Structured Decision Forests For Multi-modal Ultrasound Image Registration

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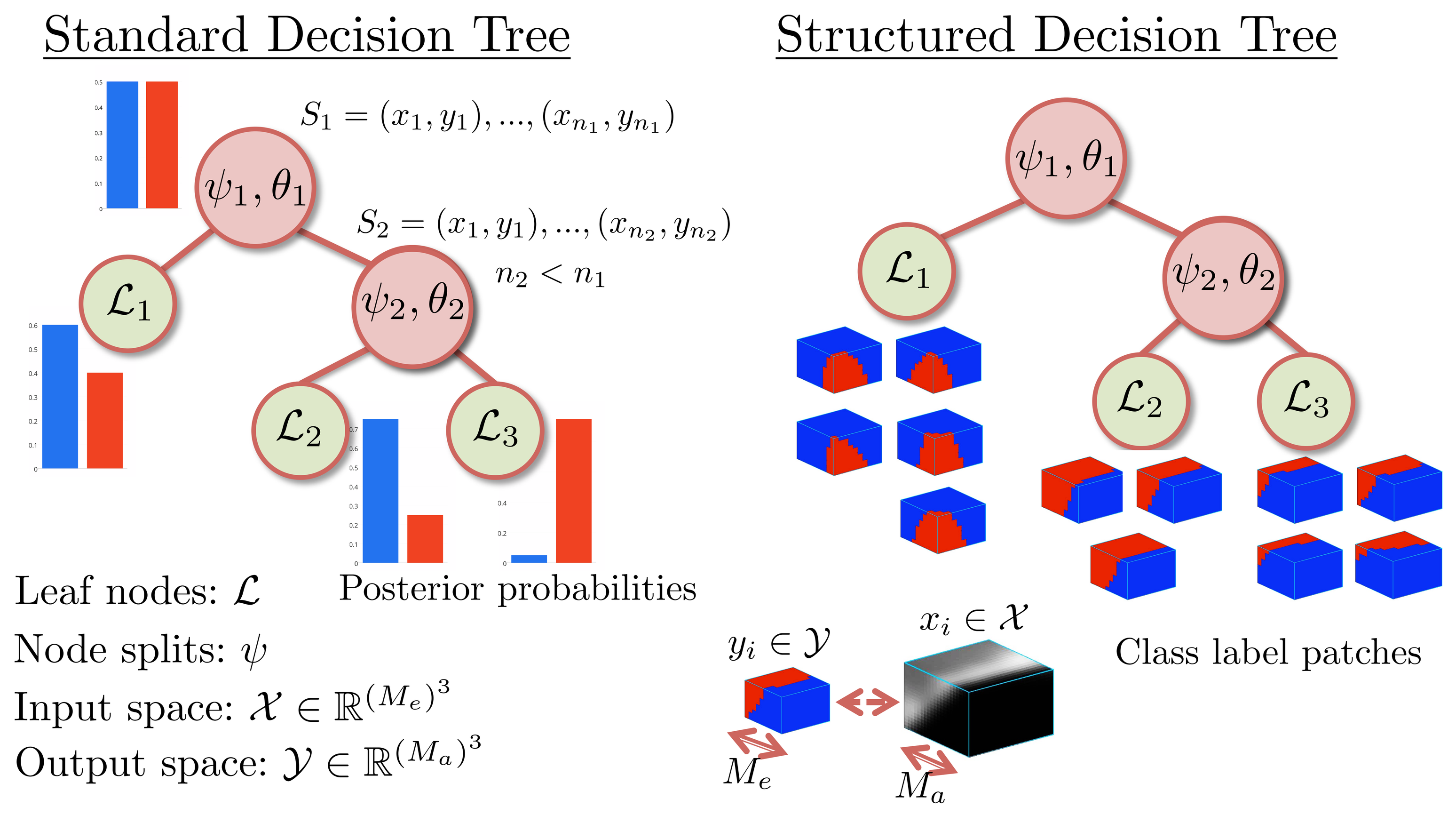
Motivation

Interventional procedures in cardiovascular diseases often require ultrasound (US) image guidance. These US images must be combined with pre-operatively acquired tomographic images to provide a roadmap for the intervention. Existing multi-modal US registration techniques often do not achieve reliable registration due to low US image quality. To address this problem, a novel medical image representation based on a trained decision forest named probabilistic edge map (PEM) is proposed. PEMs generate similar anatomical representations from different modalities and can thus guide a multi-modal image registration more robustly and accurately.

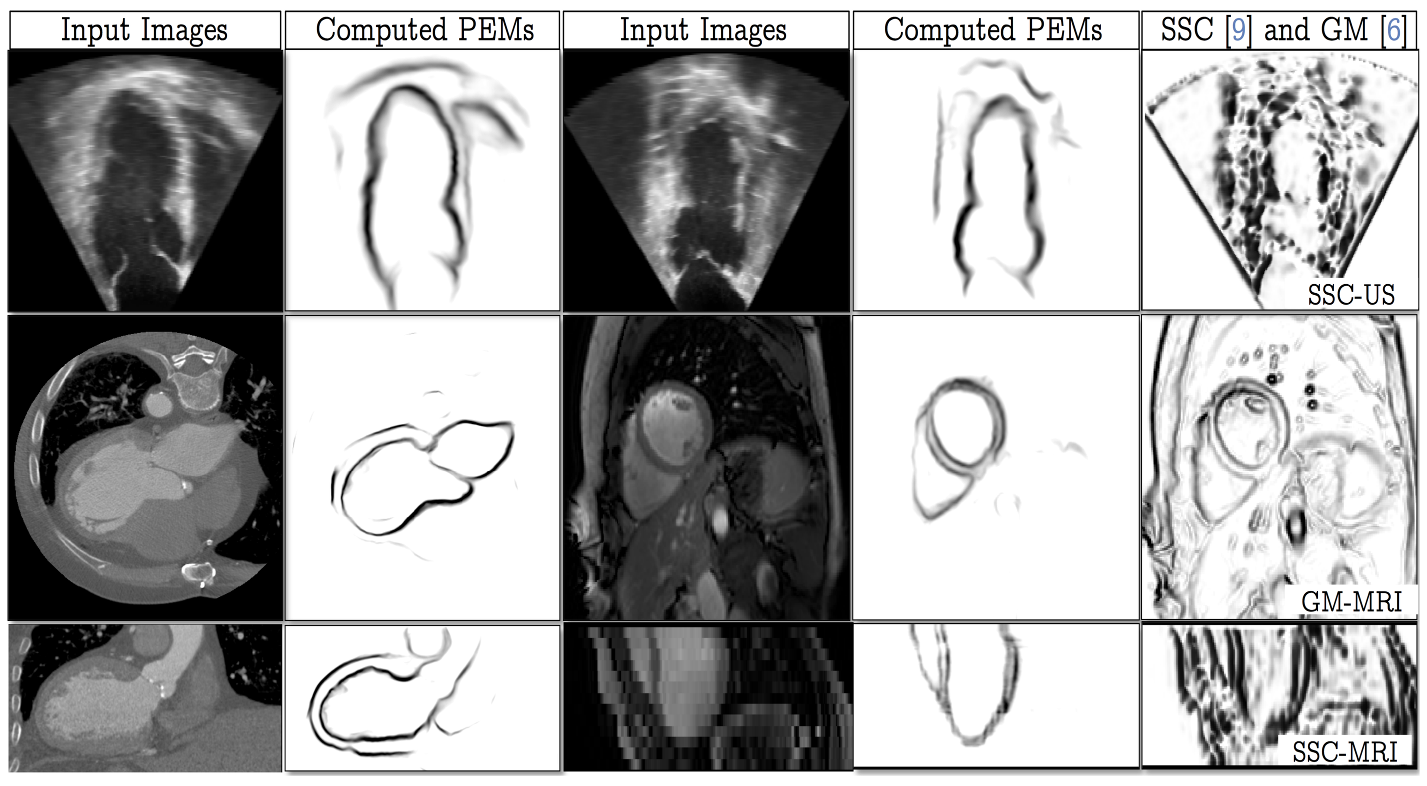
Structured Decision Forest (SDF)



⇒ In SDFs [1], the output space $\mathcal{Y}$ is defined by structured segmentation labels rather than a single label $y_i \in \{0, 1\}$ posterior distribution.

⇒ The standard entropy based training objectives can be used to train weak classifiers as long as the label patches can be clustered into two or more subgroups at each tree node split.

Probabilistic Edge Maps (PEMs)



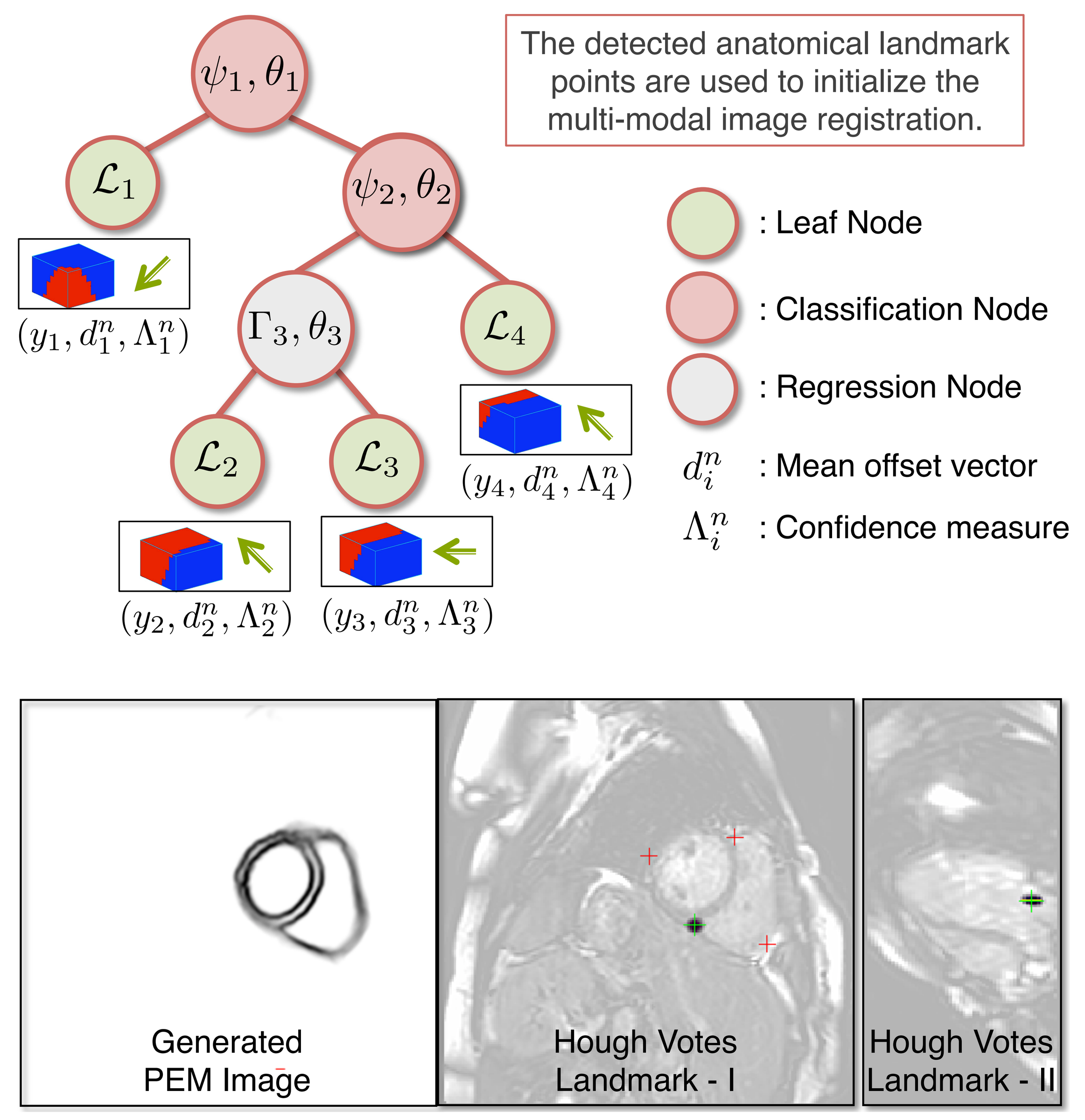
Edge Map Properties

⇒ Modality independent and computationally efficient (20 sec/image)

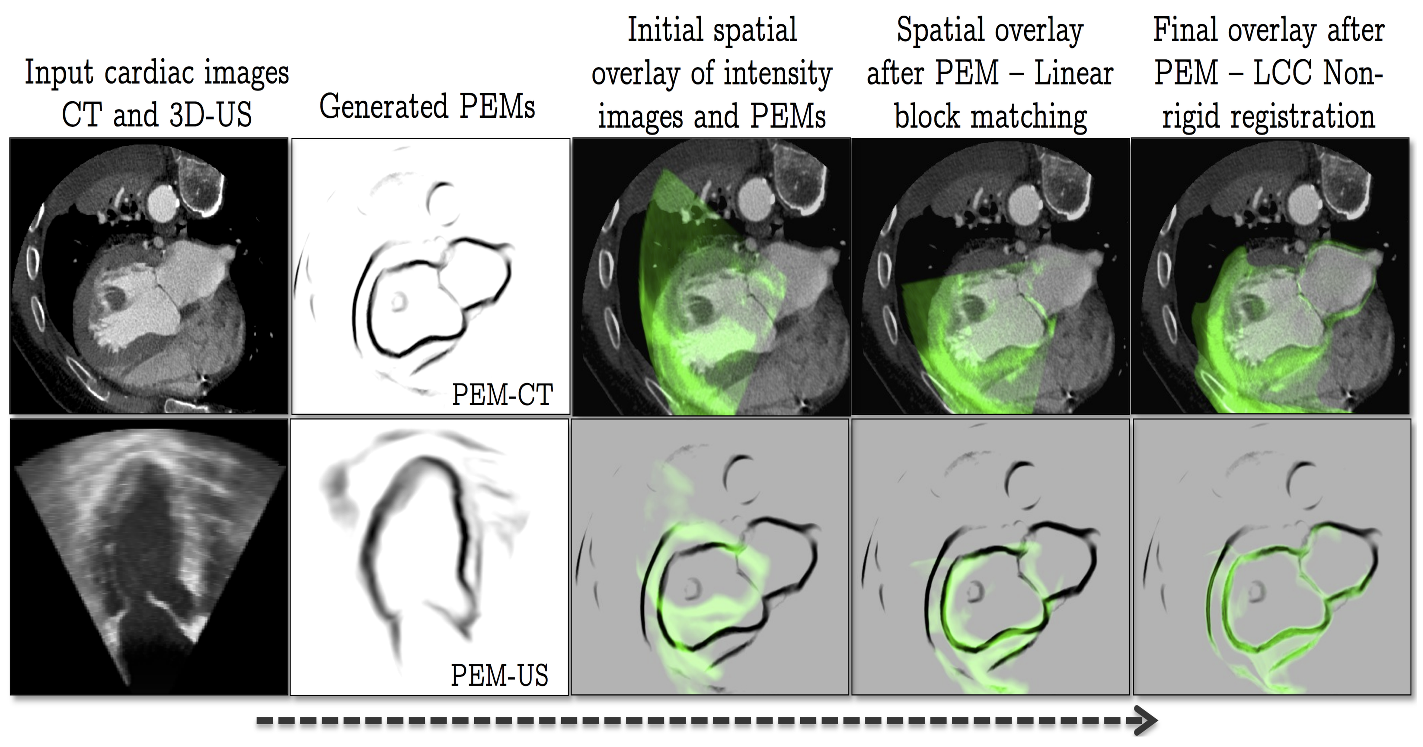
⇒ Compared to the self-similarity (SSC) [2] and gradient magnitude (GM) representations, PEMs produce more accurate and smoother anatomical representations.

⇒ The classifiers can be trained to be target organ selective (e.g. only myocardium)

Structured Regression



Multi-modal Image Registration Framework



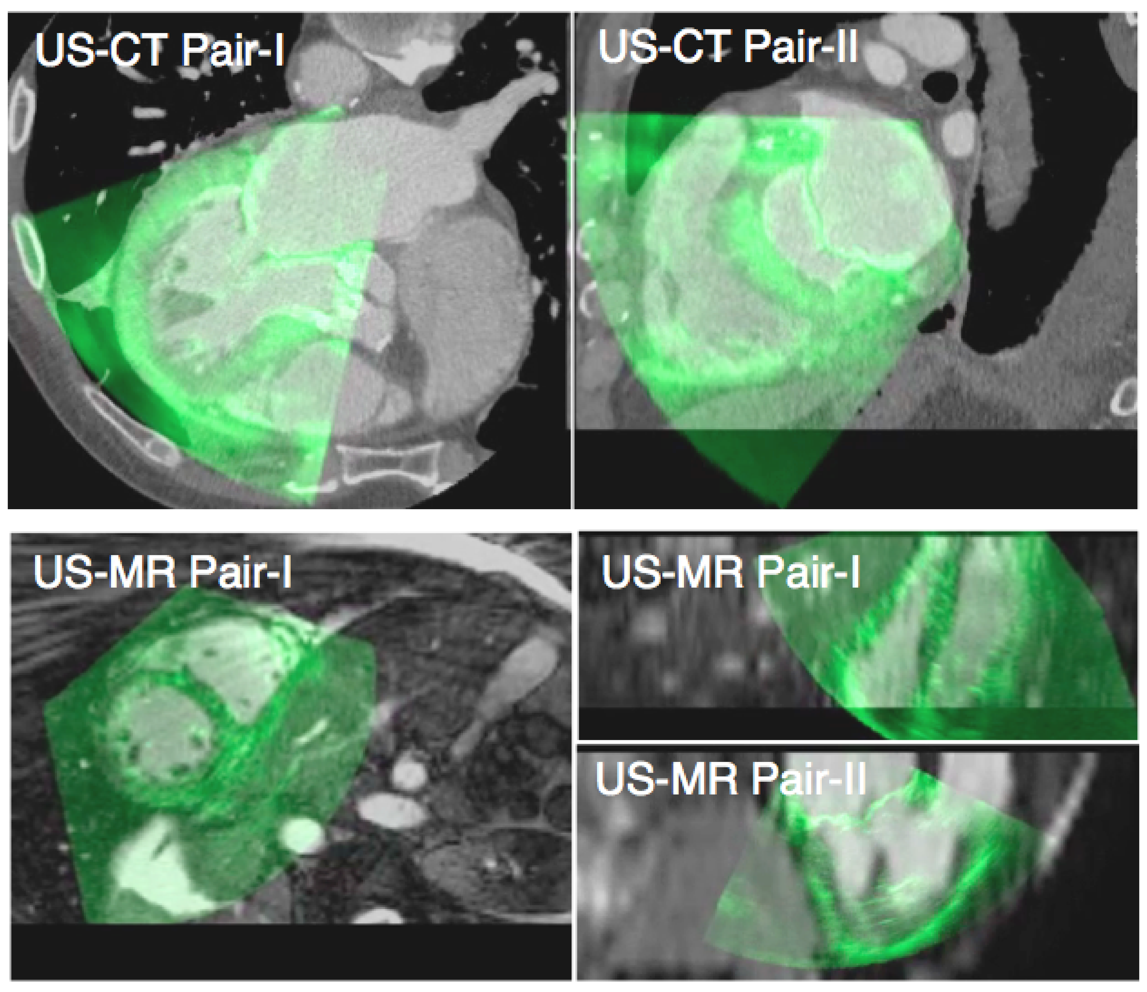
⇒ The images are first mapped into the PEM space, and then they are registered using only the generated PEM representations.

⇒ Local correlation coefficient is used as the similarity metric.

⇒ The images are first globally and then locally aligned using robust block matching and B-spline FFD based registration methods.

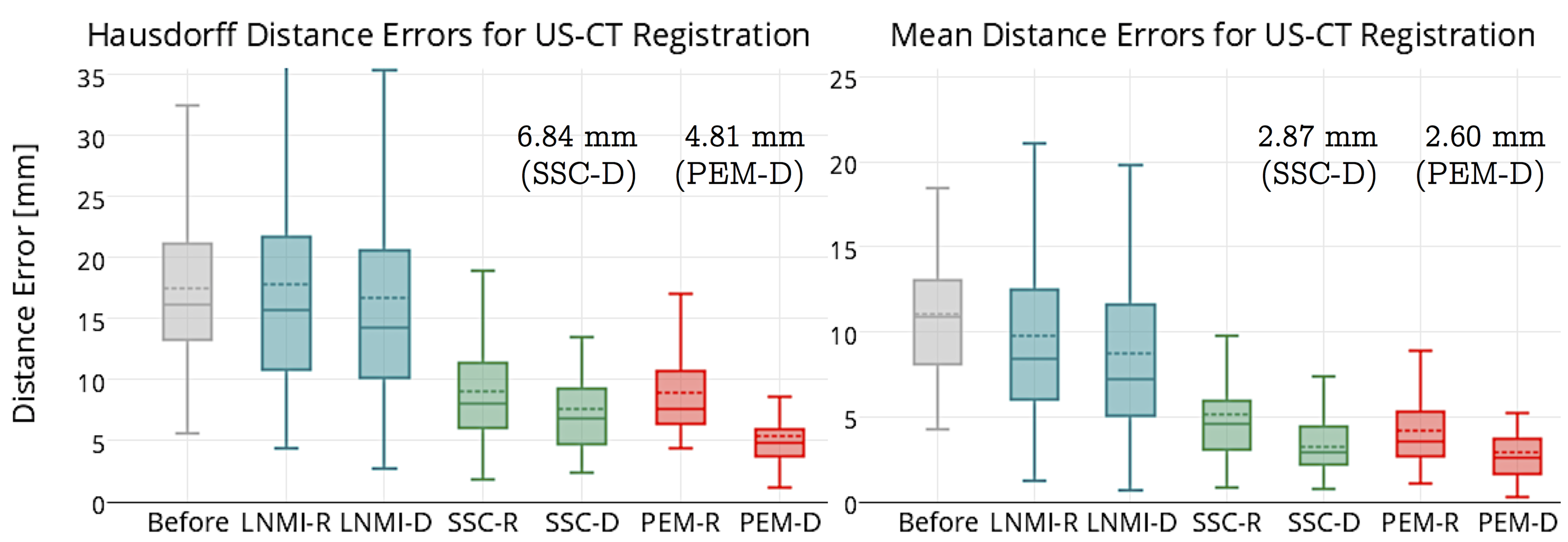
Registration Results

The images are overlaid on top of each other. The US images are shown in green color map and the MR/CT images are in gray in color map.

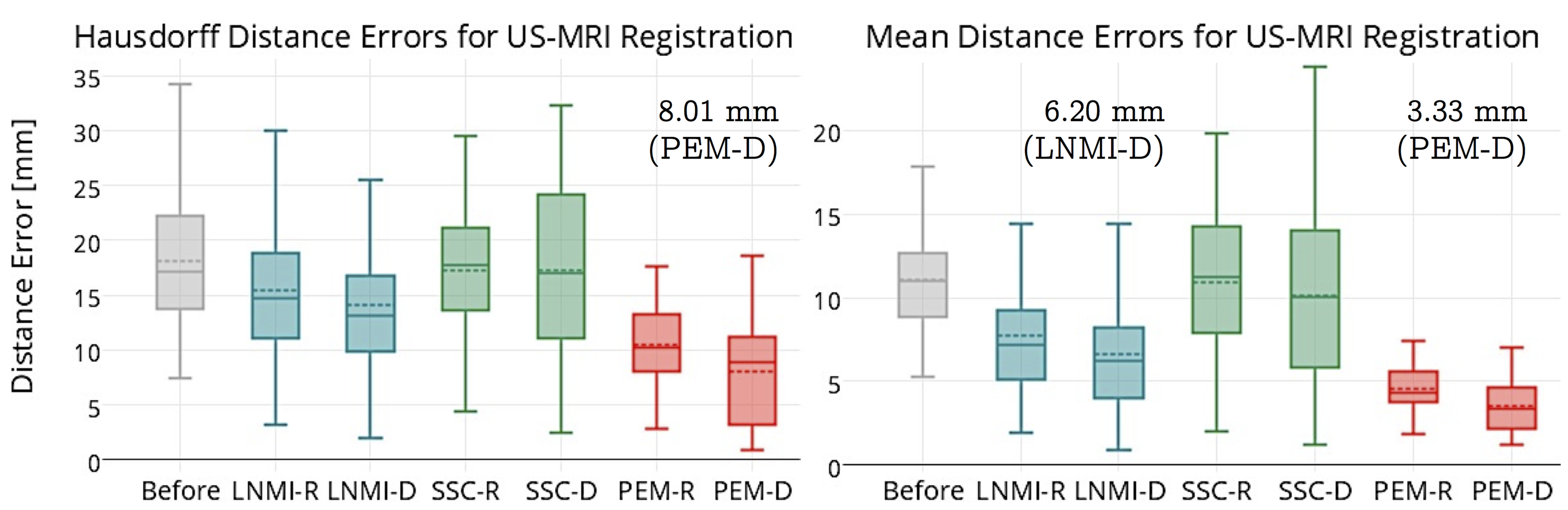


Spatial Alignment of US/CT & US/MR Images

US/CT and US/MR Image Registration Evaluation



US/CT registration errors after rigid (-R) and deformable (-D) alignments



US/MR registration errors after rigid (-R) and deformable (-D) alignments

Experimental Details

⇒ The distance errors were computed using seven anatomical landmarks: apex (1), apical (2), basal (2), and mid-ventricle parts (2).

⇒ 17 pairs of images were used in the evaluation, which are disjoint from the PEM training dataset of cardiac images (50-80 images/modality).

⇒ The proposed PEM representation is compared against the self-similarity descriptor (SSC) [2] and local-NMI (LNMI) [3] image similarity based registration methods.

References

[1] Dollár, P., Zitnick, C.L.: Structured forests for fast edge detection. In: ICCV (2013)

[2] Heinrich, M.P., et al.: Towards realtime multimodal fusion for image-guided interventions using self-similarities. In: MICCAI (2013)

[3] Klein, S., et al.: Automatic segmentation of the prostate in 3D MR images by atlas matching using localized mutual information. Medical Physics 35(4), 1407–17 (2008)