Introduction

- High-resolution (HR) magnetic resonance imaging (MRI) enables 3-D imaging of delicate anatomical structures
- HR MRI can support e.g. the early detection of pathologies
- However, the HR MR acquisition leads to long scan times
- Reduced acquisition times while retaining high resolution
- Retrospective resolution enhancement of low-resolution (LR) MR volumes with volumetric super-resolution forests (VSRF)

Material and Methods

VSRF builds on random forest regression [1] to learn a locally linear mapping between LR and HR 3-D patches (Fig. 1).

Random Forest Training
- At each node: optimization of variance-based quality measure [1]
- At the leaves: learning mapping using ridge regression [1]

Random Forest Inference
- LR feature vectors traverse each of the trees
- Median ensemble model to combine forest predictions

Feature and Patch Extraction
- Customized features (1st and 2nd order derivatives, edge magnitude and orientation) computed from upscaled LR volume
- Extract n x n x n patches from feature and difference volumes
- PCA dimensionality reduction of LR feature vector

Results and Discussion

MRI Datasets
- Mouse brain (Train 13, Validation 3, Test 5 volumes)
- Kirby 21 human brain [2] (Train 10, Validation 2, Test 30 volumes)

Comparison of VSRF to State-of-the-Arts
- Considerably sharper than competing methods (Fig. 2,3)
- Achieves highest PSNR and SSIM [3] values (Tab. 1)

Influence of Parameters for VSRF
- Effectiveness even with a small amount of training data (Fig. 4a)
- Median ensemble model adds additional stability against outliers (Fig. 4b) compared to average ensemble
- Further improvements by customized features (Fig. 4b)

Table 1: Quantitative evaluation of image quality with mean peak signal-to-noise ratio (PSNR) and structural similarity (SSIM) [3] (SR factor 2).

<table>
<thead>
<tr>
<th>Dataset</th>
<th>Measure</th>
<th>Tricubic</th>
<th>NLMU [4]</th>
<th>Pd. 3-D SRCNN</th>
<th>Pd. 3-D SRF</th>
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<td>Mouse</td>
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Conclusion

- Visual and quantitative improvement in image quality
- Fast training and inference performance
- Effective even with limited amount of training data
- Adaptation into clinical workflows seems appealing

References


Figure 1: Training (a) and Inference (b) of Volumetric Super-Resolution Forests (VSRF)

Figure 2: Sagittal slice of the mouse brain MRI dataset (SR factor 2).

Figure 3: Coronal slice of the human brain Kirby 21 MRI dataset [2] (SR factor 2).

Figure 4: Influence of the number of (a) training volumes, (b) features and the ensemble model.