Deformable Histopathology-MRI Image Registration using Deep Learning

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INTRODUCTION

It is important to correlate histopathology images with radiological images to establish disease signatures and radiomic features defined on radiological images. Although modern imaging modalities such as CT and MRI can provide detailed patient anatomy information, the pathological interpretation of these images may be difficult and subject to physician's experiences. In contrast, histopathology images which provide tissue structure at cellular level is considered the gold standard for cancer diagnosis. Therefore, histopathological images fusion with radiological images helps interpretation and computer-aided disease classification and segmentation. In this study, a thin-plate-spline deformation model was calculated from prostate surface difference between the MRI slice and the histopathology. A DL-based method was proposed to deformably register the histopathology image to the MRI. The proposed method utilizes modality independent neighborhood descriptor (MIND) as the image similarity measure during network training. Tested on 10 cases, the SSIM between the two were on average 0.83 and 0.90 before and after registration

Contributions of our study are:

- The initial surface registration and thin-plate-spline motion modeling provides a rough prostate shape correction to facilitate following DL-based image registration process.
- The use of MIND similarity measure is an effective way of establishing image appearance correlation between different modalities.

METHODS

Datasets:

- Public datasets were downloaded from 'Cancer Imaging Archive'.
- The datasets include 28 T1, T2, DWI and DCE acquired with 3 Tesla MRI, along with corresponding histopathology images of radical prostatectomy specimens [1].
- The histology images, originally digitized at 20x magnification using Aperio slide scanner, were down-sampled by a factor of 50 to expedite image analysis..

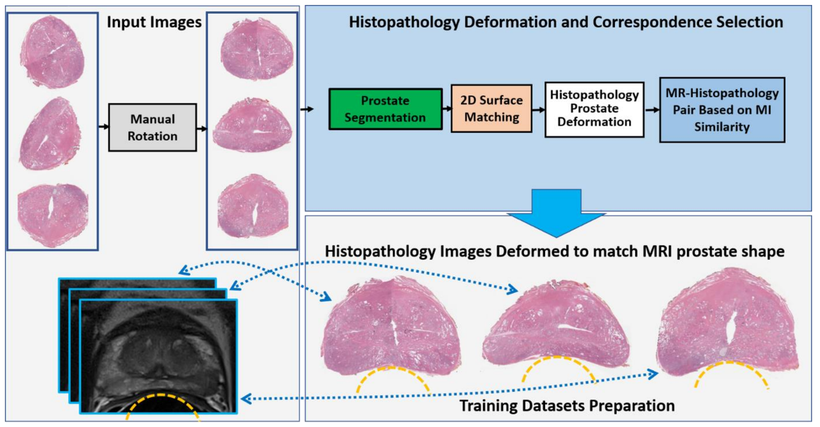

Fig 1. Training datasets preparation. Histopathology images were manually rotated. Prostate was contoured on both histopathology and MRI images.

- MRI and histology prostate images were first preprocessed to generate its corresponding modality independent neighborhood descriptor (MIND) feature maps [2]
- The network consists of 12 convolutional layers and three max pooling layers.

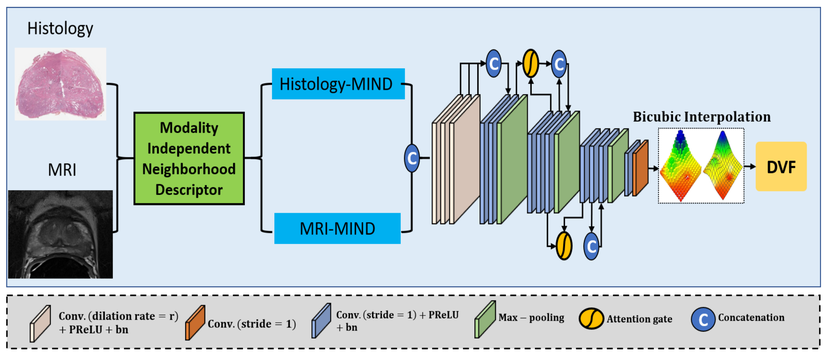

Fig 2. Schematic flow chart of the proposed method for nonrigid histology and MR image registration.

- We can see that the prostate is deformed by the endorectal MRI coil, resulting in a more compressed prostate shape than the histological images.
- After registration, the shape of the prostate is well aligned

RESULTS

Table 1. The structural similarity index between the MRI and histopathology before and after registration for 10 cases.

	Case 1	Case 2	Case 3	Case 4	Case 5	Case 6	Case 7	Case 8	Case 9	Case 10	Mean
Before	0.80	0.89	0.87	0.86	0.82	0.81	0.83	0.80	0.82	0.83	0.83
After	0.90	0.91	0.92	0.90	0.90	0.90	0.87	0.90	0.91	0.89	0.90

- To evaluate the alignment, structural similarity index (SSIM) between the MRI and histopathology was calculated before and after registration for 10 testing cases.
- The SSIM was increased from 0.83 before registration to 0.90 after registration.

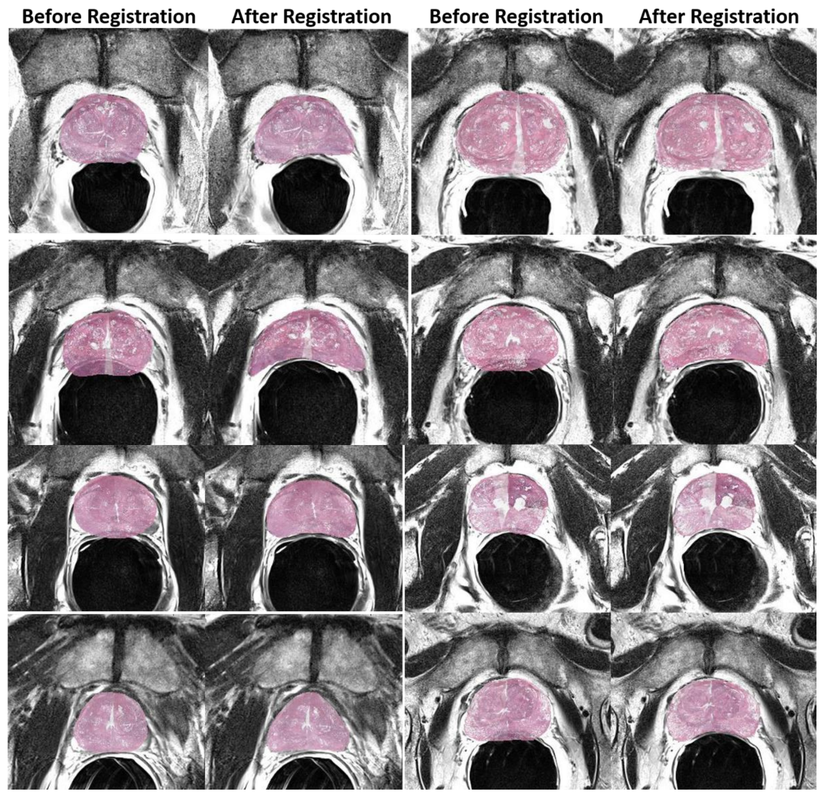

Fig 3. Histopathology images fused with MRI for four patients before and after registration.

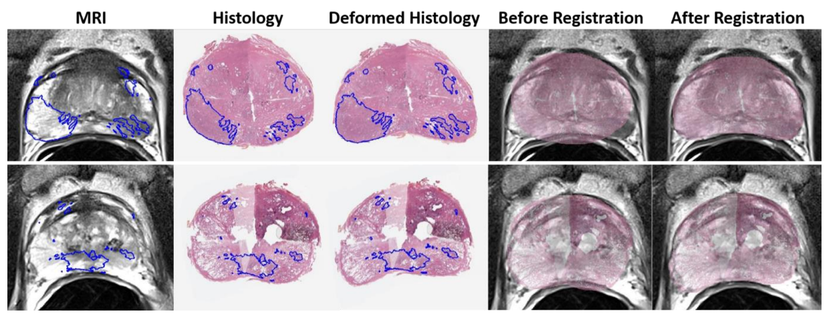

Fig 4. From left to right are MRI with mapped histological annotation, original histology with annotation, deformed histology with mapped annotation, image fusion between the histology and MRI before and after the registration.

CONCLUSIONS

A novel multi-step slice-to-volume registration method was proposed to align pre-operative MRI volume with histopathology images of prostate specimens after radical prostatectomy. The proposed method could be used to correlate disease signatures with radiomic image features to support computer-aided prostate cancer diagnosis and lesion annotation in the future.

REFERENCES

1. Toth, R., et al., Histostitche"": An informatics software platform for reconstructing whole-mount prostate histology using the extensible imaging platform framework. Journal of Pathology Informatics, 2014.
2. Heinrich, M., et al., MIND: Modality independent neighbourhood descriptor for multi-modal deformable registration. Medical image analysis, 2012. 16 7: p. 1423-35.