DEEP LEARNING BASED REGISTRATION MODEL FOR IMMUNOHISTOCHEMISTRY HISTOPATHOLOGY IMAGES: HISTOREGNET

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Histopathology Image Registration

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- Image registration is as an optimization problem seeking for a spatial transformation between the fixed and moving image
- Registration of serial histopathology Whole-Slide Images (WSIs) is highly challenging due to their overwhelming sizes and strong artifacts
- Recently, ANHIR challenge was organized to systematically compare performances of image registration algorithms for microscopy histology images where none is deep learning method in addition to the limited performance
- We propose HistoRegNet, an end-to-end unsupervised patch-based deep learning registration model to spatially align IHC histopathology images
- Our method consists of an affine module, a deformable component, and a spatial transformer network
- The experimental results manifest that the proposed method outperforms the state-of-the-art methods consistently by multiple performance metrics

Data Description

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- Raw dataset: 50 IHC WSIs of serial mouse liver tissues stained by Sirius red for collagen visualization
- Each image patch is normalized by intensity before it is provided to the deep learning model
- Pre-processing step : IHC WSIs are pre-aligned with an intensity-based rigid registration method.
- The pre-aligned WSIs are partitioned to patches of size 256 x 256 for HistoRegNet and other DL-based models training for comparison
- Total no. of patches 38,164 are split into training, validation and testing sets by the ratio of 80:10:10
- Moving image set is generated synthetically by applying rigid, affine and elastic transformations to the fixed image set
- The rotation angle is randomly chosen from the range of [-20, 20] followed by applying a deformable transformation (i.e. diffeomorphic demon) to generate the moving image set
- The registration accuracy is evaluated by multiple metrics including NCC, Normalized Mutual Information(NMI), Structural Similarity Index (SSIM), Mean Squared Error (MSE), and Dice similarity, respectively
- Performance comparison with DirNet, FAIM, sseEMnet, FCN based multi-resolution registration model, and U-Net based registration and multiple conventional image registration methods, such as Ants, SimpleElastix and diffeomorphic demons

Quantitative Registration Performance

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Metric name	Method Name								
	HistoReg-Net	DirNet	FCN	UNet	FAIM	ssEMNet	Diffeomorphic demons	Elastix	Ants
NCC	0.337	-0.423	0.314	0.410	0.001	0.168	0.152	0.203	0.191
SSIM	0.279	0.459	0.310	0.385	0.362	0.297	0.405	0.463	0.279
MSE	0.003	0.289	0.015	0.117	0.108	0.004	3583.55	2813.45	2942.82
NMI	0.173	0.058	0.171	0.184	0.008	0.013	0.131	0.044	0.029

Table 1: Quantitative evaluations of registration results from HistoRegNet, state-of-the-art deep learning models, and conventional registration methods

Metric Name	Method Name							
	Histo-RegNet	DirNet	FCN	UNet	ssEMNet	Diffeomorphic Demons	Elastix	Ants
Dice	0.823	0.342	0.7435	0.46	0.807	0.722	0.893	0.443

Table 2: Comparison of Dice co-efficient from HistoRegNet, state-of-the-art deep learning models, and conventional registration methods

Patch Registration Performance Comparison

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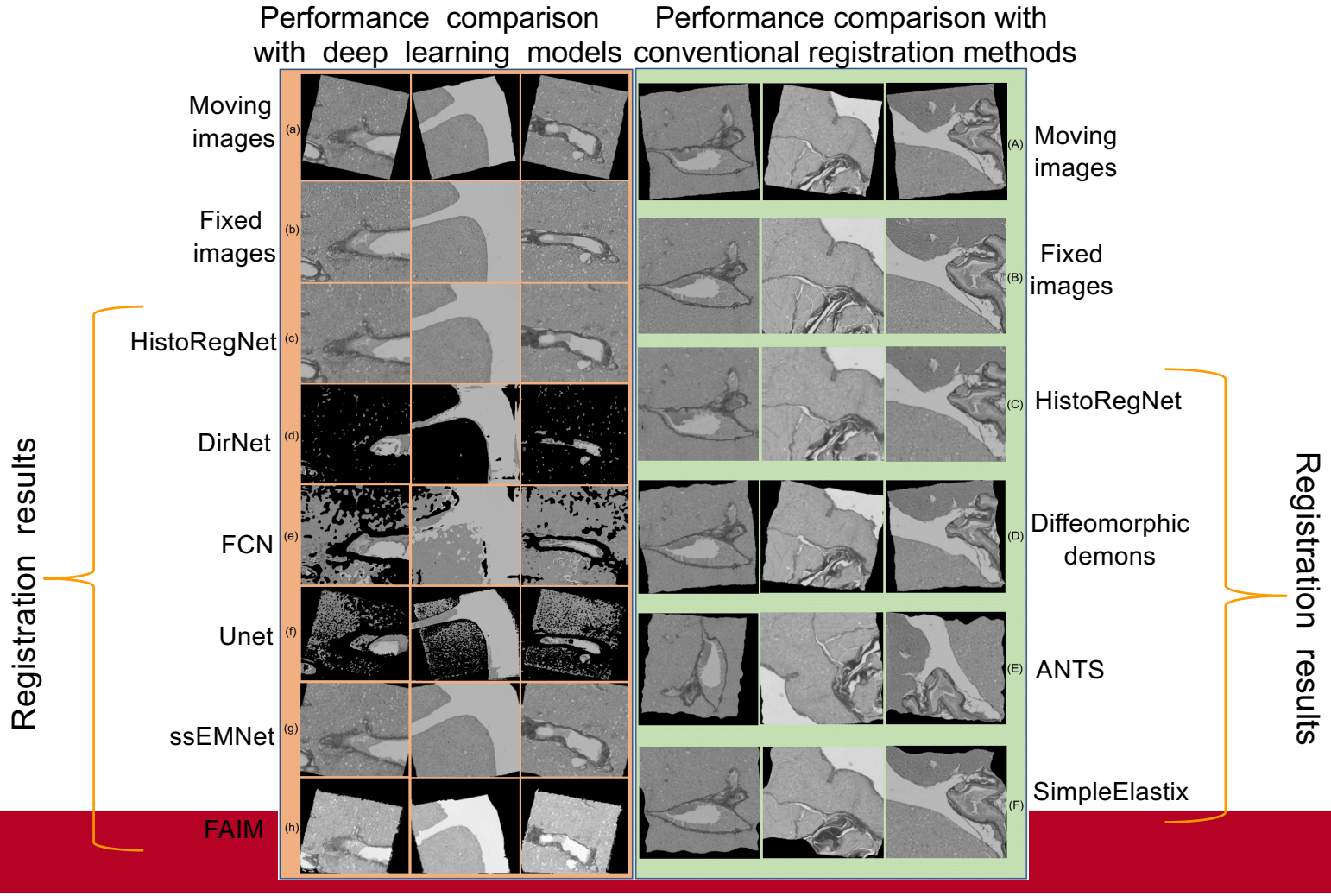

WSI Registration Performance comparison

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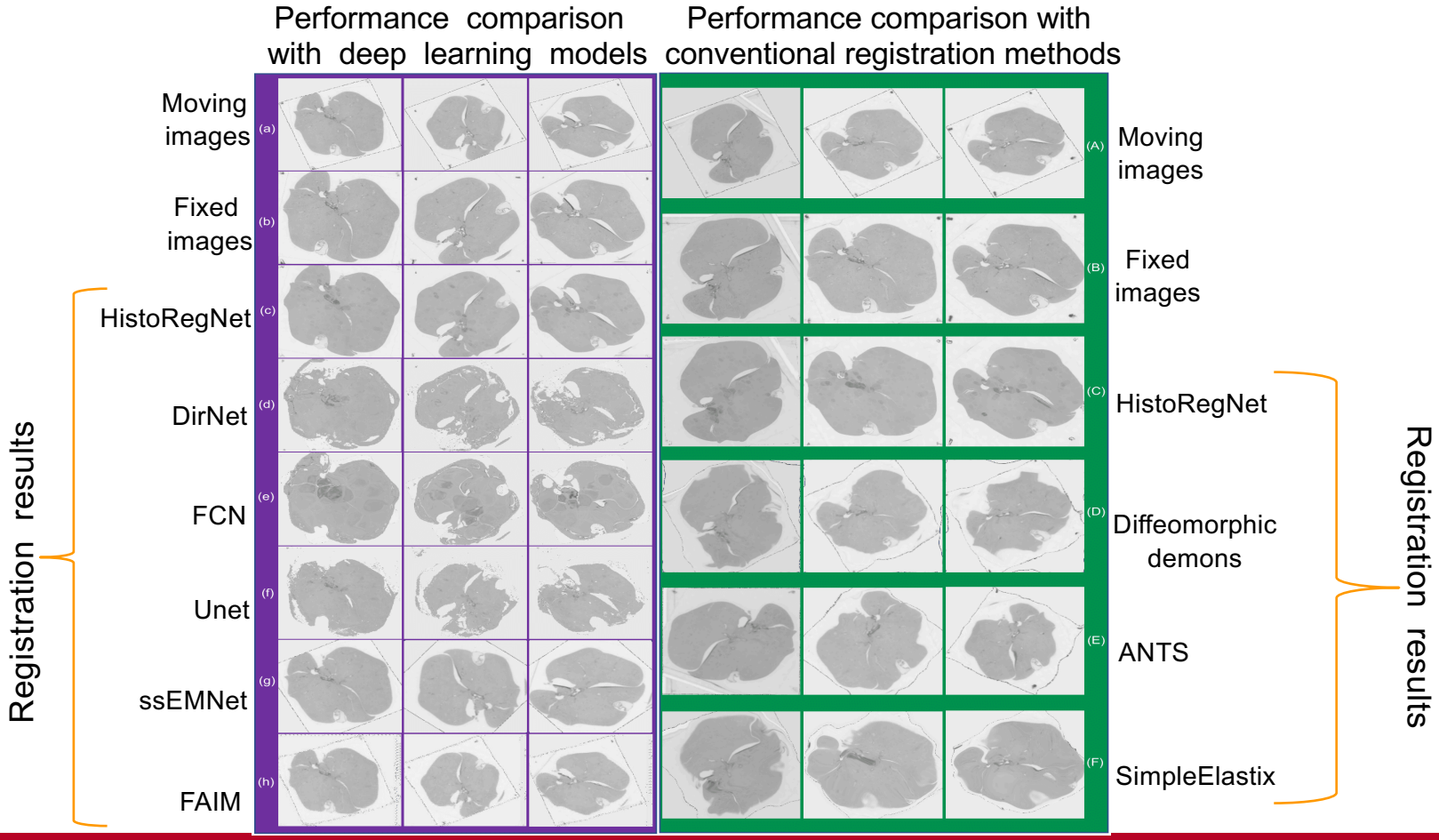

Analysis & Conclusion

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- HistoRegNet can generate high quality registered images well aligned with the fixed images
- Results from DirNet, FCN and UNet are reasonably aligned with the fixed images, but there are large tissue regions with wrong mappings
- FAIM model fail to adequately align to the moving images
- Conventional methods produce warped images poorly aligned with the fixed images
- Visual result confirms that HistoRegNet is superior to the state-of-the-art deep learning models and conventional methods for both low-resolution WSIs and high-resolution image patch registration
- HistoRegNet model achieves the best performance by the metrics of SSIM and MSE
- Although the highest dice score is achieved by SimpleElastix, this method is subject to over-deformation issues