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Validation of UniverSeg for Interventional Abdominal Angiographic Segmentation

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Introduction/Background

Automatic segmentation of angiographic structures can aid in assessment of presence and extent of vascular disease. Recent deep learning segmentation models promise automated processing, however, lack validation on interventional angiographic data. This study performs a validation test on the UniverSeg model to examine suitability for future use.

Methods/Intervention

After IRB approval, a retrospective review identified 234 patients who underwent interventional fluoroscopy of the celiac axis with iodinated contrast via intravenous catheter injection between January 1st, 2019, and December 31st, 2022. From 261 fluoroscopic acquisitions, 303 images were selected with maximum contrast from the contrast agent. From each image a partition of 128x128 pixels was selected to encompass arterial details, and a corresponding binary mask was subsequently generated by convex hull calculation. The resulting image-mask pairs were distributed into three classes of 101 pairs each. Classes were defined by decreasing arterial diameter and the number of bifurcations of the vessel. UniverSeg was applied to each class independently in a 5-fold nested cross comprehensive validation test. An analysis of model performance for in-context learning was performed for each class to determine the minimum size for average model convergence. For each class size, ranging from 1 to 81 pairs, five sample images were tested against the class with twenty repetitions iterated across the class.

Results/Outcome

Dice-Similarity-Coefficients comparing UniverSeg output to generated masks across the three classes with decreasing arterial diameters were 78.7%, 72.5%, and 59.9% (σ=5.96, 7.99, 14.29). Balanced-Average-Hausdorff-Distances, representing the maximum separation distance between prediction surface and ground truth, were 0.86, 0.71, 1.16 (σ=0.37, 0.52, 0.68) pixels respectively. Inverted mask testing revealed degradation of performance in line with published UniverSeg expectations. Class size testing in all cases showed non-linear improvement with plateauing performance with increased image sets used for in-context learning. All test images converged in performance to ±1.34 Dice-Score of the full class size value by N=51.

Conclusion

UniverSeg performed well for angiographic segmentation, with improved performance with greater class size, increased vessel diameter, and reduced bifurcations.

Statement of Impact

This study validates a potential method for arterial segmentation in interventional fluoroscopic procedures and facilitates development of vascular disease models and imaging research applications.

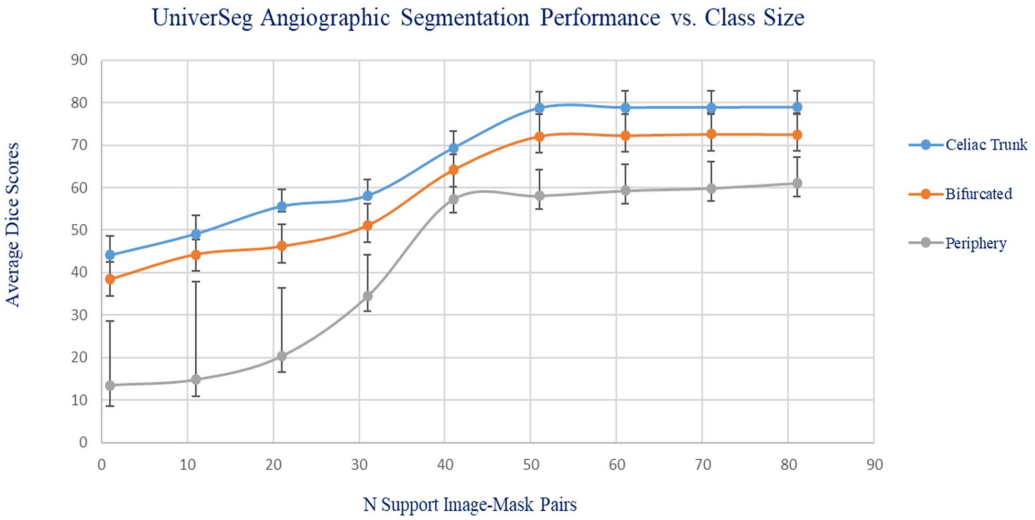

Figure 1: UniverSeg performance vs. Support Class Size Support Classes consisted of an image and its corresponding binary mask of vascular segmentation. All classes converged to within 1.34 Dice Similarity Coefficient by 51 support pairs, showing UniverSeg's cross training flexibility in outside tasks.

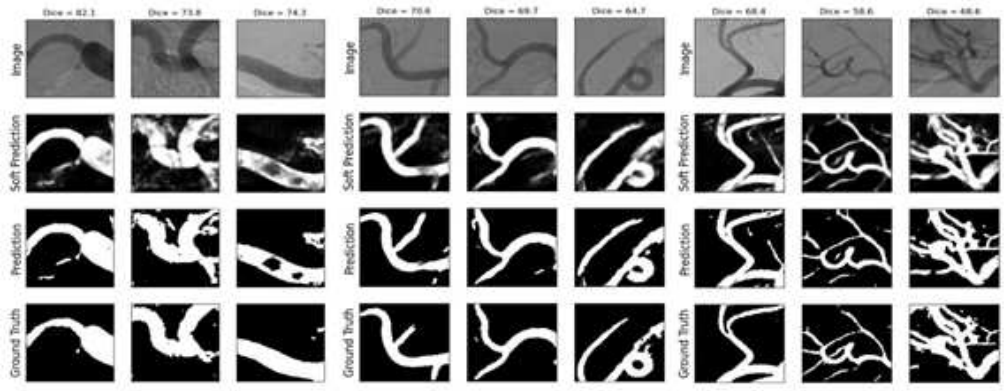

Figure 2: Sample output matrix from UniverSeg for all three class types. Columns 1-3 are samples of the Celiac Trunk class, 4-6 are within the Bifurcation class, and columns 7-9 are the Periphery class. Rows from top-to-bottom represent respectively the input image to be evaluated, UniverSeg's initial soft-prediction space, UniverSeg's final segmentation output generated by linear thresholding of the soft-prediction space, and the Ground Truth binary mask.

Universal Segmentation Validation Test Results

	Dice-Similarity-Score-Coefficients				Balanced-Average-Hausdorff-Distance			
	μ	σ	μ (Inverted)	σ (Inverted)	μ	σ	μ (Inverted)	σ (Inverted)
Class 1	78.70	5.96	76.02	4.71	0.86	0.37	0.91	0.42
Class 2	72.50	7.99	68.73	8.41	0.71	0.52	0.70	0.57
Class 3	59.90	14.29	53.13	18.29	1.16	0.68	1.22	0.75

Table 1: Universal Segmentation 5-Fold Nested Validation Test Results Columns marked with (inverted) represent the results of validation testing on the inverse problem of segmenting "not-vessel."

Keywords

Segmentation; Interventional; Angiography; Deep-Learning