T_2 Shuffling - Dynamic MRI Dimensionality Reduction

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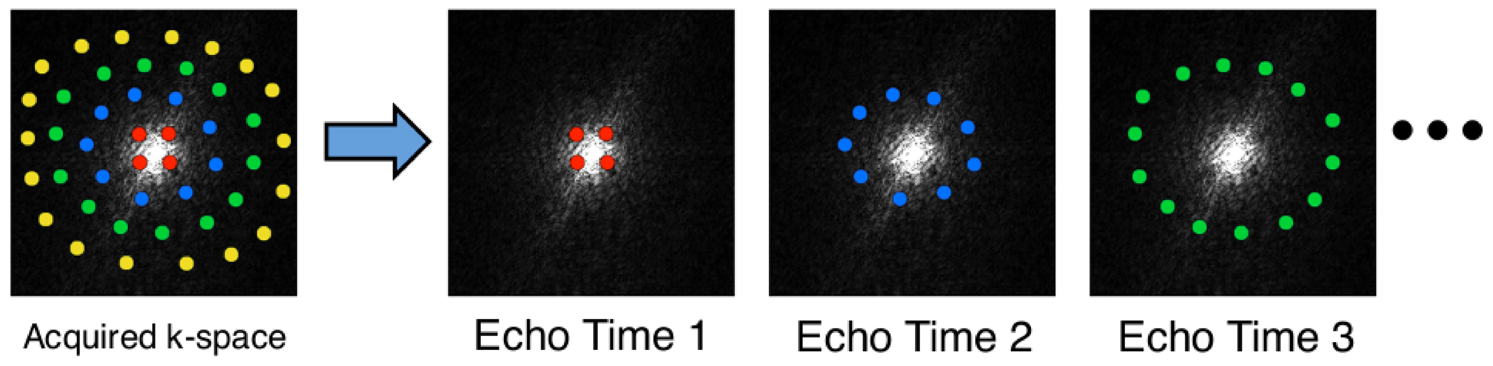
Introduction

- MRI is a safe and powerful tool that can be used to image both anatomy and function.
- Acquiring 3D MRI over time has several clinical applications:
  - Reduce image blur from conventional 3D acquisition.
  - Visualize signal behavior over time.
  - Quantify tissue parameters in anatomy.
- We aim to find a robust and low-dimensional representation of the dynamic images.

Motivation

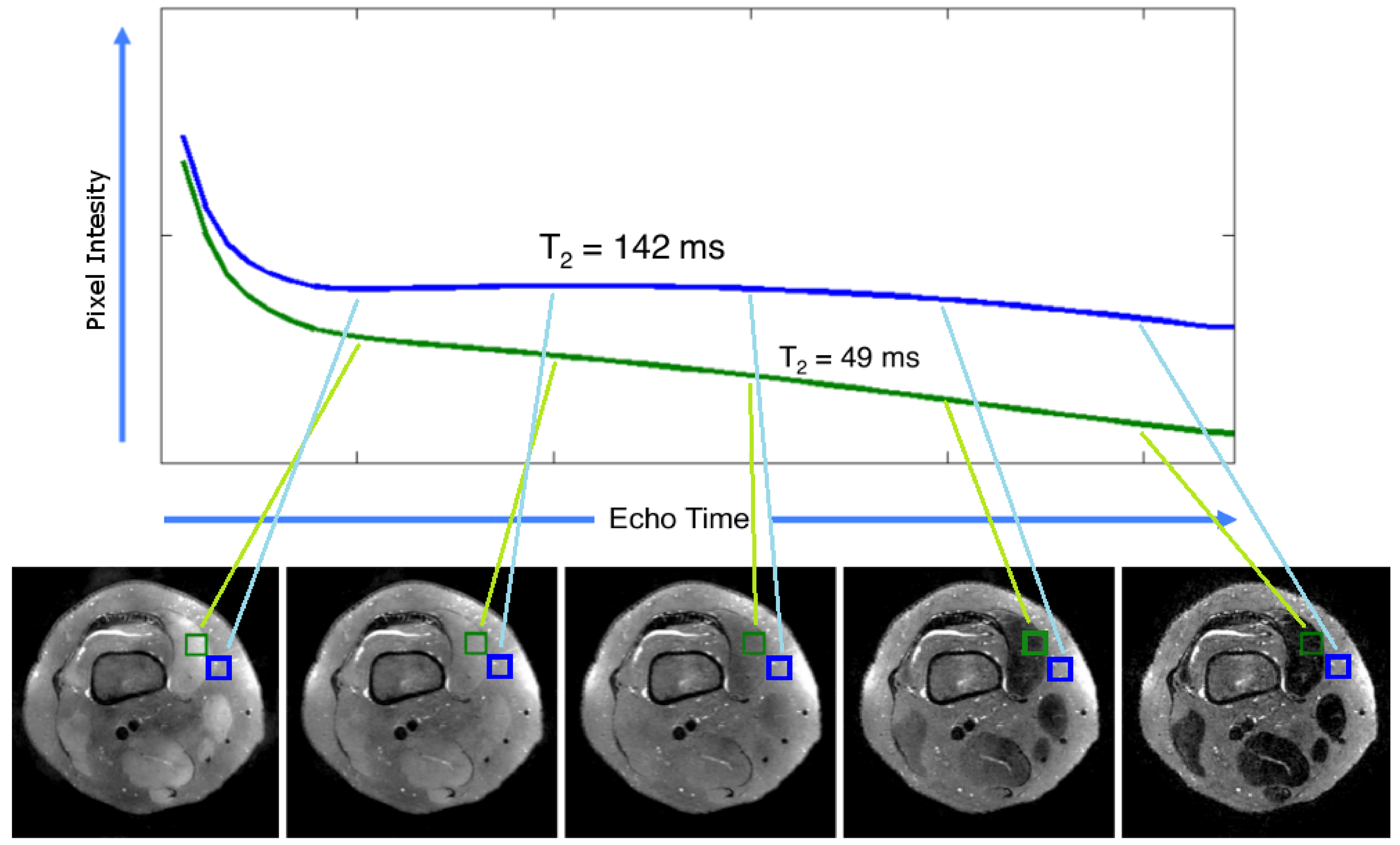
- The image's Fourier transform (called k-space) is sampled over time.
- The samples are grouped into time-consistent k-space bins.



- Goal: Clinically feasible scan times by reducing dimensionality with low model error.

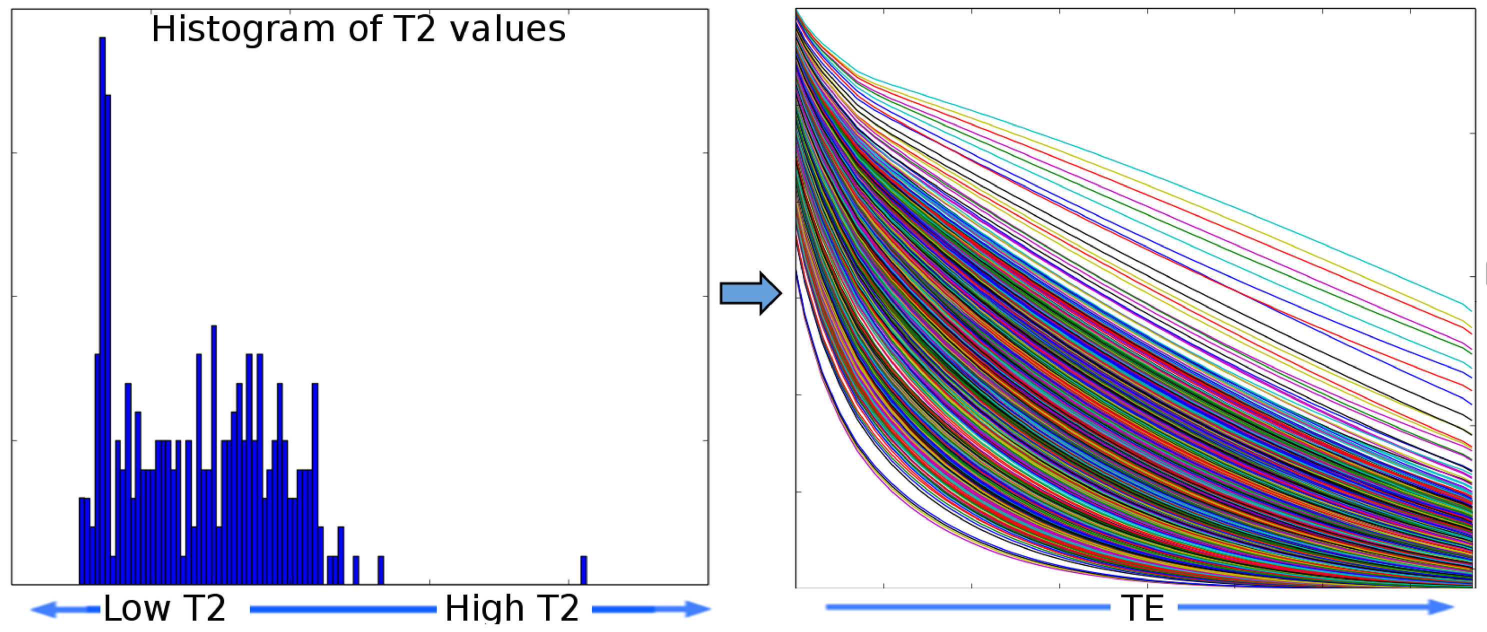
Background

Signal evolution of pixel intensity over time parametrized by tissue T_2 relaxation.



Signals evolutions are correlated $\implies$ data captured by a low-dimensional subspace.

1. Estimate T_2 distribution from tissue in anatomy of interest.
2. Simulate curves with T_2 values drawn from distribution.
3. Form matrix X with signals as columns arranged in increasing order of ℓ_2 norm.

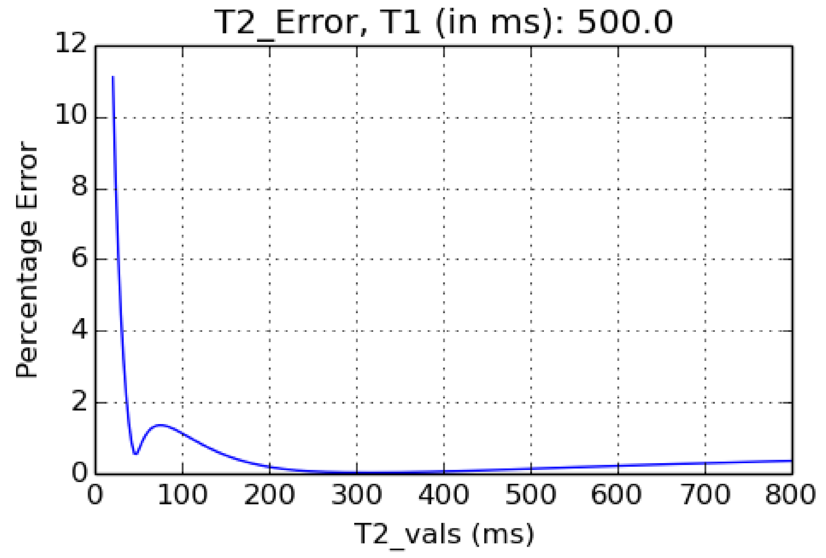


Methods and Results

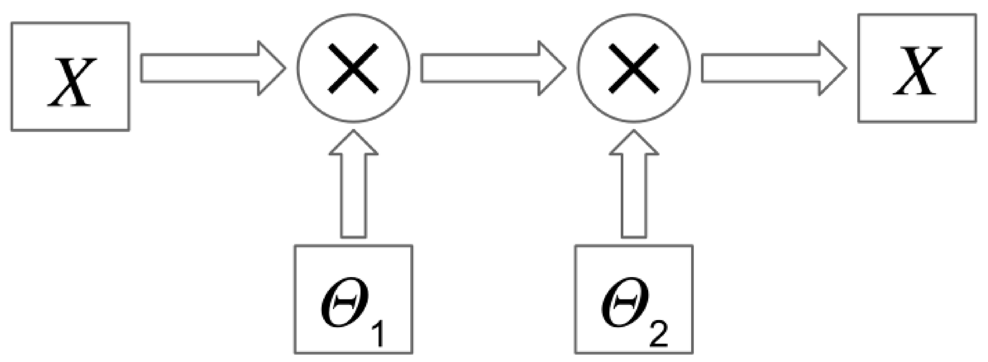
- Principal Component Analysis: Project X onto first 3 principal components, U. This solves:

$$\min_{U,A} \; ||X - UA||_F^2$$

Estimated matrix $X' = UA$. Normalized model error of X_i':



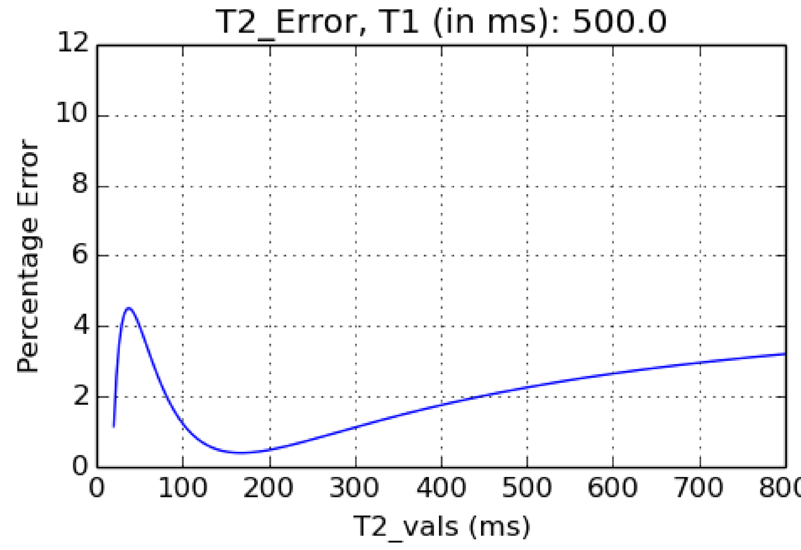
- Multilayer Linear Regressor: Inspired by Neural Networks, this only uses linear transformations.

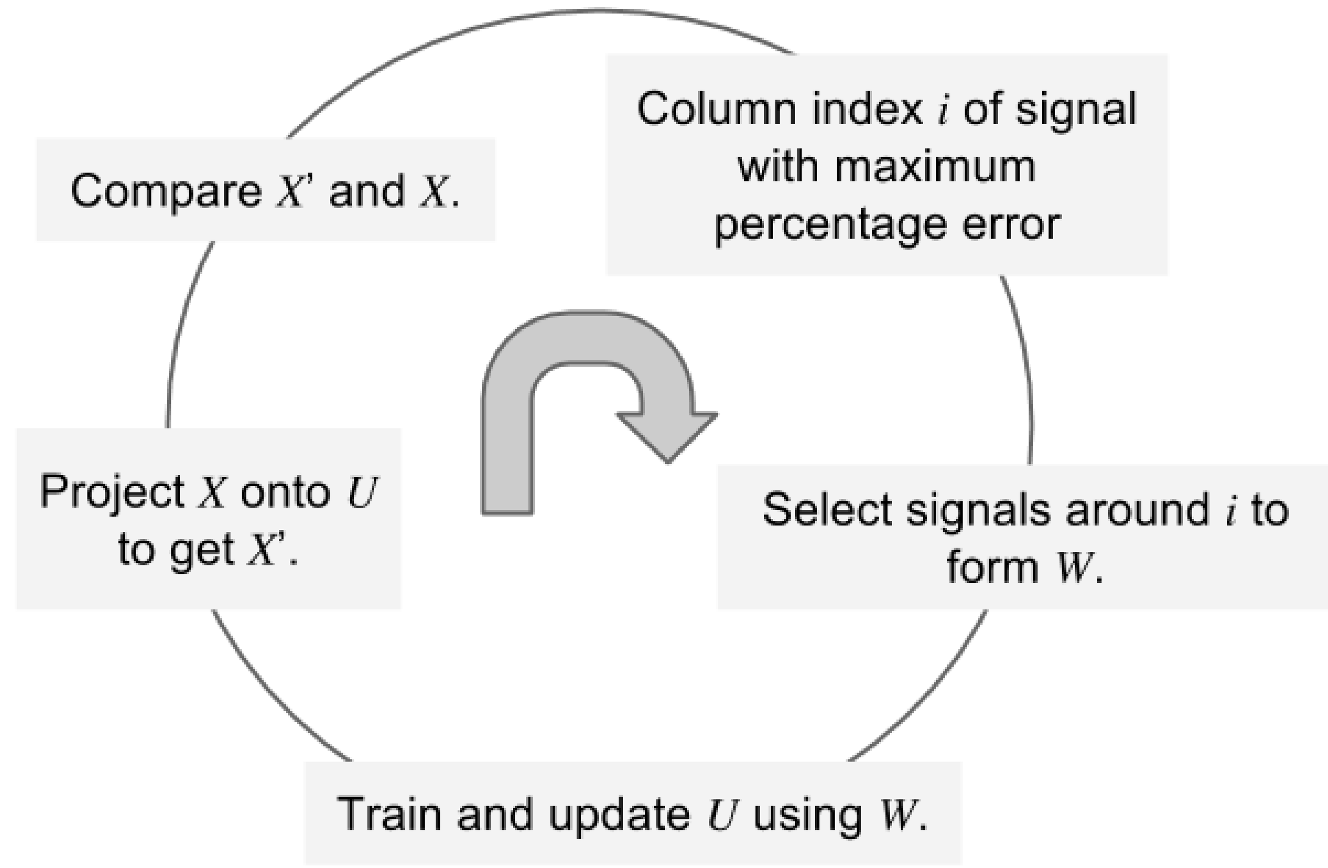


$$U \leftarrow \theta_2$$
$$A \leftarrow \theta_1 X$$

This framework is used to solve:

$$\min_{U,A} \; \max_i \; ||X_i - Ua_i||_2^2$$





- Results

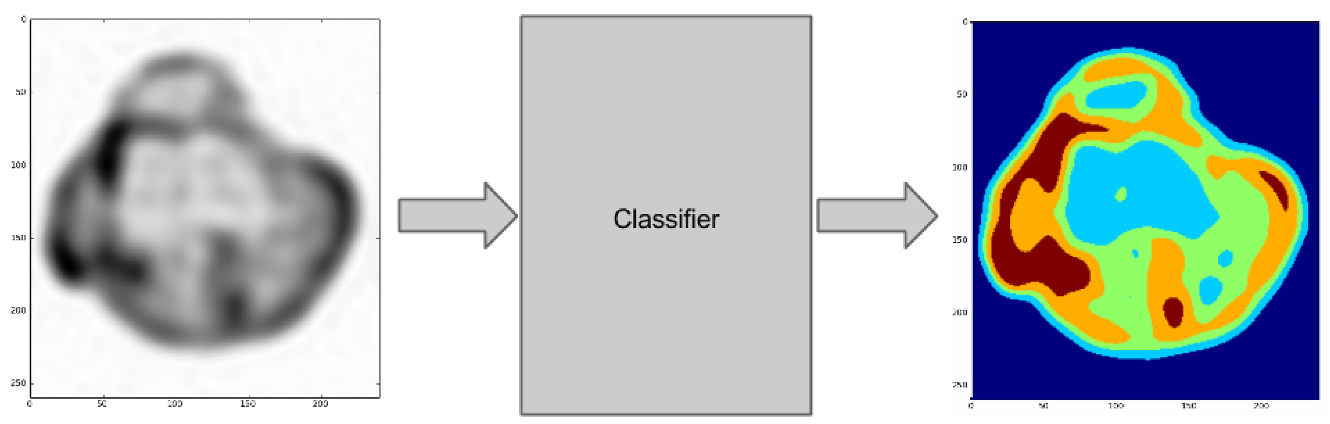
	PCA	MLR
Global Error	0.33%	2.46%
Maximal Error	11.1%	4.50%

Discussion and Conclusion

- Our flexible framework enables the evaluation of different cost functions.
- We produce a low-dimensional representation with lower maximal error at a small cost of global error.

Future Work

- T_2 mapping and classification: Classifying T_2 values from signal evolutions.



References

[1] Tamir JI, Lai P, Uecker M, Lustig M. Reduced blurring in 3D fast spin echo through joint temporal espirit reconstruction. Proc. Intl. Soc. Mag. Reson. Med. 22 2014; p. 0616.

[2] Busse RF, Hariharan H, Vu A, Brittain JH. Fast spin echo sequences with very long echo trains: design of variable refocusing flip angle schedules and generation of clinical t2 contrast. Magn Reson Med 2006; 55:10307.

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