STRESS: Super-Resolution for Dynamic Fetal MRI using Self-Supervised Learning

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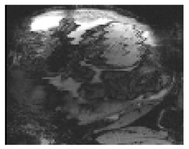
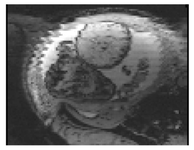
Motivation

Dynamic fetal MRI and fetal motion
- Fetal motion is unpredictable and rapid
- Inter-slice motion artifacts
- Fast imaging, e.g., EPI → low SNR / low resolution
- Ground truth high resolution data are unavailable

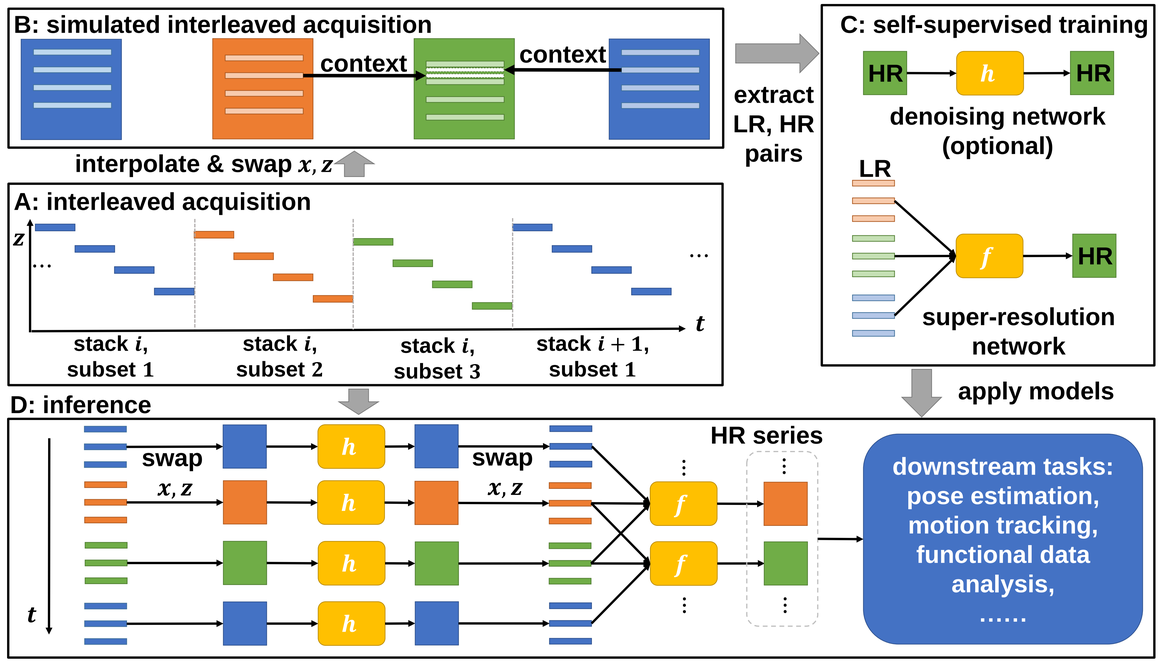



Slice-to-volume registration
- Reconstruct a static and motion-free volume
- Require multiple stacks at different orientations

Goals
- Super-resolution for dynamic fetal MRI (4D)
- Using the characteristic of interleaved slice acquisition
- Self supervised learning

Method: Spatio-Temporal Resolution Enhancement with Simulated Scans

Key Ideas: perform interleaved acquisition along the other axis on the originally acquired data to generate pairs of low- and high-resolution images to train self-supervised neural networks



Experiments

Baseline methods
- Spatial Interpolation (SI)
- Temporal Interpolation (TI)
- Spatio-Temporal Interpolation (STI)
- SMORE [1]

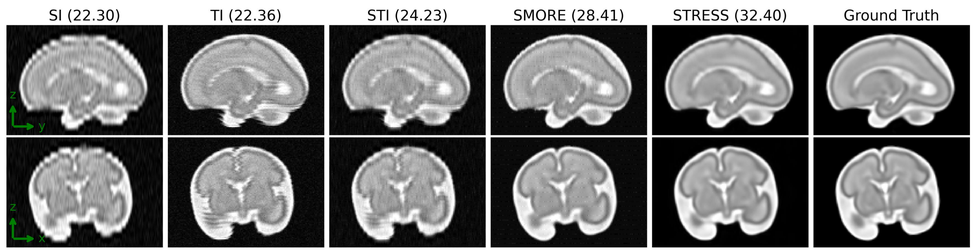
Simulated data
- Fetal brain data [2]
- Simulated motion with real trajectories
- Different interleave parameters, N_I
- Simulated Rician noise

In utero fetal EPI data
- Multi-slice EPI time series [3]
- Evaluate with fetal pose estimation [4]

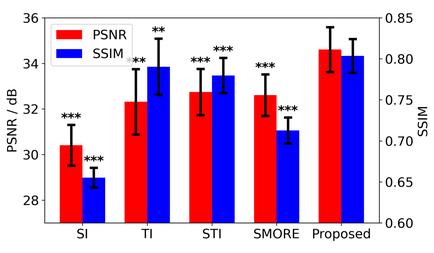
Results

simulated data

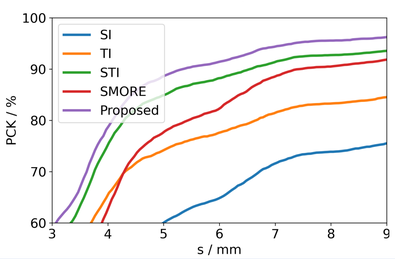
Models	PSNR			SSIM		
	$N_I = 2$	$N_I = 4$	$N_I = 6$	$N_I = 2$	$N_I = 4$	$N_I = 6$
SI	28.42	22.98	19.39	.8849	.8114	.6686
TI	25.31	25.48	25.52	.8258	.8273	.8288
STI	27.94	25.75	23.37	.8846	.8711	.8182
SMORE [1]	30.38	28.57	24.27	.9006	.8916	.8093
STRESS	**33.51**	**32.81**	**28.24**	**.9702**	**.9655**	**.9213**

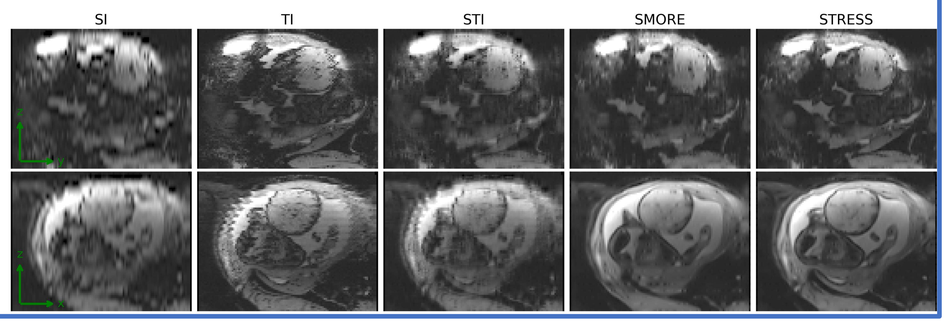


In utero fetal EPI data



Downstream task: pose estimation





Conclusions

In super-resolution of dynamic fetal imaging, internal spatial information within each frame and temporal correlation between adjacent frames can be combined to improve image quality and restore details corrupted by fetal motion.

References

[1] Zhao, C., et al. Smore: A self-supervised anti-aliasing and super-resolution algorithm for mri using deep learning. TMI 2020
[2] Gholipour, A., et al. A normative spatiotemporal mri atlas of the fetal brain for automatic segmentation and analysis of early brain growth. Scientific reports 7(1), 1–13 (2017)
[3] Luo, J., et al. In vivo quantification of placental insufficiency by bold mri: a human study. Scientific reports 7(1), 1–10 (2017)
[4] Xu, J., et al. Fetal pose estimation in volumetric mri using a 3d convolution neural network. MICCAI 2019