Semantic Segmentation of Breast Ultrasound Image with Pyramid Fuzzy Uncertainty Reduction and Direction Connectedness Feature

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Introduction

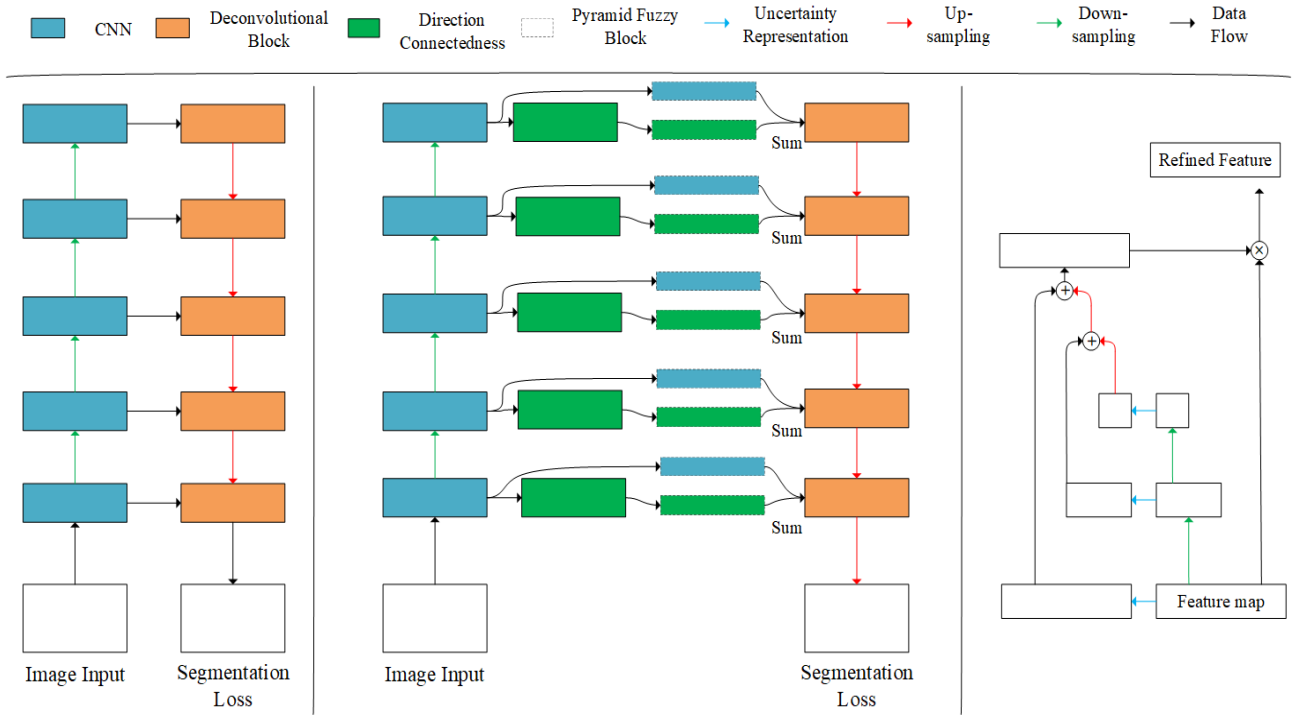
A novel deep neural network structure is developed combining with fuzzy logic and a novel context feature. The architecture is applied to breast ultrasound (BUS) image semantic segmentation. It has the following contributions:

- The proposed approach can measure the uncertainty degree for pixels in different resolution levels.
- The uncertainty degree for pixels is calculated by entropy of memberships.
- A novel context feature is proposed and combined with convolutional features to reflect the layer structure of breast.

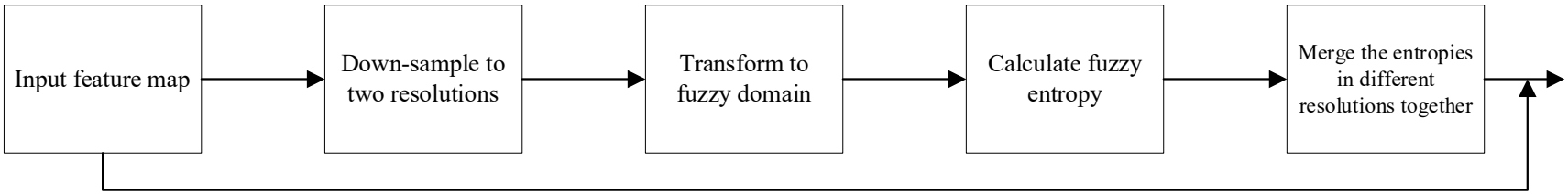
Methods

- Pyramid fuzzy block
- Direction connectedness (DC) feature

Entire network structure:

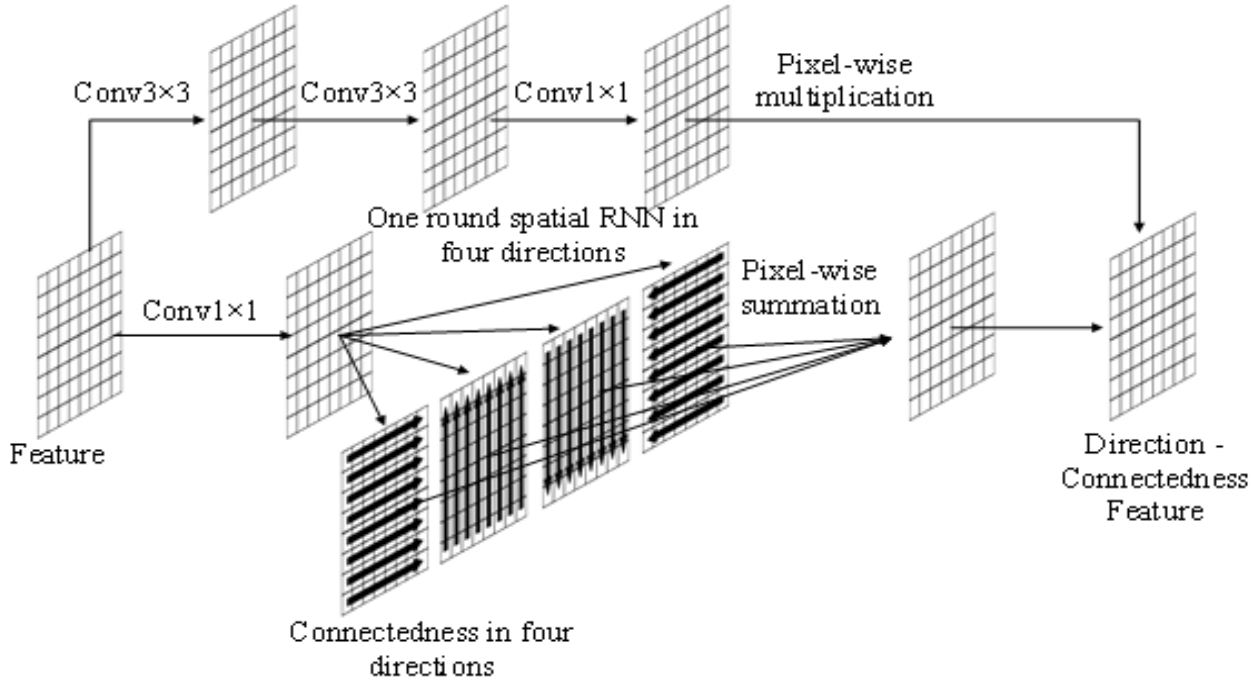


Pyramid fuzzy block



Direction-connectedness (DC) feature

The direction-connectedness (DC) feature extraction block:



Experiments

1. Datasets

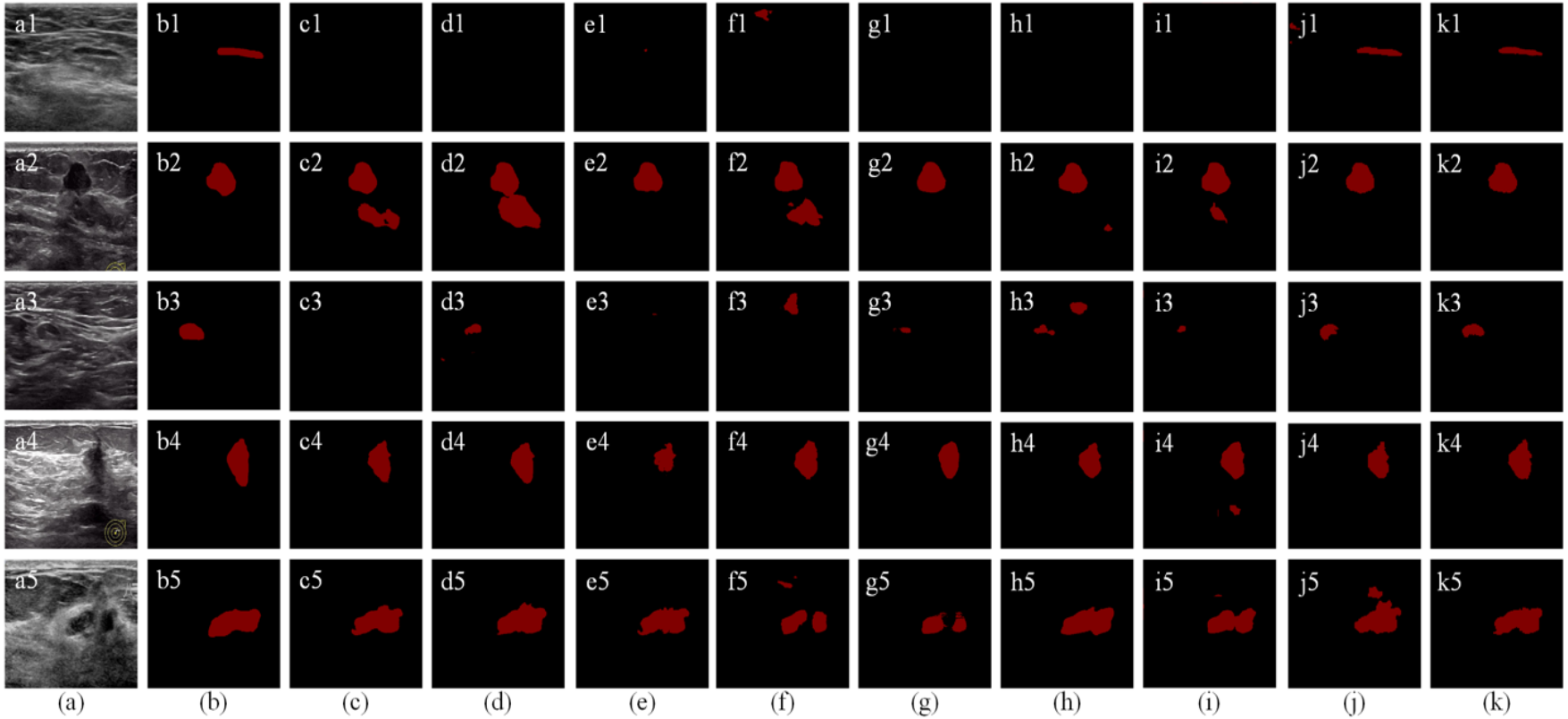
Two datasets are utilized to evaluate the proposed method: (1) a BUS image benchmark which contains pixel-wise ground truths only for tumors; (2) a multi-object BUS image dataset which contains five categories: fat layer, mammary layer, muscle layer, tumor, and background. The First dataset contains 562 images. The multi-object BUS dataset contains 325 images.

2. Experimental environment

In this research, a computer with Ubuntu 18.04 system, Intel(R) Xeon(R) CPU E5-2620 2.10GHz, and 2 NVIDIA GeForce 1080 graphics cards is used. The network weights are initialized randomly. The batch size is 8. The optimizing method is the Adam method with an initial learning rate 10^{-4}, and learning decay rate is 5×10^{-4}. The parameter β_1 for Adam method is 0.9, and the parameter β_2 for Adam's method is 0.99. All the networks (compared and proposed) are not pretrained on other datasets. The implementation is based on the Keras platform with TensorFlow backend.

Experiments

3. Tumor segmentation results on binary dataset



Segmentation results using benchmark: (a) original images; (b) ground truths; (c) results of U-Net; (d) results of ResNet-50; (e) results of ResNet-101; (f) results of Deeplab; (g) results of PSPNet; (h) results of U-Net with wavelet transform; (i) results of FCN-8s; (j) results of U-Net with DSC feature; (k) results of the proposed method.

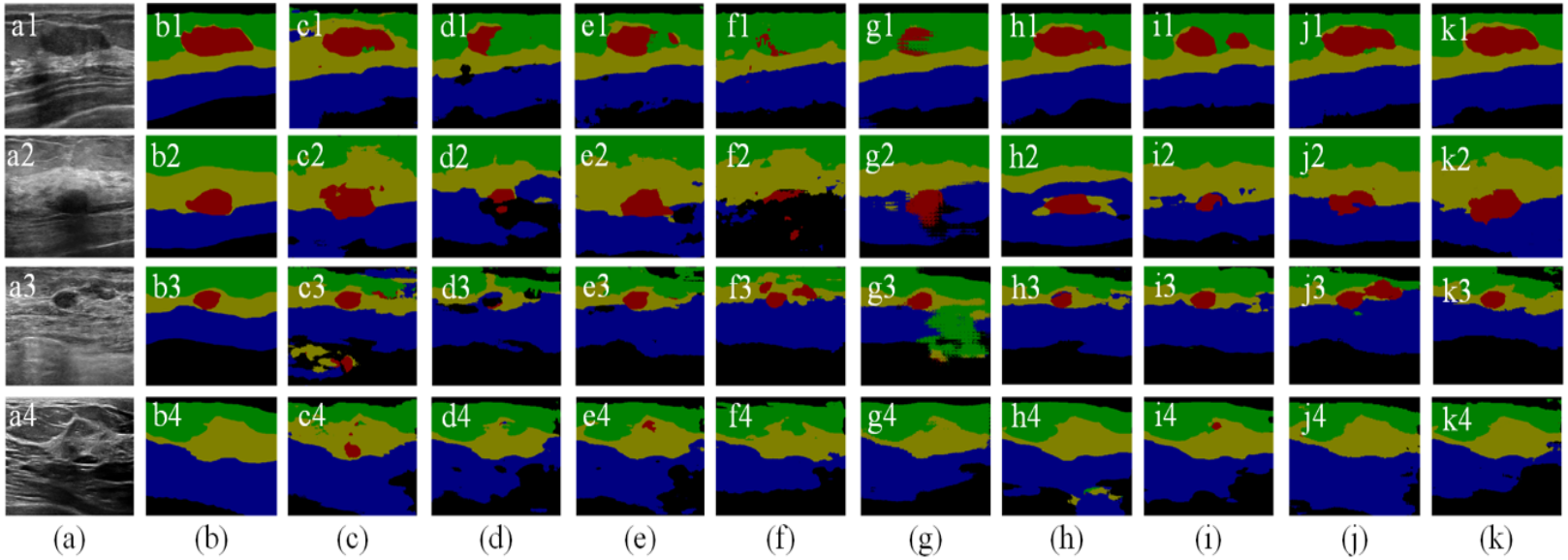
Experiments

3. Tumor segmentation results on binary dataset

	TPR	FPR	IoU	DS	AER
U-Net	0.92	0.09	0.86	0.92	0.17
Deeplab	0.89	0.11	0.82	0.89	0.22
ResNet50	0.92	0.08	0.86	0.92	0.16
ResNet101	0.92	0.10	0.85	0.91	0.18
FCN-8s	**0.94**	0.10	0.86	0.92	0.16
PSPNet	0.93	0.09	0.86	0.92	0.16
U-Net + wavelet	0.92	0.09	0.86	0.92	0.16
DSC	0.91	0.10	0.84	0.91	0.18
Proposed	0.93	**0.07**	**0.87**	**0.93**	**0.15**

Experiments

4. Multi-object segmentation for BUS image



Semantic segmentation: (a) original images; (b) ground truths; (c) results of U-Net; (d) results of ResNet-50; (e) results of ResNet-101; (f) results of Deeplab; (g) results of PSPNet; (h) results of U-Net with wavelet transform; and (i) results of FCN-8s; (j) results of U-Net with DSC feature; and (k) results of the proposed method.

Experiments

4. Multi-object segmentation for BUS image

Evaluation metric is IoU

	Fat	Mammary	Muscle	Background	Tumor	Mean
U-Net	70.34	66.72	66.17	65.91	74.66	68.76
ResNet-50	82.58	73.98	73.08	77.23	76.34	76.64
ResNet-101	81.50	73.41	72.07	74.47	75.29	75.35
FCN-8s	82.57	75.47	**75.53**	78.59	74.42	77.32
PSPNet	82.07	74.40	74.49	77.36	74.75	76.61
Deeplab	78.91	68.71	67.33	73.94	69.04	71.58
U-Net + wavelet	84.05	75.92	74.89	78.35	74.88	77.62
DSC	83.86	76.38	74.95	77.25	78.07	78.10
Proposed	**84.45**	**76.90**	75.48	**79.35**	**79.63**	**79.16**

Conclusions

- Fuzzy logic can handle the uncertainty in convolutional feature maps.
- Feature maps in different resolutions can provide more uncertainty information compared with feature maps in one resolution.
- Fuzzy entropy can be used in representing uncertainty.
- The proposed DC feature can reflect the layer structure of BUS image.
- The proposed method increases the segmentation accuracy for BUS image.

Thanks!

Questions?