Motion Estimation in Rotational Angiography with α-Expansion Moves

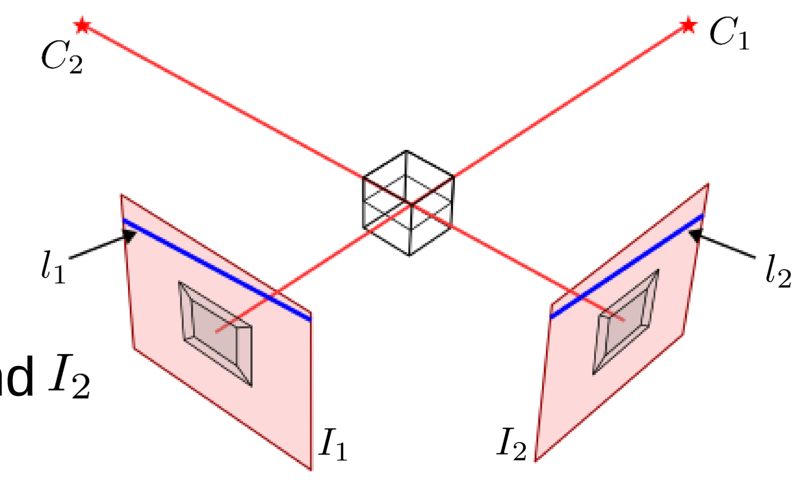
Lina Felsner [1], André Aichert [1], Mathias Unberath [1,2], and Andreas Maier [1,2]

[1] Pattern Recognition Lab, Department of Computer Science, Friedrich-Alexander University Erlangen-Nuremberg, Germany

[2] Erlangen Graduate School in Advanced Optical Technologies,Germany

Introduction

- Rotational coronary angiography ⟶ 3D reconstruction
- Movement of the heart (**Fig.1**) ⟶ Insufficient quality of reconstruction [1]
- Background subtraction enables estimation of craniocaudal shifts between radiographic images [2] by
- Optimizing epipolar consistency (EC) [3]
  - ⟶ Lines l_1 and l_2 should contain the same information
  - ⟶ Metric computes differences of line integrals between image I_1 and I_2
- Recurrent motion of similar structures
  - ⟶ Multiple local minima in the objective function (**Fig. 2**)
- Optimization is complicated



Materials and Methods

- Estimate shifts of the projection images
  - ⟶ Minimizing the inconsistency between images
- Discrete graph-based optimization
- Set of detector shifts, on for each of the n images $\mathcal{V} = \{v_1, ..., v_n\}$
- Energy:

$$E(\mathcal{V}) = E_{data}(\mathcal{V}) + \lambda \cdot E_{prior}(\mathcal{V})$$

- Data term: agreement of estimates and observed data

$$E_{data}(\mathcal{V}) = \sum_{i=1}^{n} \sum_{\substack{j=1 \\ j \neq i}}^{n} \text{EC}\left(I_i,\, I_j,\, v_i,\, v_j\right)$$

- Prior term: neighborhood constraint that prefers smooth motion over time

$$E_{prior}(\mathcal{V}) = \sum_{\{i,j\} \in \mathcal{N}} |\ v_i - v_j\ |$$

- Discrete shifts in a range of $\pm r \cdot s$ and a spacing of s, which form a set of labels $\mathcal{L} = \{v = i \cdot s \in \mathbb{R} \mid \ i \in \{-r, \ldots, +r\}\}$
- Optimization problem: optimal labeling $\mathcal{V}^\star = \underset{\mathcal{V}}{\operatorname{argmin}}\ E\left(\mathcal{V}\right)$

α-Expansion Algorithm [4] :

- Solves a sequence of binary problems for all expanding labels $\alpha \in \mathcal{L}$
- For each label α, a minimum cut on the graph represents the optimal assignment of α to each projection versus its current estimate
- Iterate to convergence

Experiments:

Two realizations of heart and breathing motion, simulated with the XCAT phantom [5]. Motion estimation of vertical detector shifts in a range of $\pm$150 pixels at one pixel step size. Use grid-search as ground-truth.

Results and Discussion

- Results in **Fig. 3** for grid-search and α-expansion moves for both datasets
- Both methods are in good agreement after two iterations
- Reduction of the inconsistency in **Fig. 4**
- More stable than grid-search with respect to the selection of the right parameters and sequence of optimization
- α-expansion moves are resistant to jumps due to the smoothness regularizer and searching strategy

Conclusion and Outlook

- Proposed method: reliable, flexible, robust
- Able to use relative shifts: reduction in the number of labels
- Further acceleration with a coarse-to-fine approach
- Apply to real patient data

Contact

lina.felsner@fau.de

http://www5.cs.fau.de/~felsner

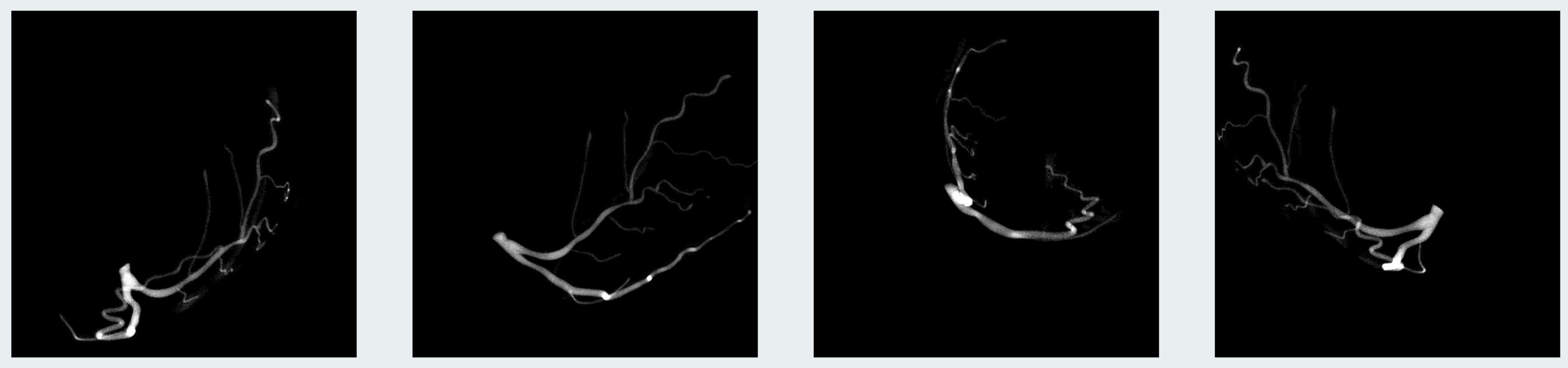


Figure 1: Four different views of segmented vessels of the X-ray angiography acquisition of phantom I.

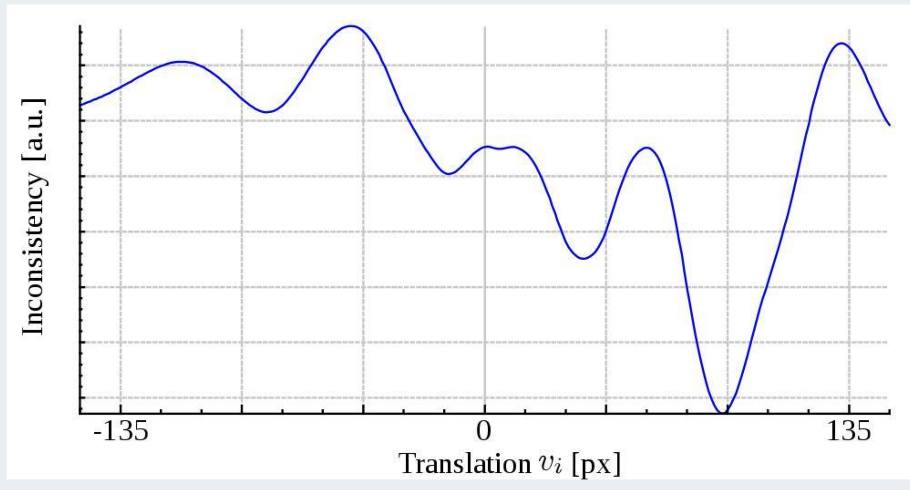
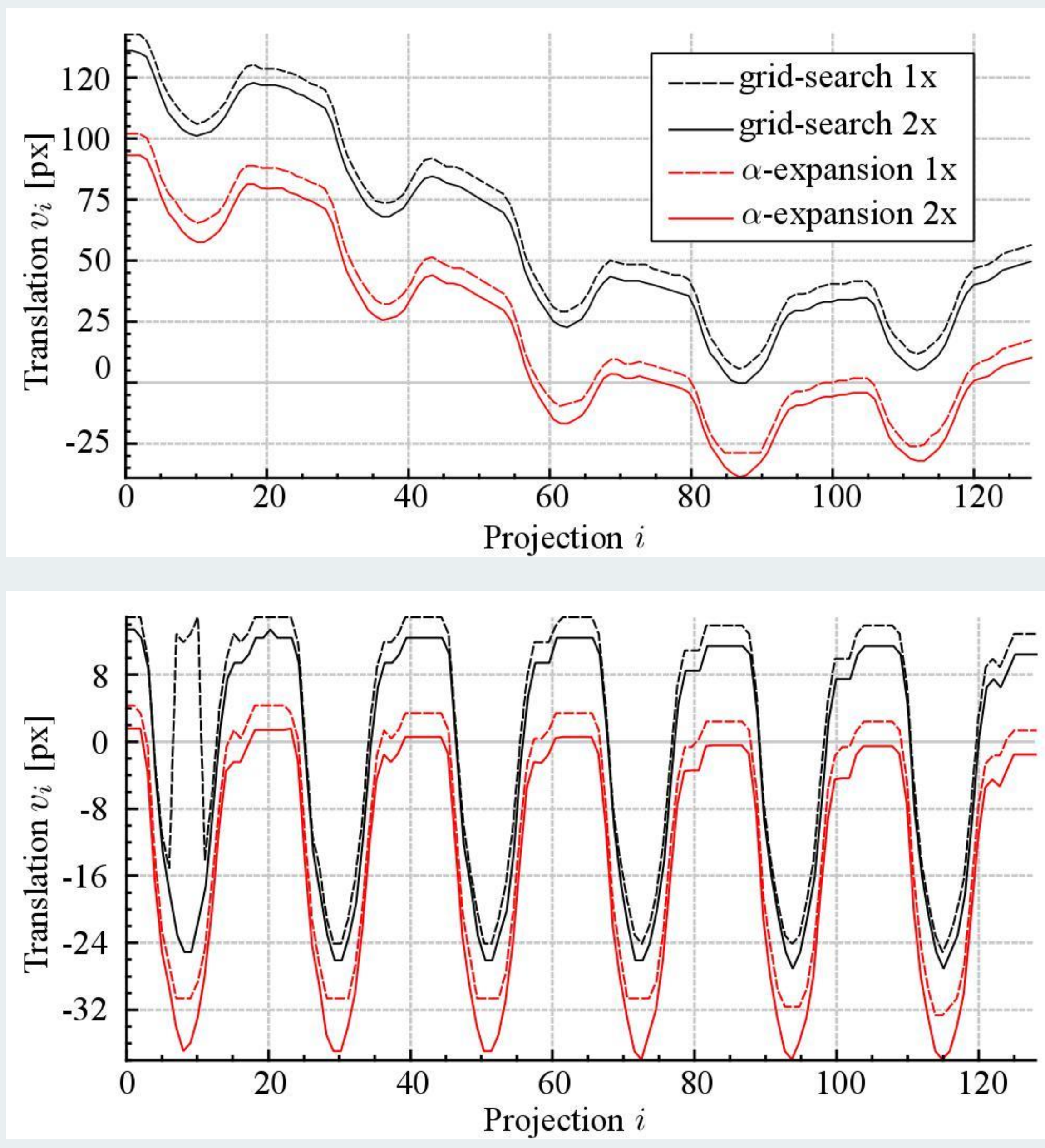


Figure 2: Highly non-convex cost function of one view with respect to all other views with a vertical translation of $\pm$ 150 pixels.



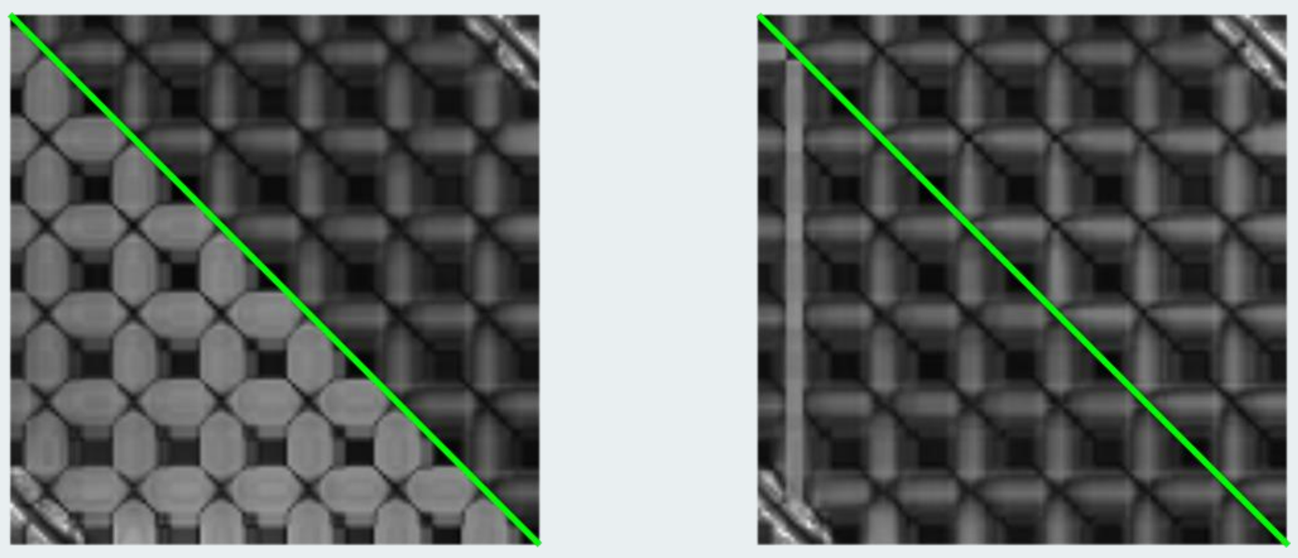
Phantom I

0.75 respiratory motion and 5 cardiac cycles

Phantom II

0.2 respiratory motion and 6 cardiac cycles

Figure 3: Motion estimation of two phantom datasets. Estimated shifts are plotted by projection index for grid-search and α-expansion moves.



Consistency before (below the green line) and after motion estimation (above the green line)

Consistency after one optimization for grid-search (below the green line) and α-expansion moves (above the green line)

Figure 4: Consistency images for phantom II. The consistency metric EC is evaluated for each pair of projections.

References

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