DISTANCE-TO-CONTOUR CONDITIONED COREGISTRATION FOR PANCREATIC CANCER RT

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Background & Purpose

- Longitudinal deformable image registration (DIR) is crucial for accurate dose accumulation in magnetic resonance-guided adaptive radiotherapy (MRgART).
- The abdomen presents major challenges for DIR due to substantial inter-fraction changes; spatial shifts, gas, and food contents drastically alter image intensities.
- Standard DIR methods that rely on image intensity similarities are highly susceptible to inaccurate deformations when these anatomical and contrast shifts occur.
- This makes it difficult to accurately perform dose accumulation on the organs-at-risk (OARs) in the context of pancreatic cancer RT.

Purpose

- We develop **DisCo** (**Dis**tance-to-**Co**ntour **Co**nditioned **Co**registration), a progressive method robust to both geometric and intensity shifts.
- **DisCo** improves upon the ProRSeg paradigm by creating a self-reinforcing loop: segmentations inform the registration (via surface distance maps), and the registration informs the segmentation.

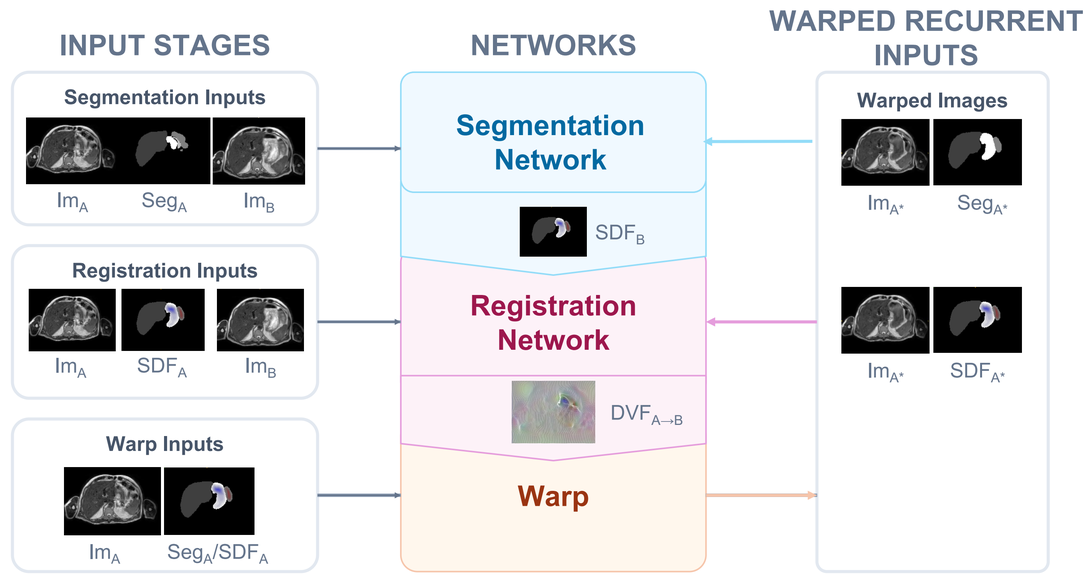

Figure 1. DisCo design diagram. DisCo uses the contours from the segmentor (after undergoing the surface distance transform) to condition the registration network, resulting in a reciprocal transfer of information between the registration and the segmentation network across CLSTM iterations

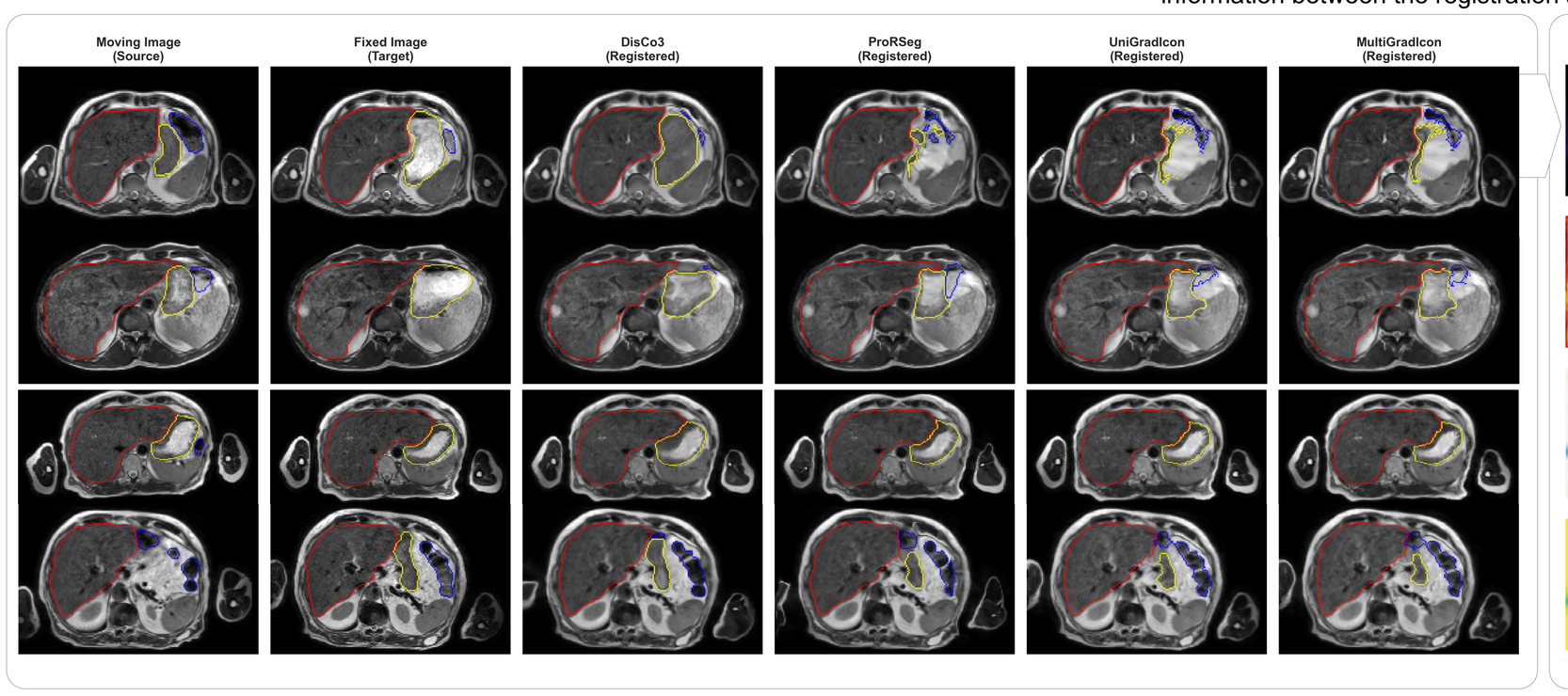

Figure 2. Example model results with original moving and fixed images (column 1 and 2) and deformed structures and images for each model. (liver=red, stomach =yellow, small bowel = green, large bowel = blue)

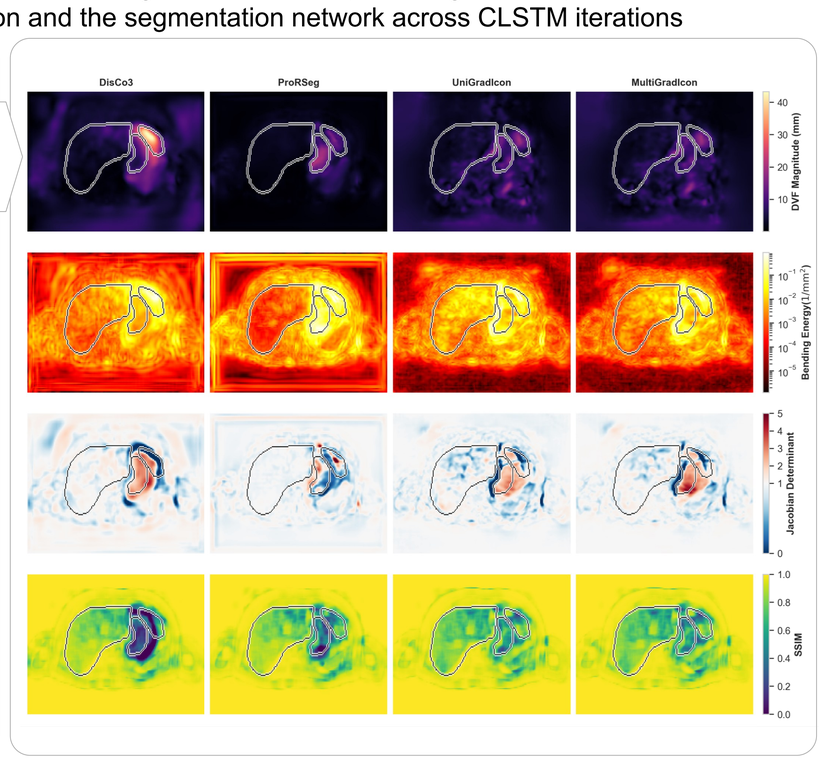

Figure 3. For one patient (top row of figure 2) we show the DVF magnitude, bending energy, Jacobian determinant, and structural similarity metric (SSIM).

Key Results - Structural Alignment and Dosimetry

- After training on a set of 30 patients (150 scans) DisCo was tested on a set of 9 patients (45 scans). Four example test registrations are seen in figure 2.
- DisCo achieved significantly higher Dice-Sørensen coefficients (DSC, $p < 0.001$) and lower 95th percentile Hausdorf distances (HD95, $p < 0.001$) across OARs compared to ProRSeg[1], UniGradIcon[2], and MultiGradIcon[3]. See figure 4
- **Overall Metrics:** DisCo's mean organ DSC was 0.84 compared to 0.77 for ProRSeg and 0.78 for both UniGradIcon and MultiGradIcon.
- DisCo's mean HD95 was 6.8 mm versus 10.8 mm for ProRSeg, and 9.4 for both UniGradIcon and MultiGradIcon.
- **Organ-Specific Gains:** The most substantial registration improvements were observed in the highly variable large and small bowels.
- **Dosimetric Impact:** Dose-organ overlap (DOO) was significantly improved by DisCo over other models for the large and small bowel.
- **Ablation Findings:** Continuous distance-to-contour mapping proved superior to using binary masks alone, yielding better structural fidelity (DSC and HD95).

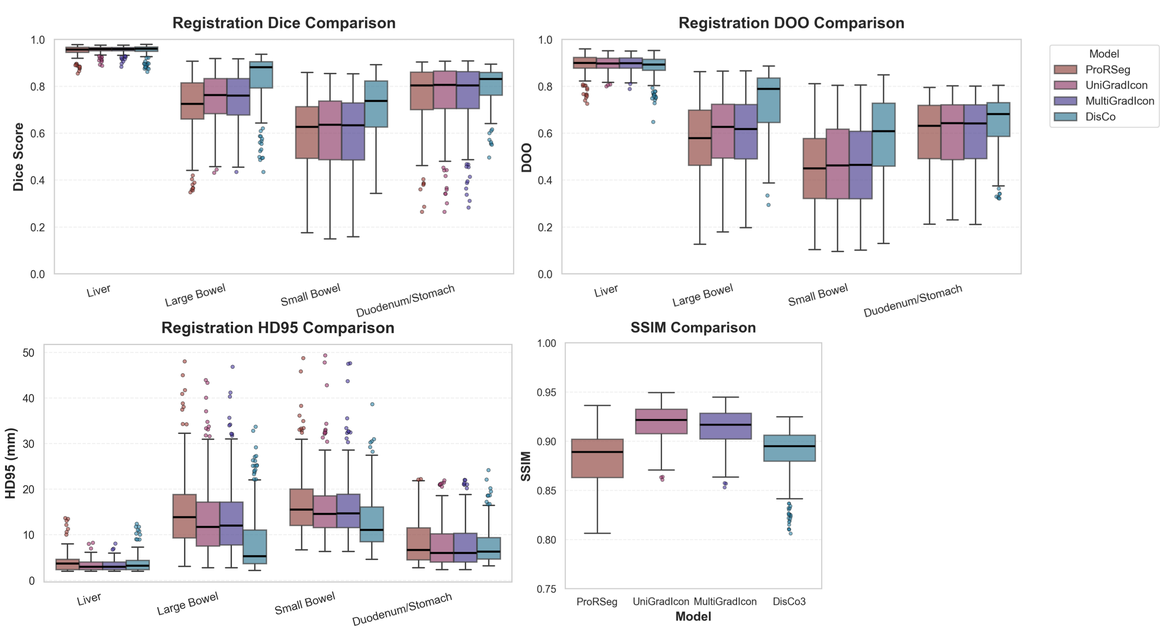

Figure 4. Model comparison DSC, DOO, HD95, and global SSIM

Key Results - Extreme Anatomical Variations

- In extreme test cases featuring massive variations in stomach filling and image intensity, DisCo successfully segmented and properly deformed the moving image. (see top row of figure 2)
- Conversely, alternative models incorrectly deformed non-stomach tissues (like visceral fat) to match the high-intensity stomach target.
- While DisCo's structural similarity index (SSIM) was sometimes lower, this correctly reflects the model recognizing that structural alignment takes precedence over artificially matching changed pixel intensities. (see figure 3)

Conclusions

- Jointly and reciprocally informing both registration and segmentation networks yields superior results for both tasks compared to standard iterative methods.
- Progressively refined segmentation, when encoded in the continuous feature space of a surface distance map, significantly enhances alignment for highly deforming organs.
- DisCo is robust to unusual anatomies and severe appearance variations not encountered during training.
- Clinical Utility: DisCo's modular nature allows the automatic segmentor to be swapped out; clinicians can supply manually corrected contours to directly guide and correct the registration.

[1] J. Jiang *et al.*, "Progressively refined deep joint registration segmentation (ProRSeg) of gastrointestinal organs at risk: Application to MRI and cone-beam CT," *Medical Physics*, vol. 50, no. 8, pp. 4758–4774, 2023, doi: 10.1002/mp.16527.

[2] L. Tian *et al.*, "uniGradICON: A Foundation Model for Medical Image Registration," arXiv.org. Accessed: Jun. 05, 2026. [Online]. Available: https://arxiv.org/abs/2403.05780v1

[3] B. Demir *et al.*, "multiGradICON: A Foundation Model for Multimodal Medical Image Registration," arXiv.org. Accessed: Jun. 05, 2026. [Online]. Available: https://arxiv.org/abs/2408.00221v2