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Region-aware Diagnosis of Clinically Significant Prostate Cancer via Semi-supervised Learning Segmentation

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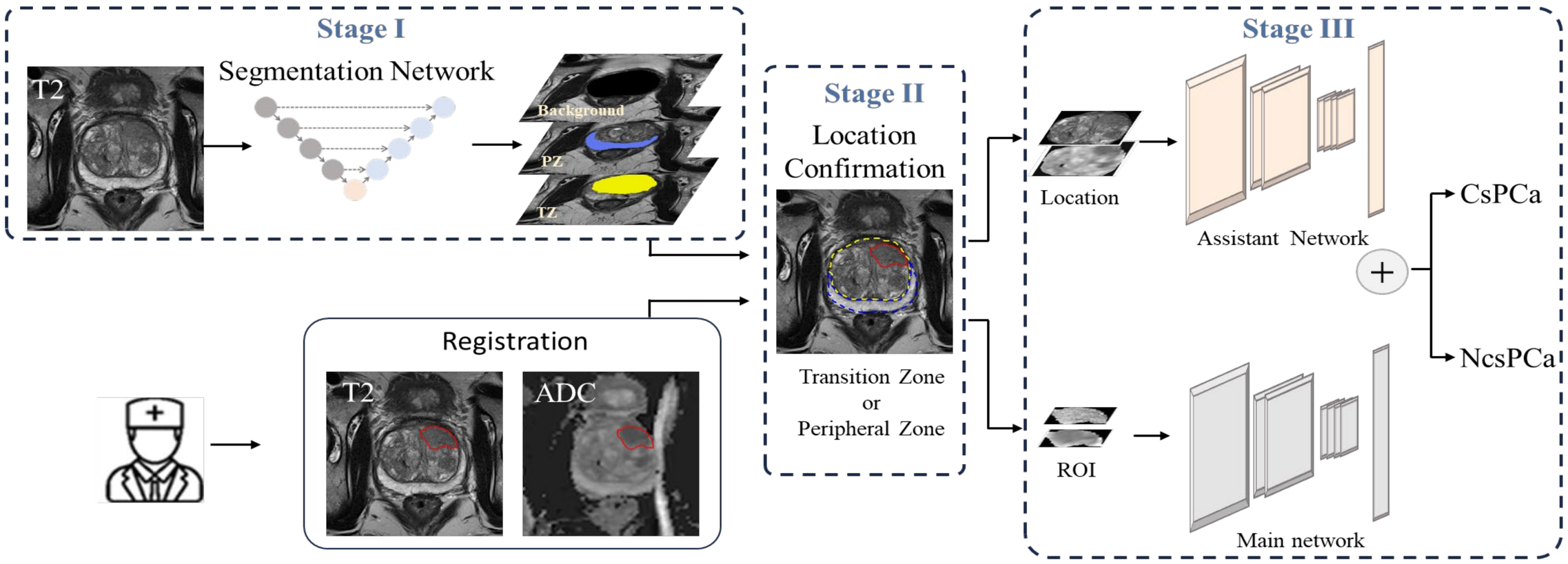
Prostate cancer (PCa) is a common malignant tumor in men, and multiparametric magnetic resonance imaging (mpMRI) plays a crucial role in the early diagnosis and staging of PCa. However, the current diagnostic system has low specificity and is highly influenced by the experience of radiologists. To address this issue, this study combines semi-supervised learning to achieve high-precision prostate region segmentation, utilizing limited labeled data and unlabeled data to improve segmentation accuracy. Based on the anatomical structure prior information extracted from the segmentation results, an auxiliary branch and main trunk network are designed to work in tandem, enhancing the model's ability to distinguish clinically significant PCa (csPCa).

Methods

- **Overview of the overall model**

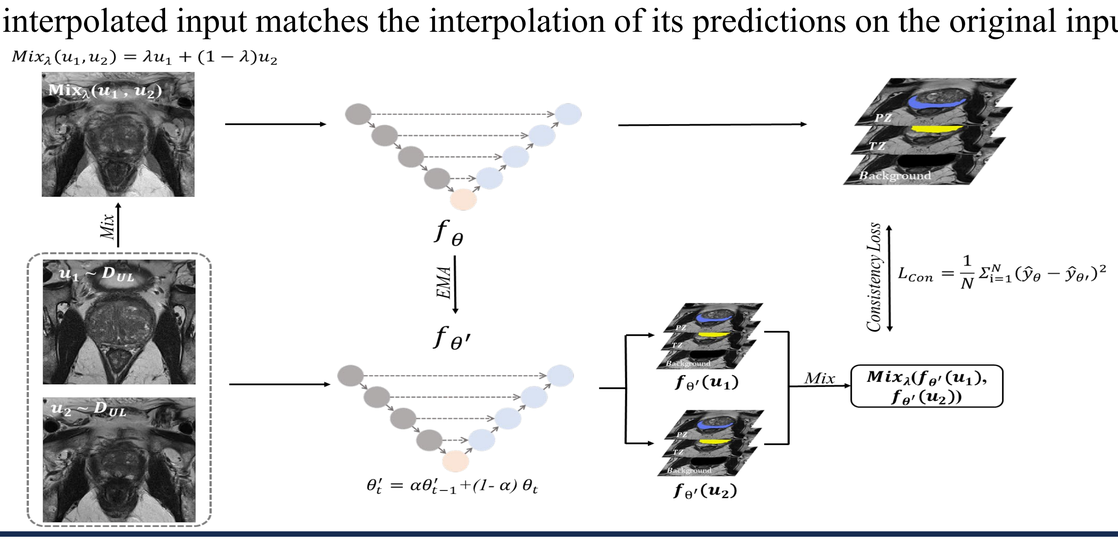
Tumor ROIs outlined by physicians are automatically assigned to PZ or TZ. The main network classifies lesions using ADC and T2 tumor patches, while an auxiliary branch incorporates zonal structural information to enhance discriminative power and robustness.



- **Semi-supervised learning segmentation strategy**

Interpolation Consistency Training (ICT) enforces that a model's prediction on an interpolated input matches the interpolation of its predictions on the original inputs.

$$Mix_\lambda(u_1, u_2) = \lambda u_1 + (1-\lambda)u_2$$

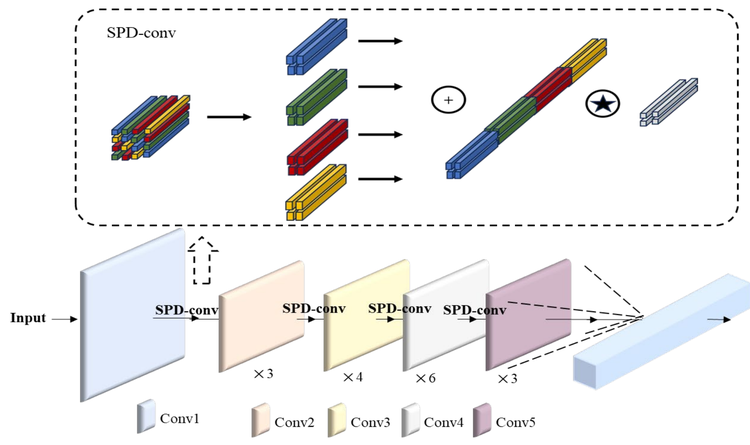


- **Classification network**

A learnable feature weight evaluation module is constructed to adaptively adjust the contribution ratio between backbone and auxiliary features.

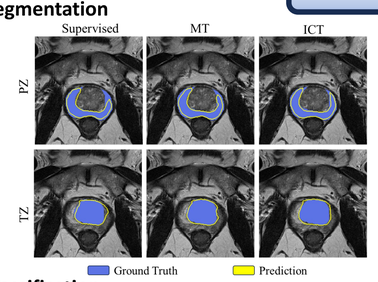
SPD-ResNet 50

Spd1	SPD-conv
Conv1	3*3, 64
Conv2	[1*1, 64; 3*3, 64; 1*1, 256] *3
Spd1	SPD-conv
Conv3	[1*1, 128; 3*3, 128; 1*1, 512] *4
Spd1	SPD-conv
Conv4	[1*1, 256; 3*3, 256; 1*1, 1024] *6
Spd1	SPD-conv
Conv5	[1*1, 512; 3*3, 512; 1*1, 2048] *3
	Average pool, fc, sigmoid



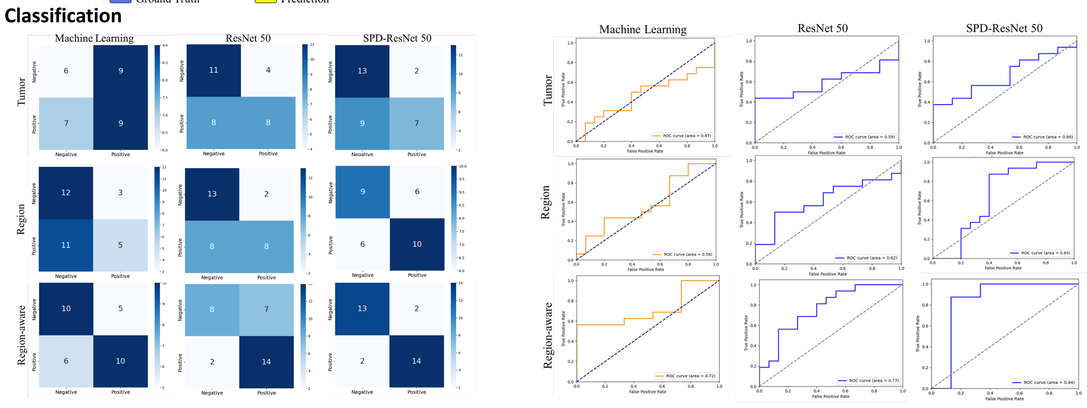
Methods

- **Segmentation**



	PZ		TZ	
	Dice (%)	HD95	Dice (%)	HD95
Supervised	72.42	4.59	82.44	4.60
Mean Teacher	75.37	4.09	86.37	3.20
ICT	**76.38**	**4.04**	**87.72**	**2.70**

- **Classification**



		Accuracy	Precision	F1 Score	Sensitivity	Specificity	AUC
Machine Learning	Tumor	48.39	50.00	52.94	56.25	40.00	0.47
	Only Region	54.84	41.67	52.94	31.25	**80.00**	0.58
	Region-aware	**64.52**	**66.67**	**64.52**	**62.50**	66.67	**0.72**
Resnet	Tumor	61.29	66.67	57.14	50.00	73.33	0.59
	Only Region	64.52	**80.00**	61.54	50.00	**86.67**	0.62
	Region-aware	**70.97**	66.67	**75.68**	**87.50**	53.33	**0.77**
SPD-Resnet	Tumor	64.52	77.78	56.00	43.75	86.60	0.66
	Only Region	61.29	62.50	62.50	62.50	60.00	0.65
	Region-aware	**87.10**	**87.50**	**87.50**	**87.50**	**86.67**	**0.84**

Dataset

We used the ProstateX dataset. Among the T2-weighted MRI sequences, 98 cases are annotated while 248 cases are unannotated. We selected 112 patients who underwent biopsy and categorized them into csPCa and non-significant prostate cancer (ncsPCa) groups.

Conclusion

The experiments demonstrate that the anatomical regions of the prostate play a crucial role in the computer-aided diagnosis of clinically significant prostate cancer. In particular, incorporating anatomical information helps improve both the accuracy and the reliability of detection models. At the same time, the application of semi-supervised learning substantially reduces the amount of annotated data required for prostate region delineation, thereby lowering the cost of data preparation and making large-scale deployment more feasible. Looking ahead, future studies will aim to integrate clinical data to further validate the importance of prostate anatomical regions across different Gleason grades, providing more comprehensive insights into their role in diagnosis, prognosis, and risk stratification of prostate cancer.

Acknowledgments

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