Out of Sample Performance of a Deep Learning Based Registration Quality Assurance Method

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INTRODUCTION

- Deformable image registration(DIR) is widely used in radiation oncology, despite lacking a ground-truth for validating individual results.
- Quality assurance(QA) of DIR in the clinic relies on either visual inspection, or performance in phantom, which are time-consuming and impractical.

AIM

- To develop a QA Deep Neural Network(DNN) for DIR of thoracic CT images. (previous work)
- To evaluate how this algorithm generalizes to diverse datasets and registration algorithms.

METHODS

a) Register two thoracic CT datasets(with annotated landmarks) with two DIR algorithms

Datasets		DIR algorithms	
Dirlab	Long4DCT(in-house)	B-spline	Dramms

b) Training data preparation

- Input:
Randomly resample 32*32*32 patches from fixed image / moving image/ jacobian map, and fuse them into one image as three channels.
- Gound truth:
Calculate mean landmark distance error of each patch, thresholded as 0 – acceptable / 1 – need to be review

c) Training and testing QA DNN model (Figure 2)

d) Performance evaluation (Robustness & Accuracy) (Table 1, Figure 1)

RESULTS

Training Data	Training Registration	Held-out Data	Held-out Registration	Held-out Accuracy	Held-out AUC	Out-of-sample Data	Out-of-sample Registration	Out-of-sample Accuracy	Out-of-sample AUC
Dirlab	B-spline	Dirlab	B-spline	0.95	0.99	Long4DCT	B-spline	0.88	0.94
						Long4DCT	DRAMMS	0.87	0.94
						Dirlab	DRAMMS	0.89	0.96
Dirlab	B-spline	Dirlab	B-spline	0.95	0.99	Long4DCT	B-spline	0.88	0.94
Dirlab	DRAMMS	Dirlab	DRAMMS	0.95	0.99	Long4DCT	DRAMMS	0.87	0.93
Dirlab	B-spline	Dirlab	B-spline	0.95	0.99	Dirlab	DRAMMS	0.92	0.97
Long4DCT	B-spline	Long4DCT	B-spline	0.91	0.97	Long4DCT	DRAMMS	0.90	0.96

Table 1: **Overall Accuracy and Area under Curve(AUC) of our model**

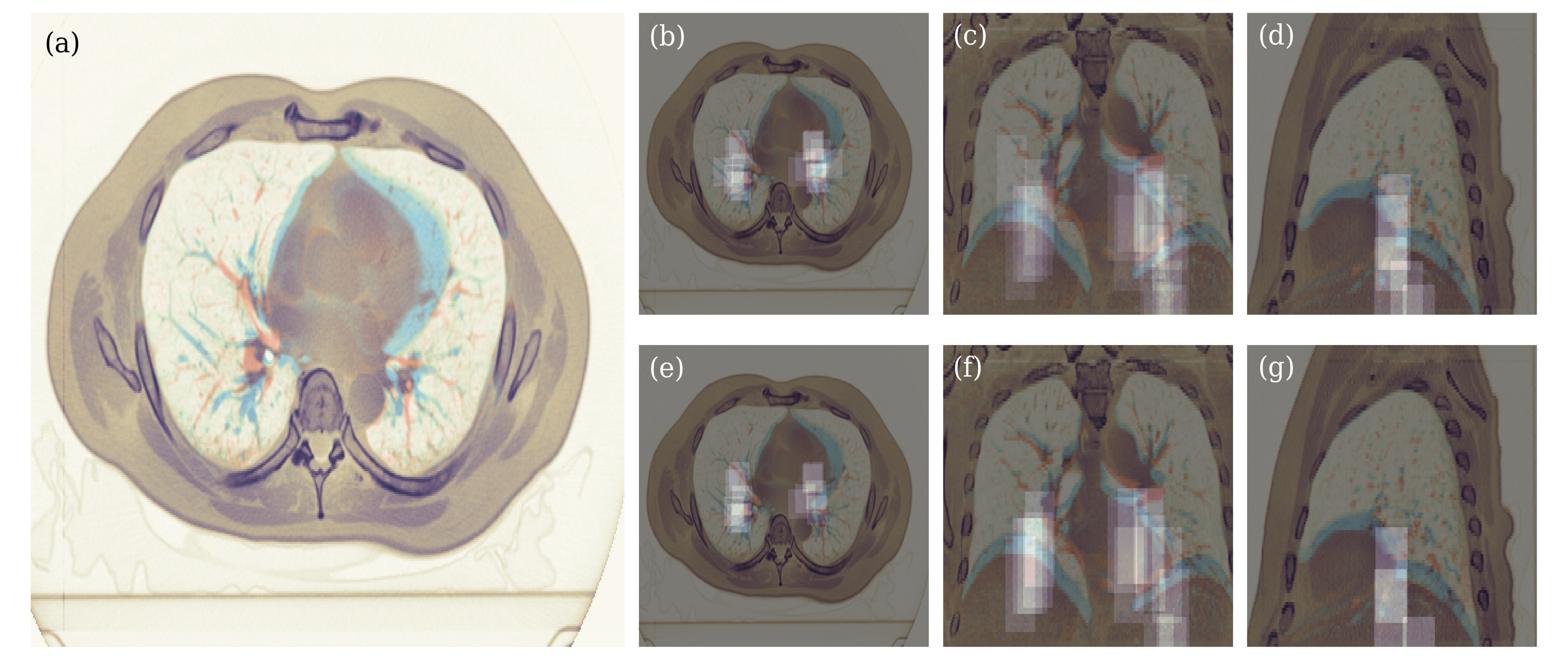


Figure 1:
(a), overlapping of original fixed and registered moving image
(b)-(d), overlay of predicted label map in 3 axes
(e)-(g), overlay of true label map in 3 axes

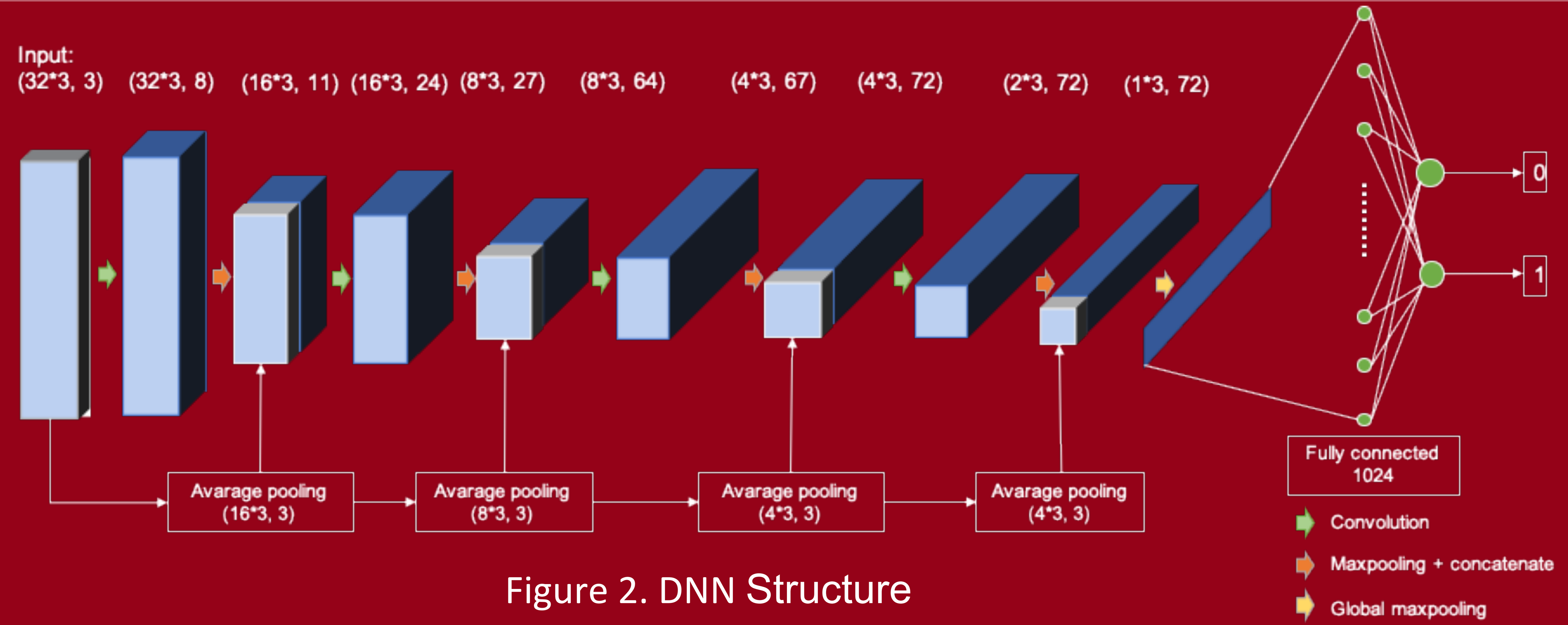
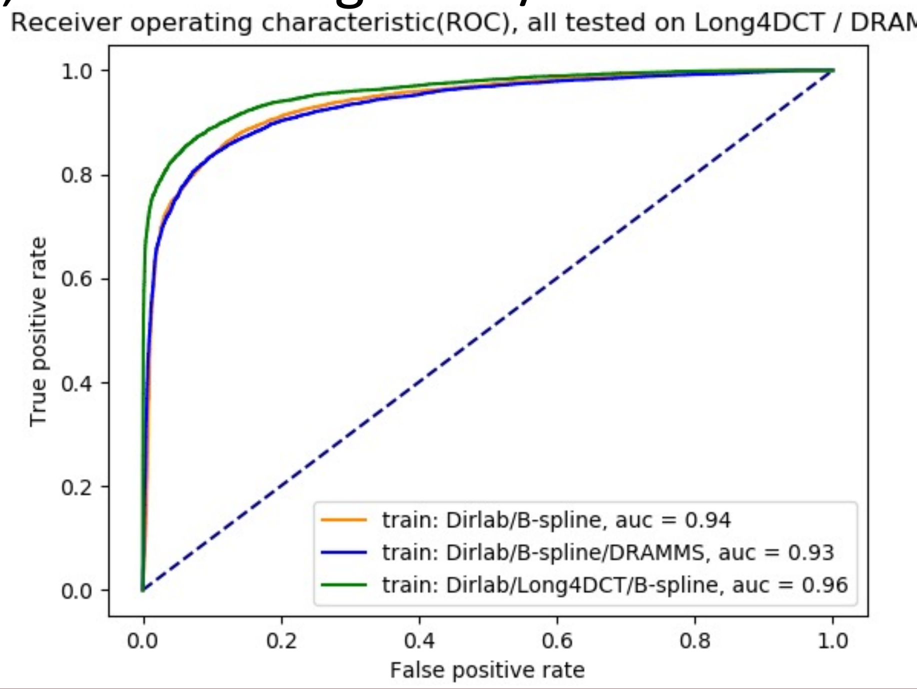


Figure 2. DNN Structure

RESULTS

- The Area Under Curve (AUC) for training Dirlab / B-spline tested on held out Dirlab / B-spline was 0.99, on Long4DCT / B-spline was 0.94, on Dirlab / DRAMMS was 0.96, and on Long4DCT / DRAMMS was 0.94.
- Training on multiple registration algorithms Dirlab / B-spline / DRAMMS gave AUC 0.99 for Dirlab / B-spline, 0.94 for Long4DCT / B-spline, 0.99 for Dirlab / DRAMMS, and 0.93 for Long4DCT / DRAMMS.
- By training on Dirlab / Long4DCT / B-spline, the AUC for testing on Dirlab / B-spline was 0.99, for Long4DCT / B-spline was 0.97, for Dirlab / DRAMMS was 0.97, and for Long4DCT / DRAMMS was 0.96.



CONCLUSIONS

- Our registration QA algorithm showed reliable inference ability across various datasets and DIR, however, training with diverse datasets provided slightly better performance than by adding DIR algorithms.
- Enriching training data by different dataset combinations obtained some improvement, demonstrating that our model's robustness has the potential for improvement.

REFERENCES

- Galib, Shaikat M., et al. "A fast and scalable method for quality assurance of deformable image registration on lung CT scans using convolutional neural networks." Medical physics 47.1 (2020): 99-109.

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