Direct Segmentation from Projections

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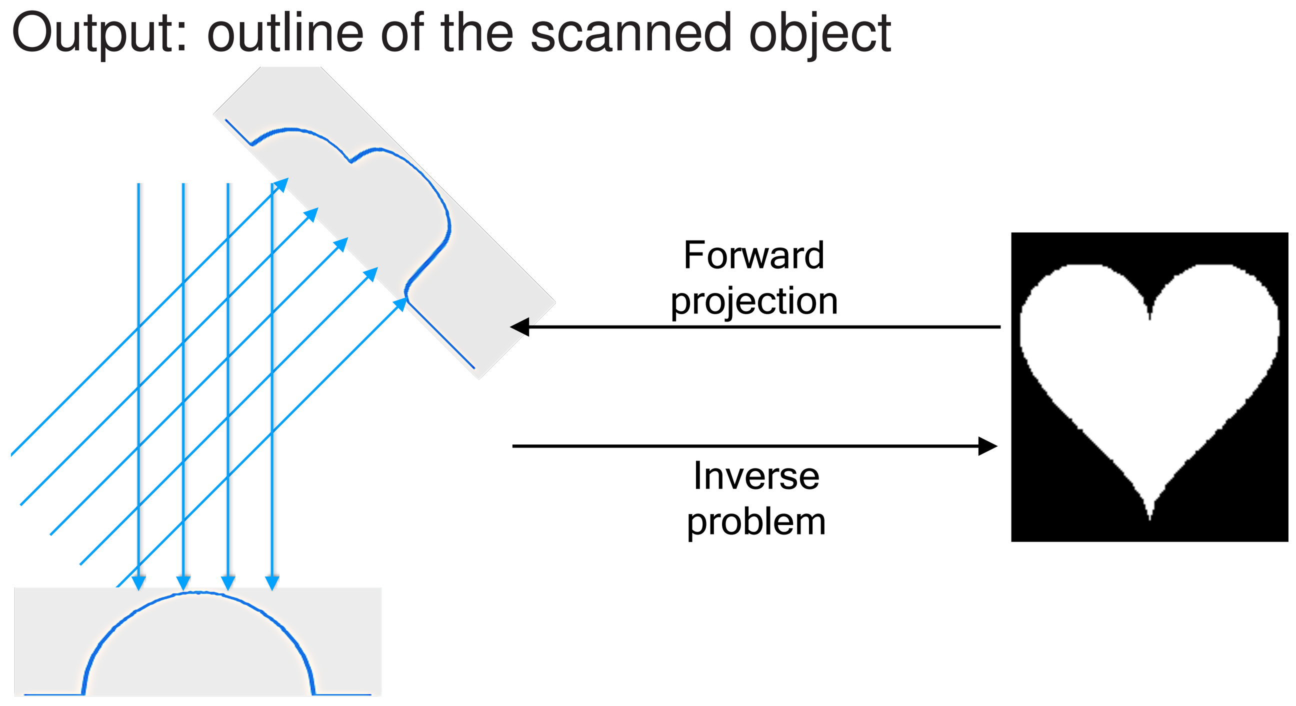
Introduction

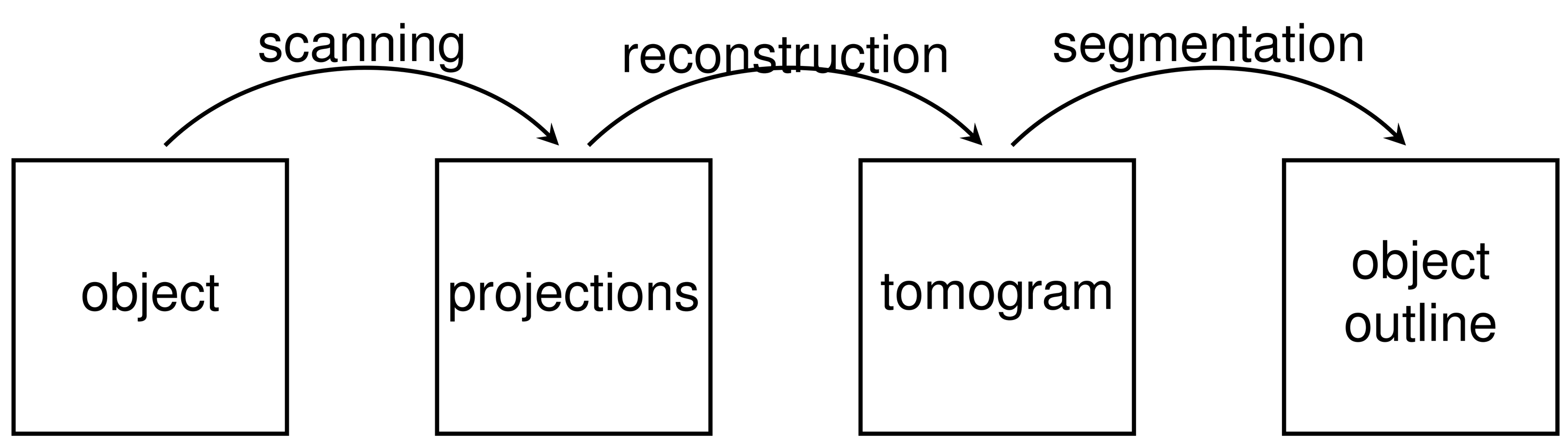
Problem definition: Tomographic reconstruction and segmentation

- Input: projections (sinogram), e.g., from X-ray.
- Output: outline of the scanned object



Contribution: We propose a direct segmentation method from projection data. Its main benefit is to directly optimize the error between sinogram data and the segmentation. The segmentation is represend by a parametric curve, which can reduce the pixel artifacts and provide more accurate geometrical measurements than traditional methods.

Existing approaches



Errors are propagated due to multi-step pipeline.

- As for the reconstruction method, algebraic iterative methods are popular, which are robust to noisy projection data, easy to impose prior knowledge such as non-negativity. But they are still not robust in challenging situations such as limited angle data.
- As for the segmentation method, level-set method is popular due to topological adaptivity.

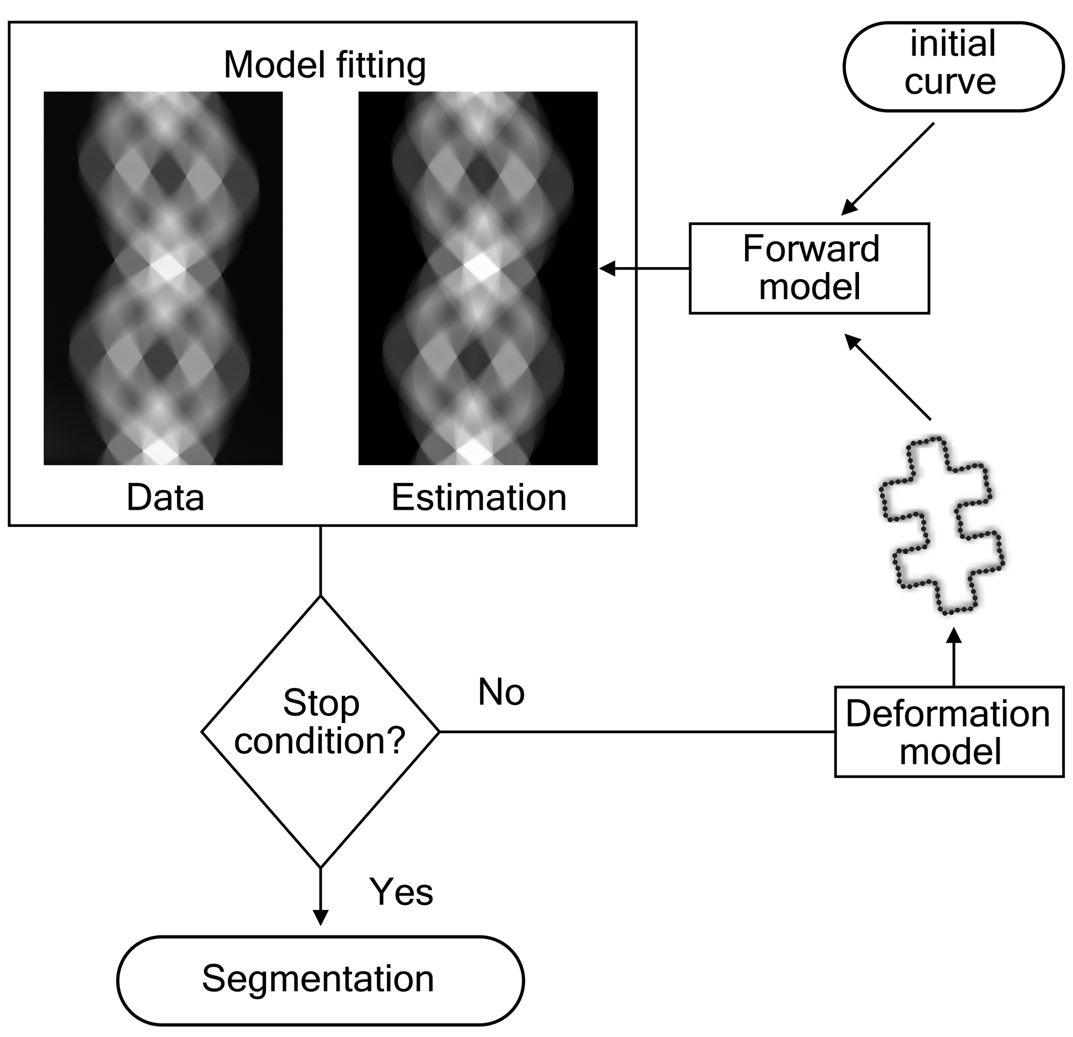
Our approach

Segmentation without reconstruction [1]:

- Represent the object using a discrete parametric curve in the reconstruction domain.
- Roughly initialize and then deform the curve to fit projection data.
- The objects of interest are assumed to have a constant attenuation coefficients.

$$\min E(C,\mu) = \sum_\theta \int_S (p(\theta,s) - \mu\hat{p}(\theta,s))^2 ds + R(C)$$

- p: sinogram data
- $\hat{p}$: estimated sinogram by our forward projection
- μ : Attenuation coefficient (is assumed to be constant)
- R: regularization (e.g., curve length)



Optimization

Forward model The forward model transforms the curve into sinogram domain:

$$\hat{p}(\theta, s) = \int_{\text{int}(C)} \delta(L_\theta(x,y) - s)\, dxdy$$

where $L_\theta(x,y)$ is related to projection ray, given an angle θ and detector location s (e.g., $L_\theta(x,y) = x\cos\theta + y\sin\theta$ in parallel beam). We provide an efficient method to calculate forward projection from a curve:

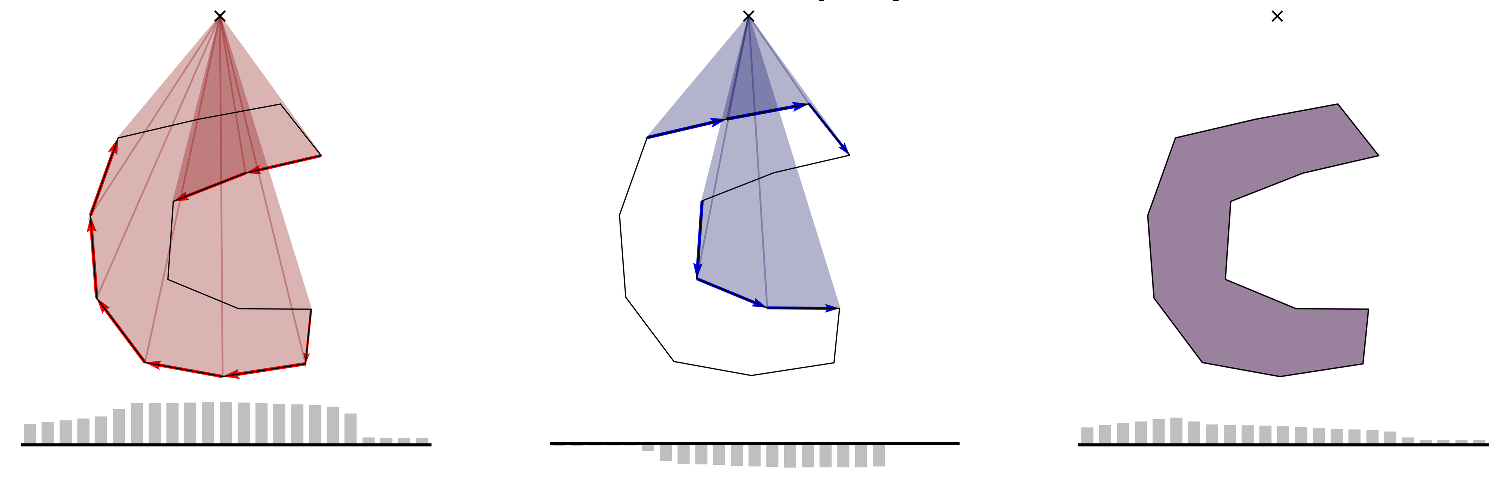


Illustration of forward model with fan beam, given a projection angle θ

Depending on the orientation of the curve, we add [Left] or subtract [Middle] the length of line between the source and the points in the curve. After summing these values, we obtain the final projection values [Right].

Attenuation coefficient Optimize the energy with respect to μ.

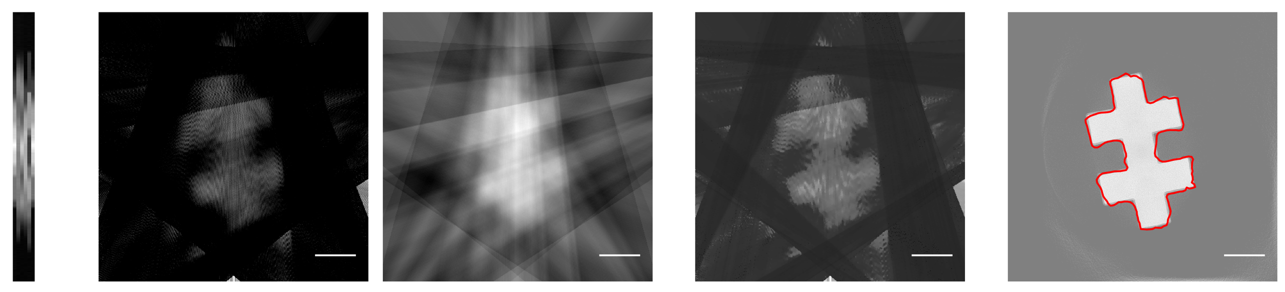
Curve deformation Optimize the energy with respect to the curve. For the data fidelity term, we can derive the equation of curve evolution:

$$C_t(q) = \tau\mu \sum_\theta (p - \mu\hat{p})(\theta, L_\theta(C(q)))\mathcal{N}(q)$$

where $\mathcal{N}$ represents the outward unit normal vector and τ the step size.

Experiment on real data with limited angle

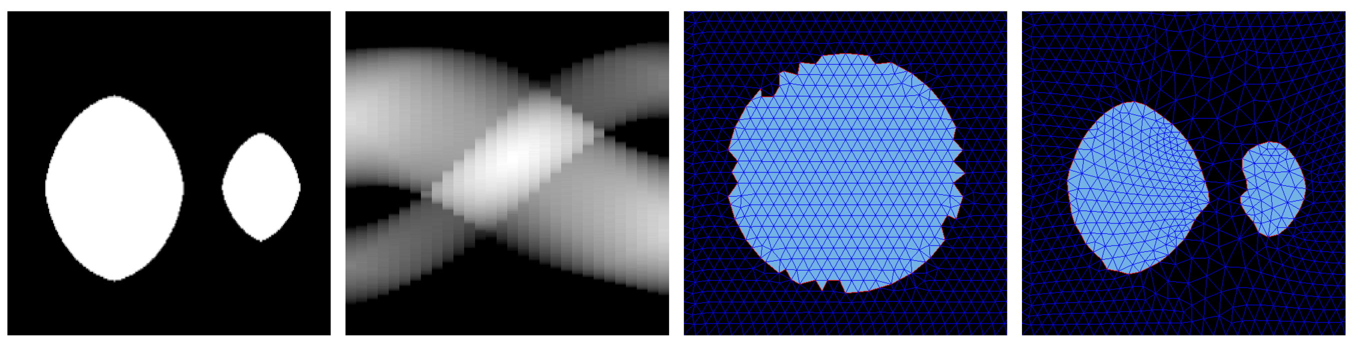
\# of angles: 6



Input SART [3] CGLS TVRDART [4] Ours

Future plan

We are working on applying mesh-based curve representation [2] for supporting multiple materials and topological changes.



Object Sinogram iter=0 35

We plan to extend to 3D data and dynamic tomography.

References

[1] V. A. Dahl, A. B. Dahl, and P. C. Hansen, “Computing segmentations directly from x-ray projection data via parametric deformable curves,” Meas. Sci. Technol. 2018.

[2] M. K. Misztal and J. A. Bærentzen, “Topology-adaptive interface tracking using the deformable simplicial complex,” TOG 2012.

[3] A. H. Andersen and A. C. Kak, “Simultaneous Algebraic Reconstruction Technique (SART): A superior implementation of the ART algorithm,” Ultrason. Imaging, 1984.

[4] X. Zhuge, W. J. Palenstijn, and K. J. Batenburg, “TVR-DART: A More Robust Algorithm for Discrete Tomography From Limited Projection Data With Automated Gray Value Estimation,” TIP 2016.

Acknowledgement

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