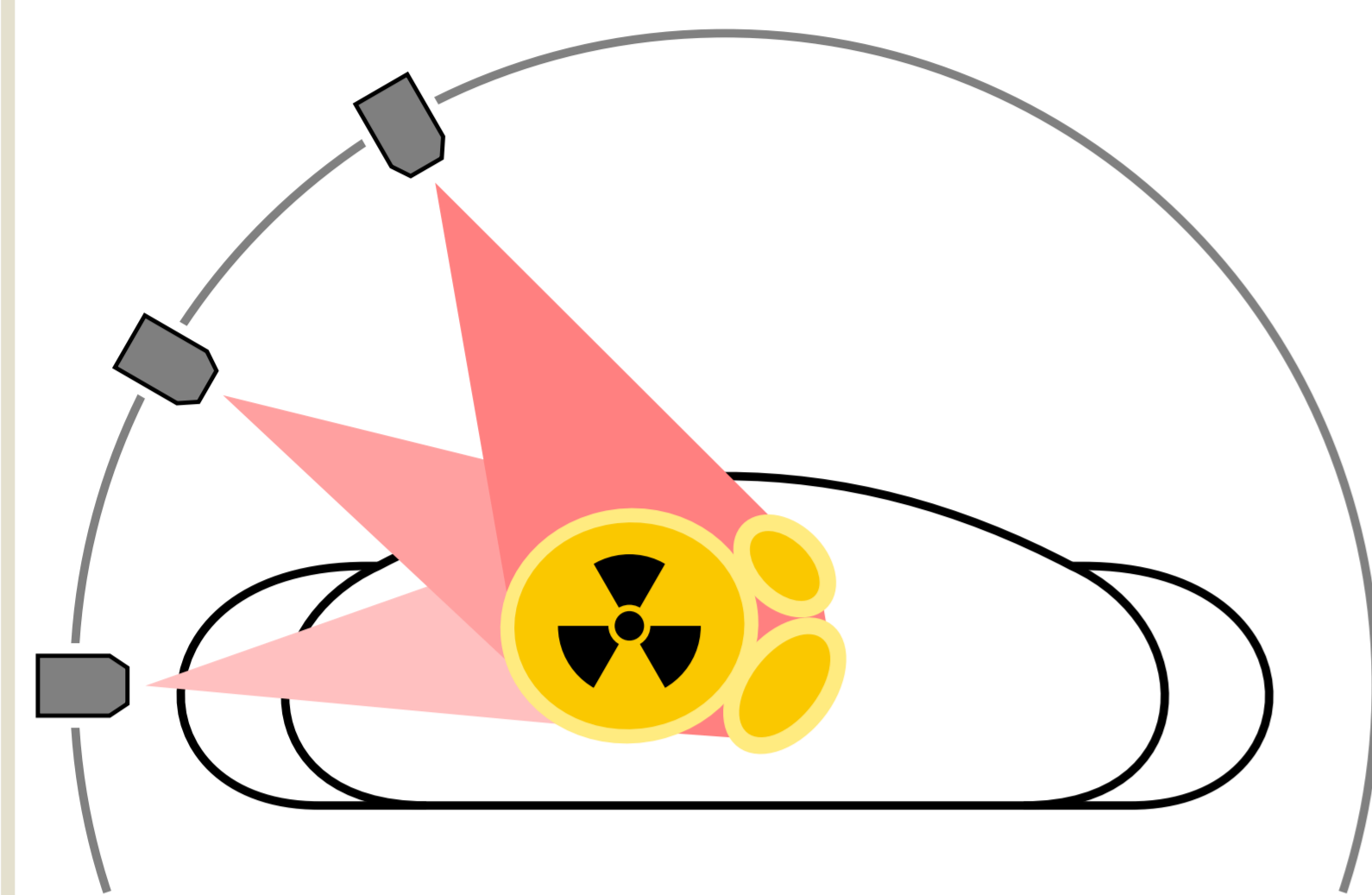


Optimization of Acquisition Geometry for Intra-operative Tomographic Imaging

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SPECT (Radio-tracer marks cancer tissue)



- ▶ Completeness for reconstruction by design
- ▶ Bulky device, long duration of measurement

Freehand SPECT



Optical Tracking

Hand-held gamma detector

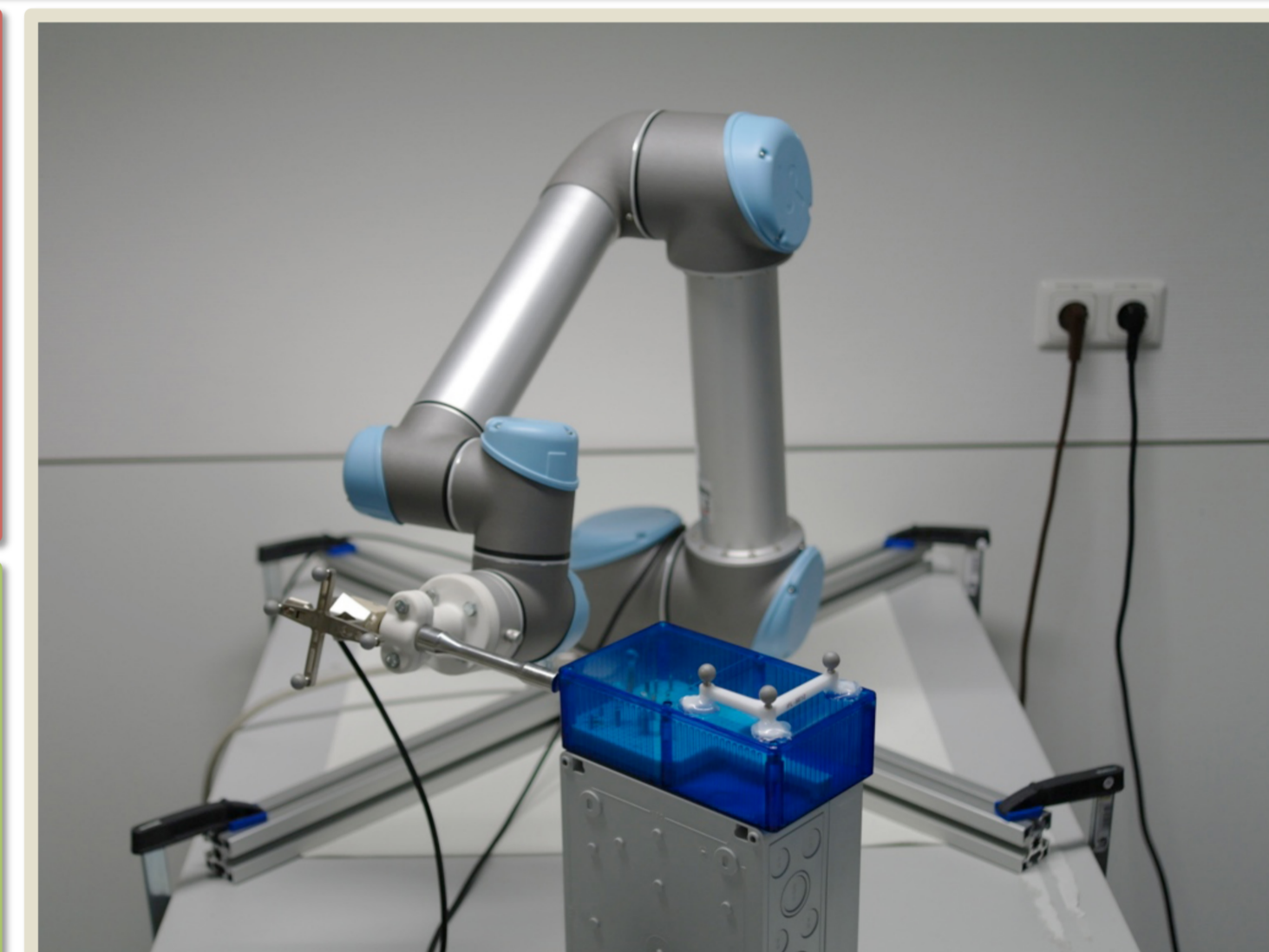
- ▶ Quality depends on operator's experience
- ▶ **Intra-operative use**, fast localized imaging

Problem Statement

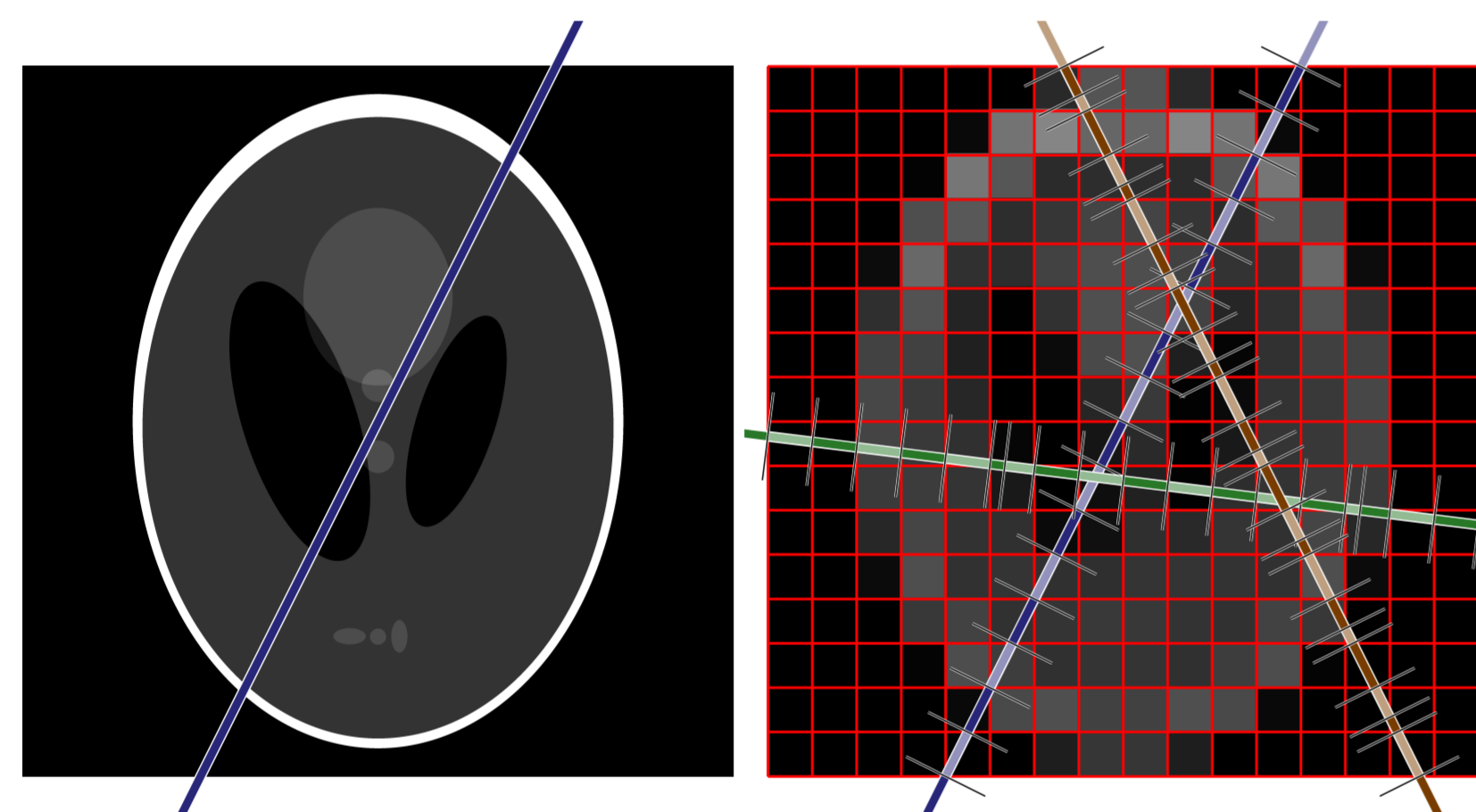
- ▶ Characterize trajectories leading to good tomographic reconstructions
- ▶ Guide a robot along such a path in real-time

Contributions

- ▶ Use numerical condition of linear reconstruction system



Algebraic Reconstruction



$$M_j : (\Omega \rightarrow \mathbb{R}) \rightarrow \mathbb{R} \quad m_j = \langle a_j^T, x \rangle$$

$$m_j = \int_{L_j} f(x) dx$$

$$= \mathcal{M}_j(f)$$

$$\approx \mathcal{M}_j(\sum_i x_i \cdot b_i)$$

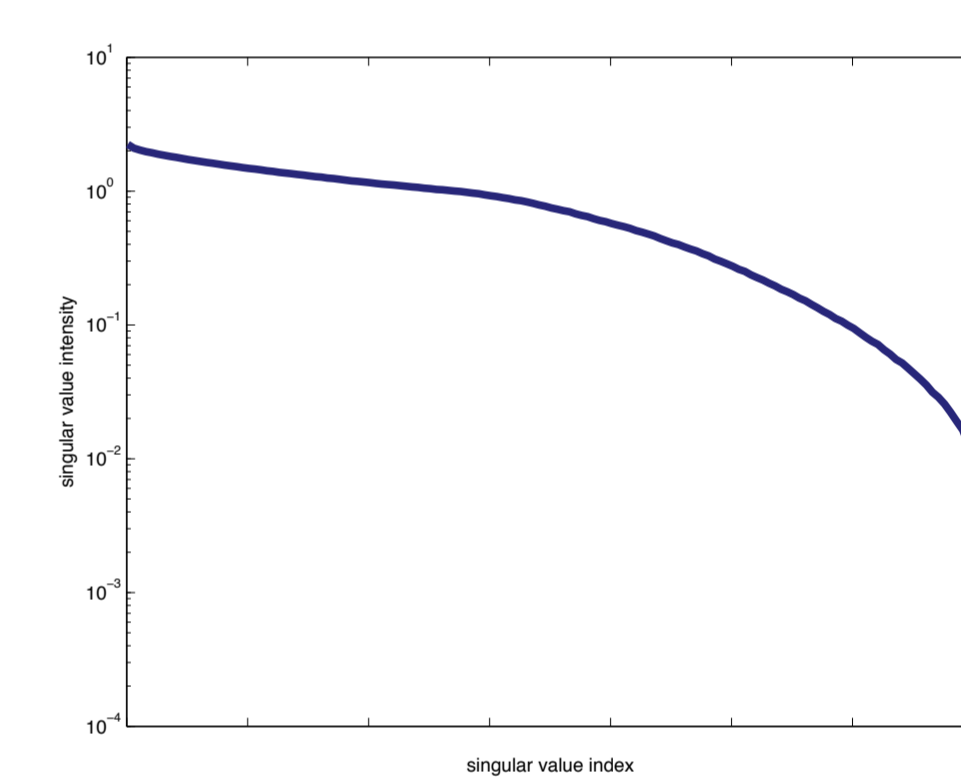
$$= \sum_i x_i \cdot \underbrace{\mathcal{M}_j(b_i)}_{=: a_{ji}}$$

$$m = \begin{pmatrix} - a_1 - \\ - a_2 - \\ - a_3 - \\ \vdots \end{pmatrix} x = A \cdot x$$

Singular Value Spectrum

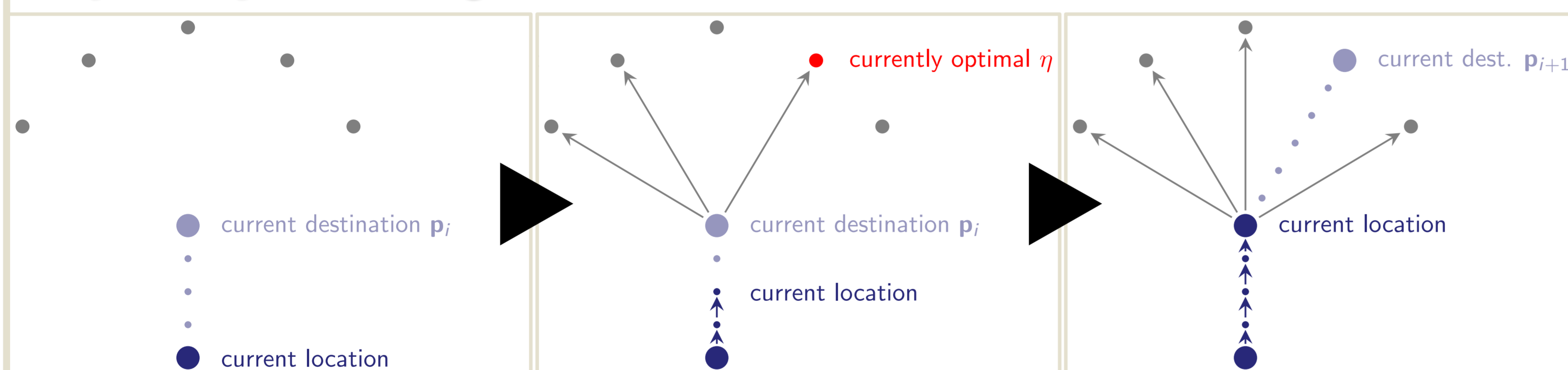
$$A = U \begin{pmatrix} \sigma_1 & & & \\ & \sigma_2 & & \\ & & \ddots & \\ & & & \sigma_S \end{pmatrix} V^T$$

$$\eta(A) = \sum_i \sigma_i$$



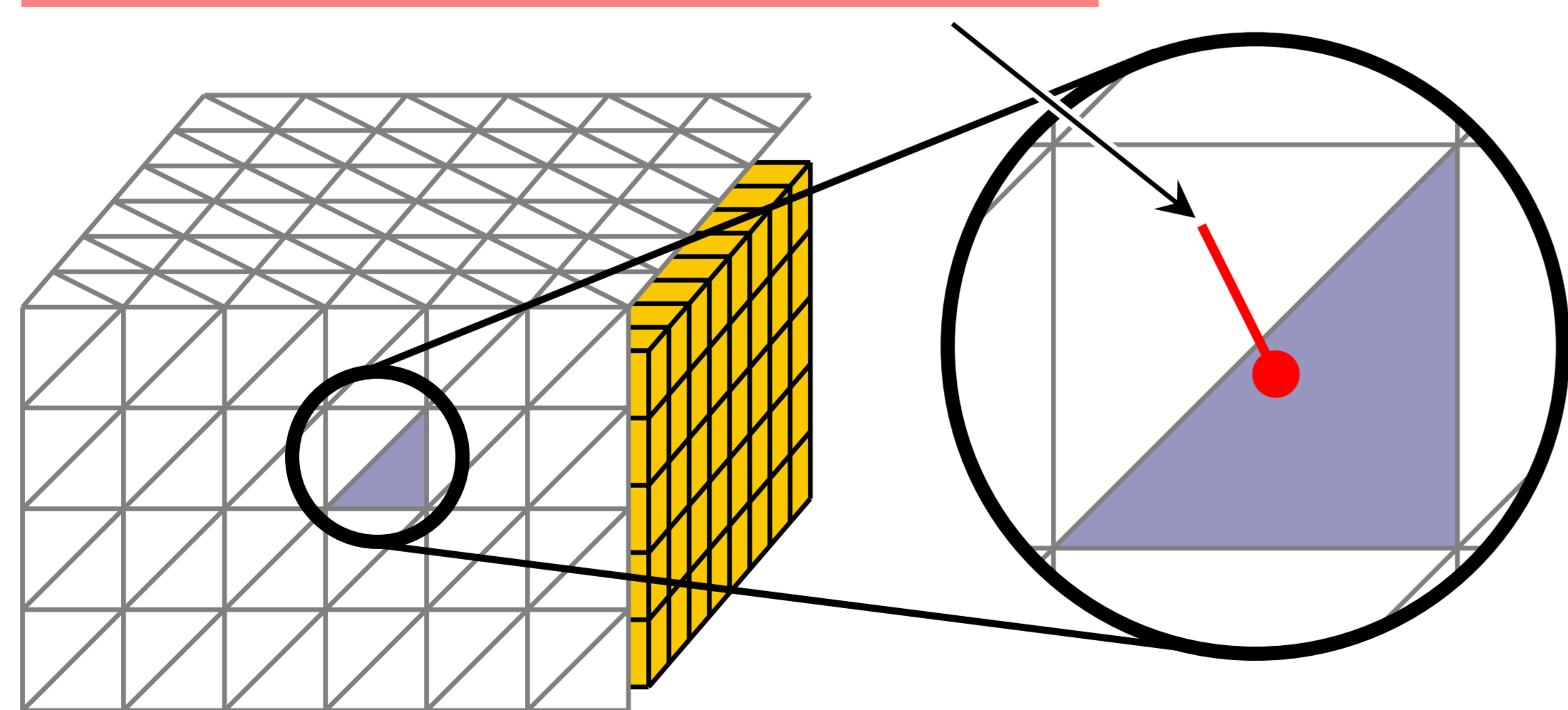
- ▶ Slow to compute, incremental scheme

Trajectory Planning

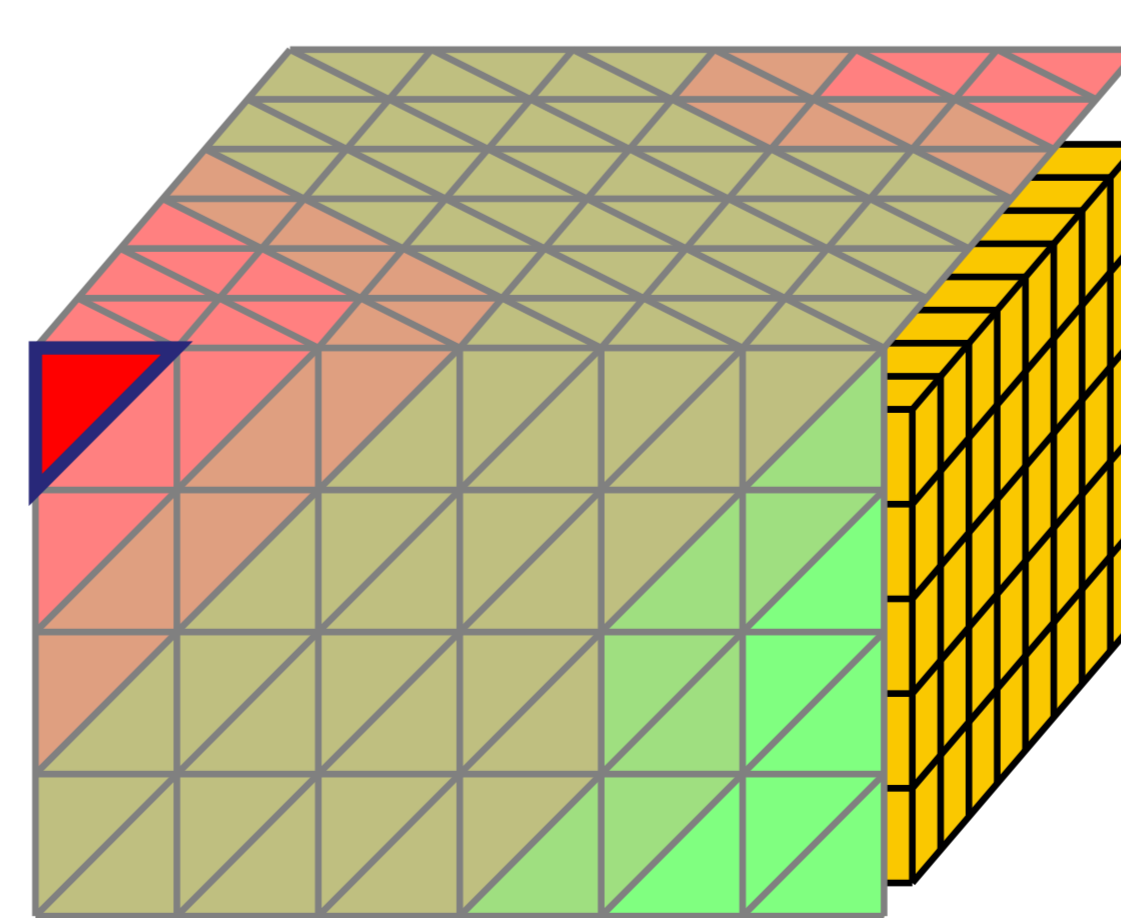


- ▶ Take matrix A_i at current destination p_i , and extend it optimally
- ▶ Random candidate for every triangle

$$\text{random pose, evaluate } \eta \begin{pmatrix} A_i \\ - a_* - \end{pmatrix}$$



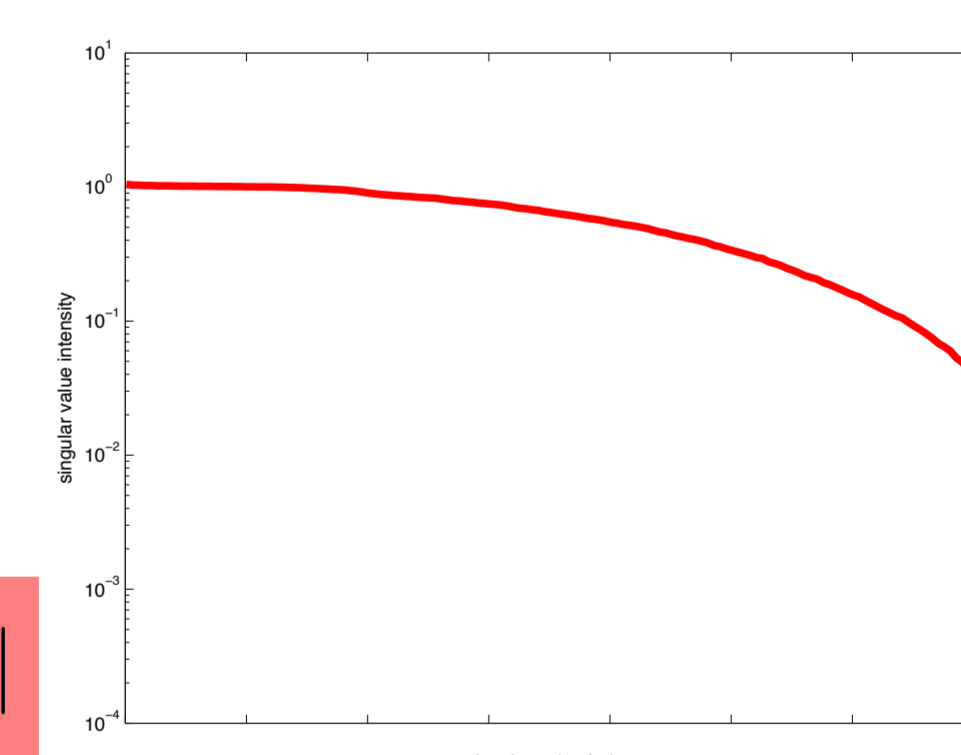
- ▶ Yields "need for measurement" for entire surface



Pivoted QR

$$A = Q \begin{pmatrix} r_{11} & r_{12} & \dots \\ & r_{22} & \dots \\ & & \ddots \end{pmatrix} P^T$$

$$\eta(A) = \|\text{diag}(R)\|_{\ell_1} = \sum_i |r_{ii}|$$



- ▶ Very fast to compute

References

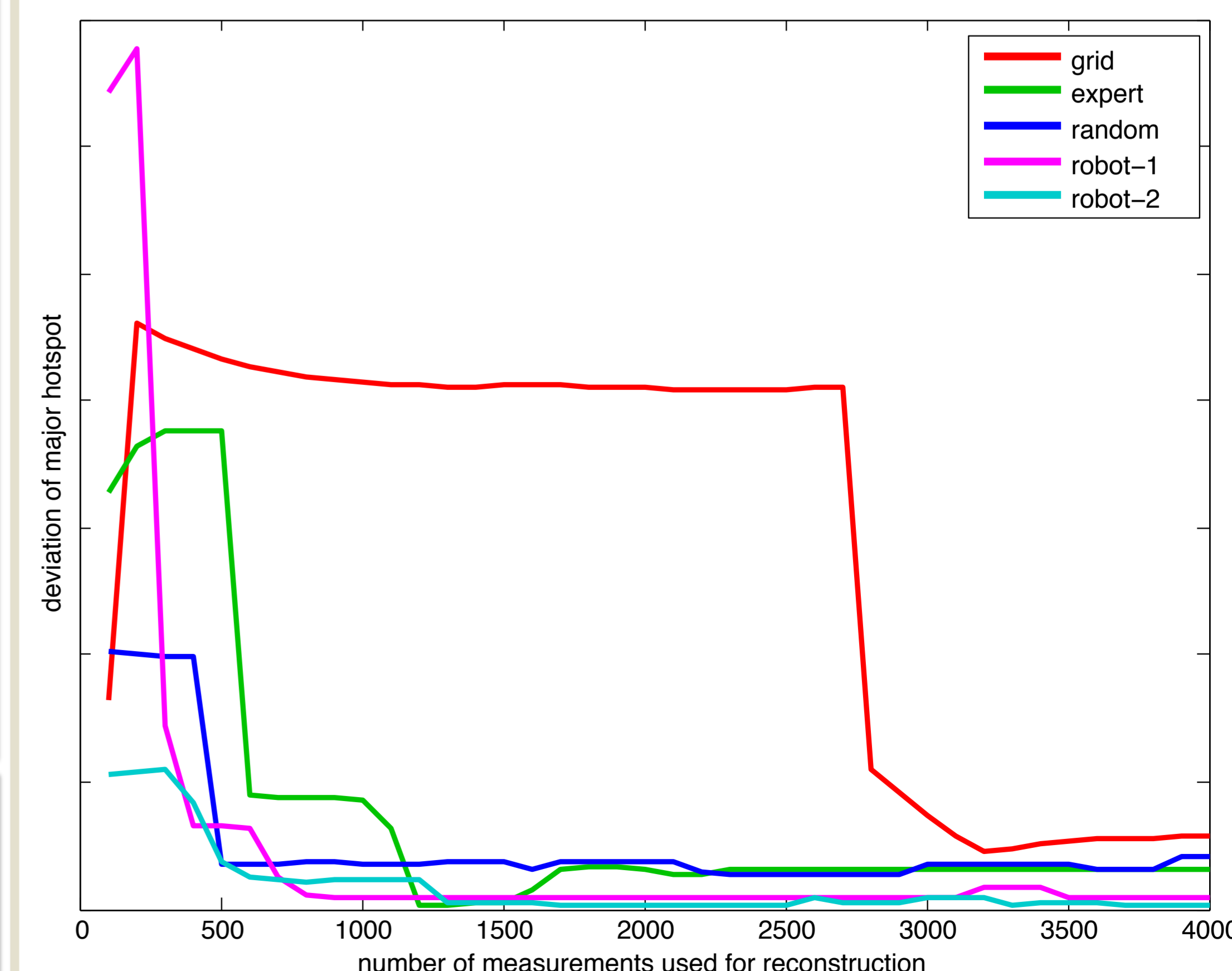
- ▶ T. Wendler et al., Eur J Nucl Med Mol Imaging 37 (8), 2010
- ▶ T. Lasser et al., Medical Image Analysis 11 (4), 2007
- ▶ M. Gu et al., RR-966, Yale University, 1994
- ▶ D. Chetverikov et al., Pattern Recognition Letters 31 (9), 2010
- ▶ P. C. Hansen et al., Johns Hopkins University Press 2012

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Results



- ▶ **Improved convergence**
- ▶ Works in real-time on laptop using CPU threads and LAPACK (Intel i7, 2.3 GHz)