Fully automated normal, infarcted and edema segmentation

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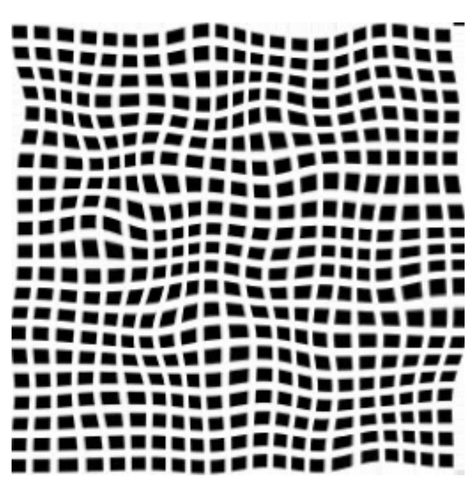
Introduction

- Utilizing the combination of CMR sequences will allow a more robust and accurate diagnostic information for myocardial infarction[1] .
- The inter-observer variation of manual scar segmentation is high with a reported Dice score of 0.5243±0.1578[1].
- This study proposes a fully automated approach by utilizing deep convolutional neural networks to delineate left vertical (LV) blood pool (BP), right ventricle (RV) BP, LV normal myocardium (NM), LV myocardial edema (ME) and LV myocardial scars (MS).

Augmentation Module

We utilize a non-rigid random warping and a random rotation scheme to augment our data.

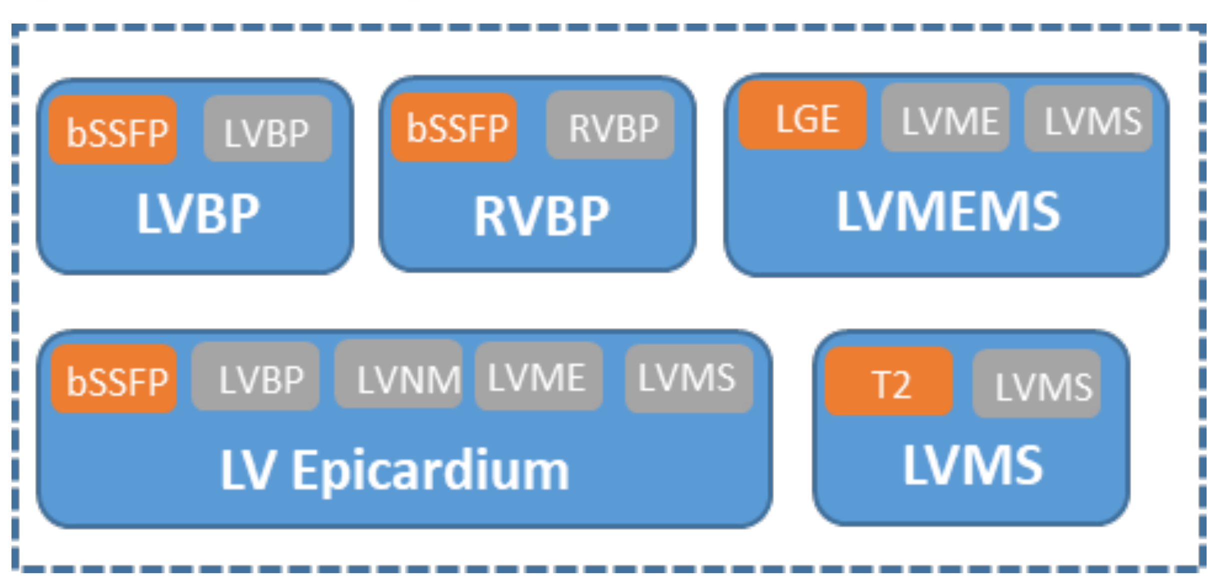


$$\begin{bmatrix} \cos(q) & \sin(q) & 0 \\ -\sin(q) & \cos(q) & 0 \\ 0 & 0 & 1 \end{bmatrix}$$

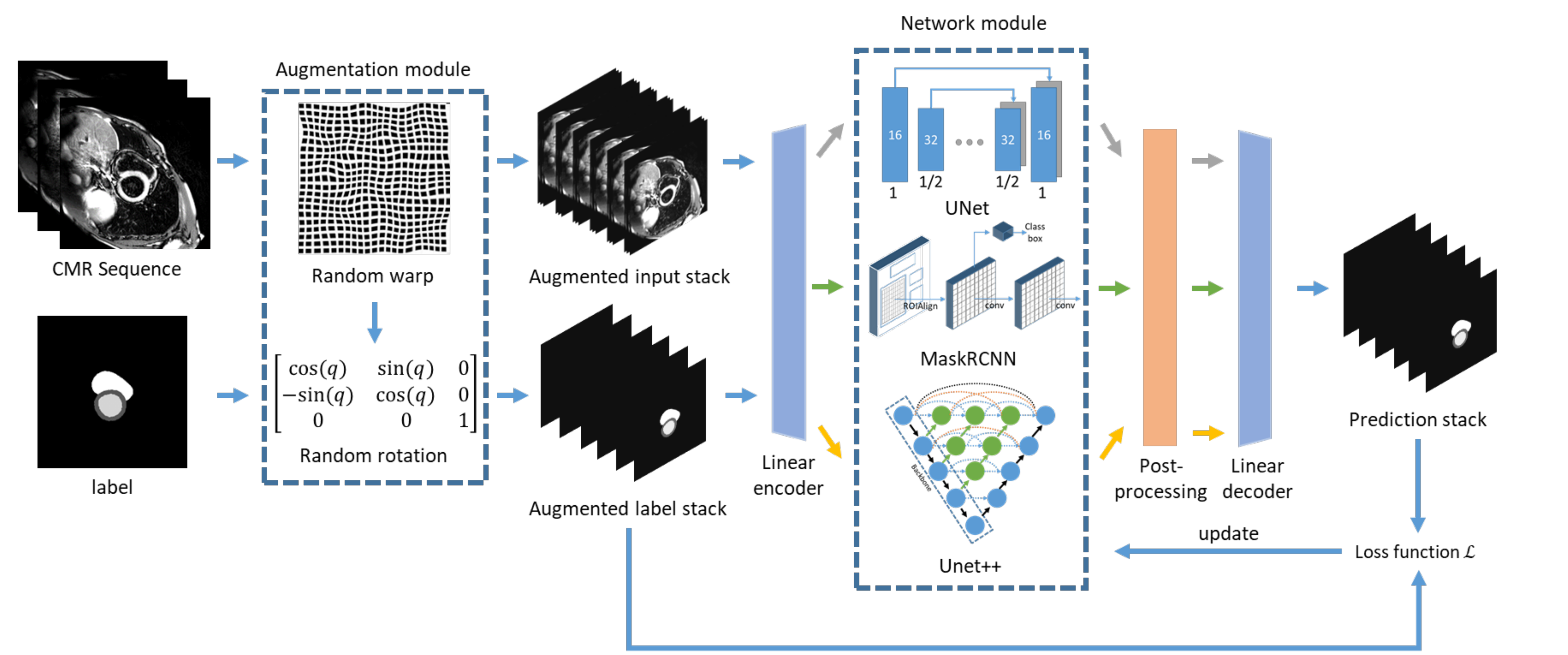
Random warp Random rotation

Linear Encoder

We encode the input and label sequences and produce five input blocks for network module.

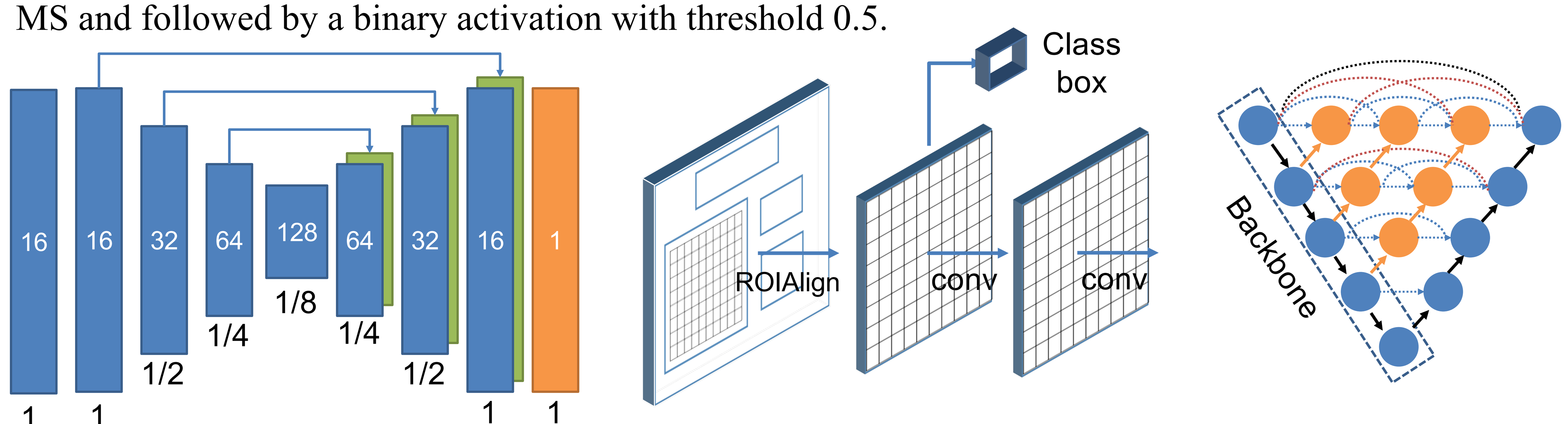


Overall Architecture



Network Module

We utilize three different architectures including U-net[2], MaskRCNN[3], and U-net++[4] with different input blocks for each model. The results are averaged from the three networks for LV ME+MS and LV MS and followed by a binary activation with threshold 0.5.



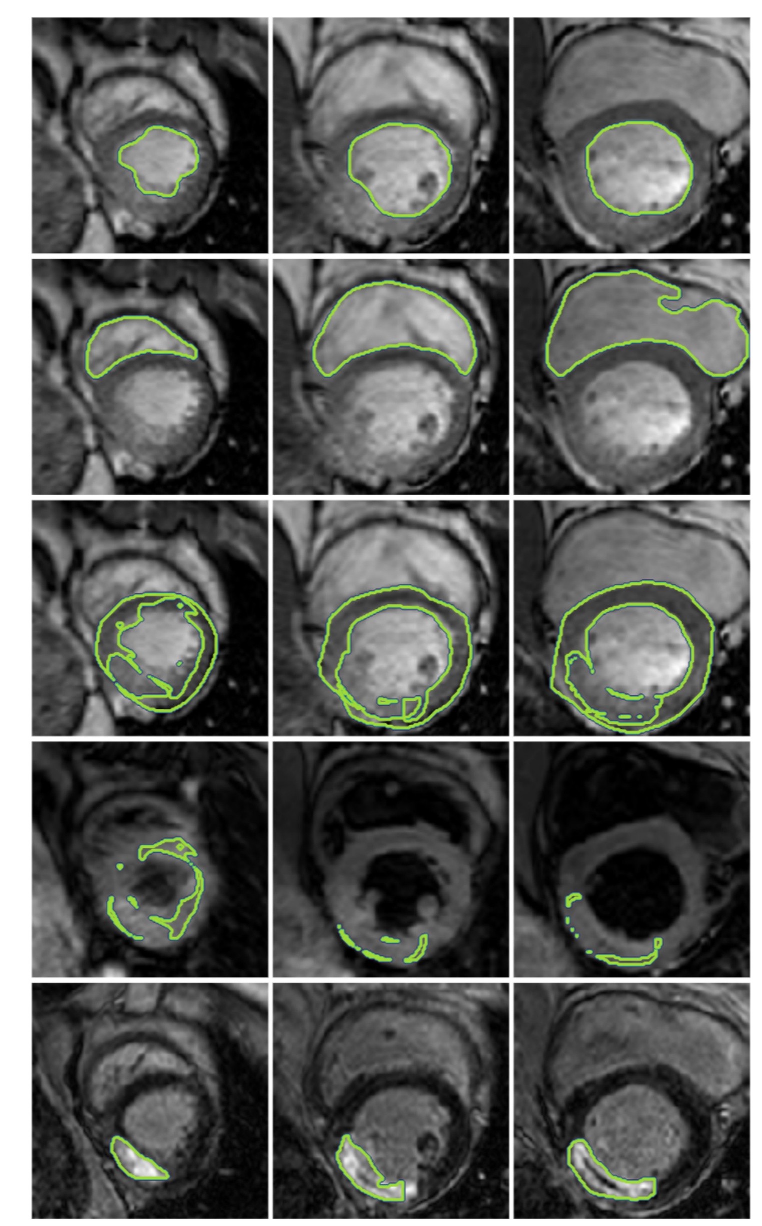
Linear Decoder

The linear decoder performs linear subtraction for predicted masks from the network module and includes a binary myocardium constraint for LV ME and LV MS.

$$P_i = \begin{cases} \sigma(\widetilde{P_0}) & i = 0 \\ \sigma(\widetilde{P_1}) & i = 1 \\ \sigma(\widetilde{P_2} - \widetilde{P_0} - \widetilde{P_3}) & i = 2 \\ \sigma(\widetilde{P_2} - \widetilde{P_0}) \circ \sigma(\widetilde{P_3} - \widetilde{P_4}) & i = 3 \\ \sigma(\widetilde{P_2} - \widetilde{P_0}) \circ \sigma(\widetilde{P_4}) & i = 4 \end{cases}$$

Results

The proposed method is evaluated over images acquired from a total of 20 cases including CMR sequences after trained and validated using 25 cases.



Methods	Dice metric (%) MS	Dice metric (%) ME+MS	Jaccard index(%) MS	Jaccard index(%) ME+MS
UNet	36.2 ± 23.2	43.2 ± 16.0	24.5 ± 18.1	28.8 ± 13.1
Proposed†	38.5 ± 24.3	54.2 ± 17.1	26.5 ± 18.9	38.9 ± 15.0
Proposed	$\mathbf{46.8 \pm 26.8}$	$\mathbf{55.7 \pm 18.3}$	$\mathbf{34.2 \pm 22.2}$	$\mathbf{40.5 \pm 16.3}$

† indicates without the linear encoder and decoder module.

References

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[3] He, Kaiming, et al. "Mask R-CNN." Proceedings of the IEEE International Conference on Computer Vision. 2017.

[4] Zhou, Zongwei, et al. "Unet++: Redesigning skip connections to exploit multiscale features in image segmentation." IEEE Transactions on Medical Imaging 39.6 (2019): 1856-1867.