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Optimal Unstructured Mesh Data Compression and Reconstruction Using Compressed Sensing

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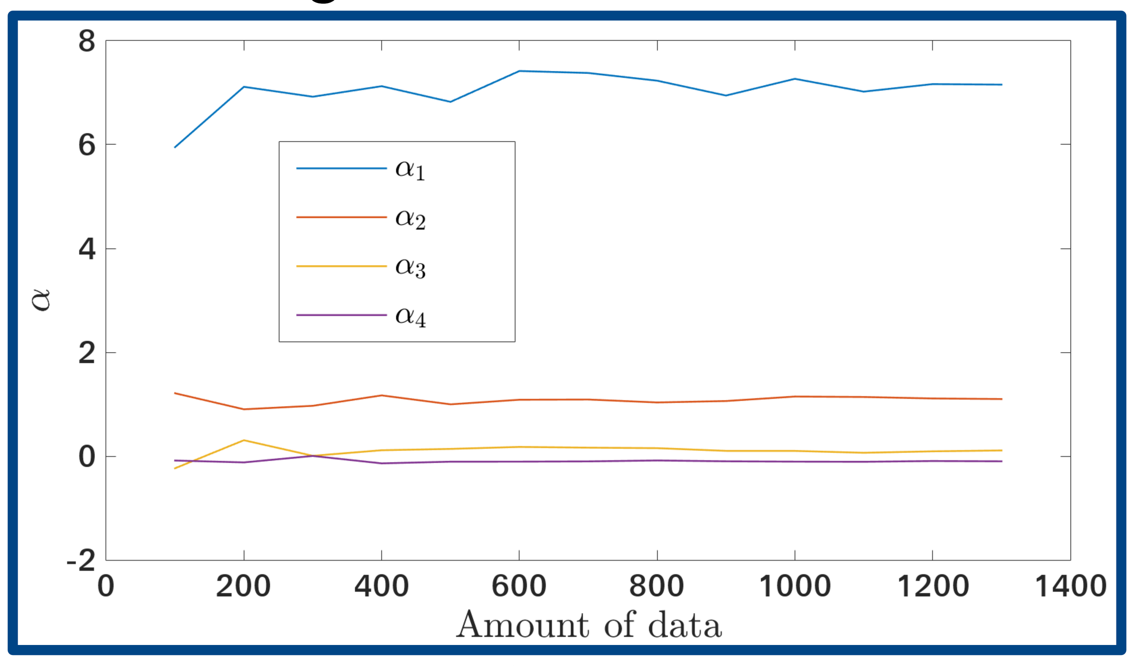
Introduction

- **Challenge:** Compress large amounts of data efficiently by determining a relationship between the data features and how well they compress.
- **Solution:** **Compressive sensing** (CS) samples the data within an alternative function space using second generation wavelets and then reconstructs the data.
- CS is fast and, unlike regular wavelet compression, it *allows interactive reconstruction and visualization* according to the required accuracy and quality.
- We empirically determine a correlation that produces an *optimal compression ratio* (R) depending on the gradient of the input function being compressed.
- Applied to 2D irregular meshes and geometries

Procedure

1. Generate hundreds of functions using a combination of sines and cosines
2. Compress the large vector ***f*** that represents a function using a sampling matrix **ϕ** into the much smaller **y** and measure the R that grants a reconstruction accuracy at a given tolerance $$y = \Phi f$$
3. Compute several statistics (mean, median, etc.) for the *gradients* of ***f***
4. Propose a correlation model for the compression ratio R as a function of the input statistics (M = max). Fit the model below to the training data statistics and find the α_i



$$R = (e^{\alpha_1})/(\mu^{\alpha_2}\sigma^{\alpha_3}M^{\alpha_4})$$

5. Test new functions by using the obtained correlation to compute a compression ratio, compress the function, and reconstruct the function. Ideally, the reconstructed image is difficult to distinguish from the original image.

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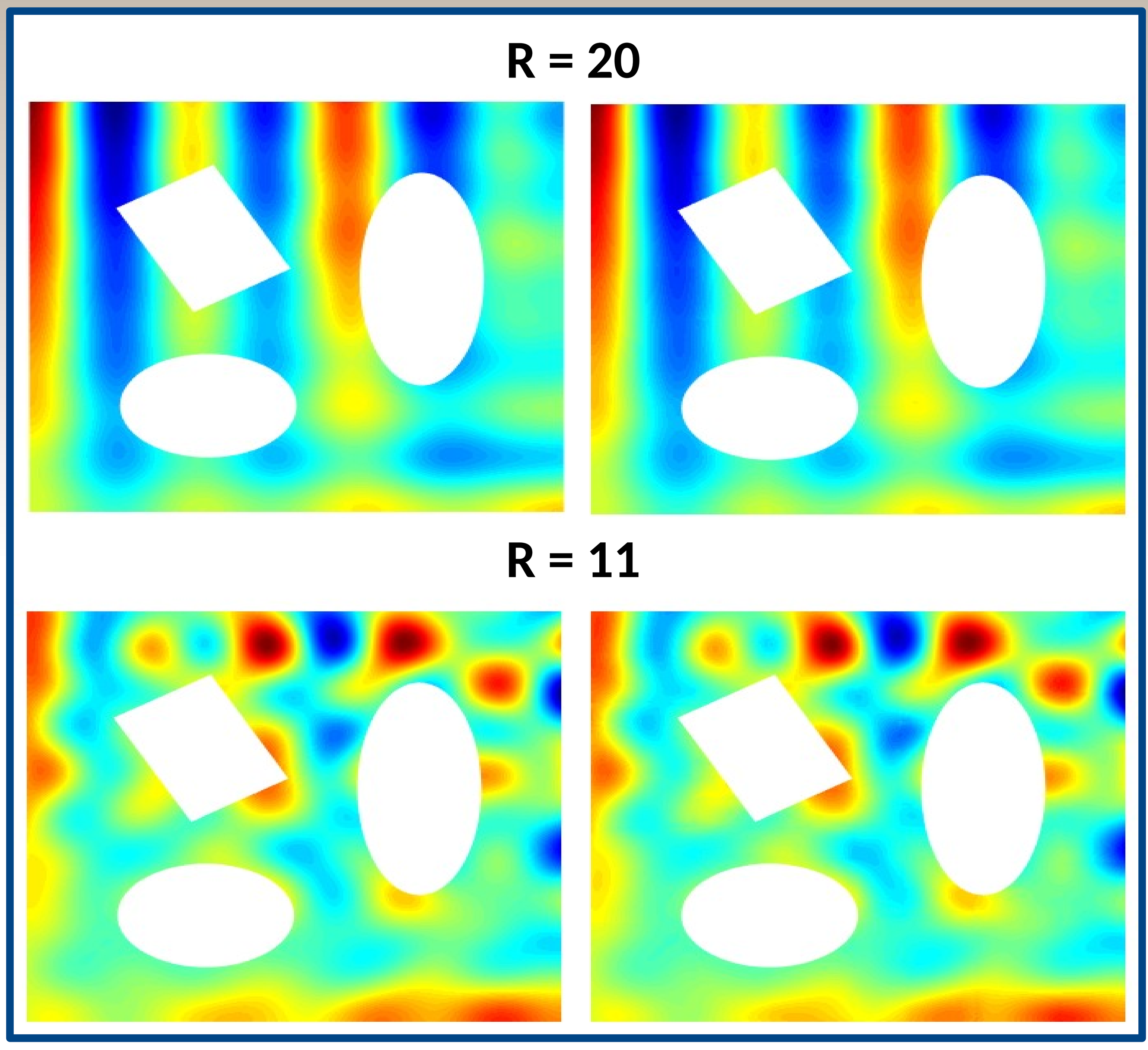
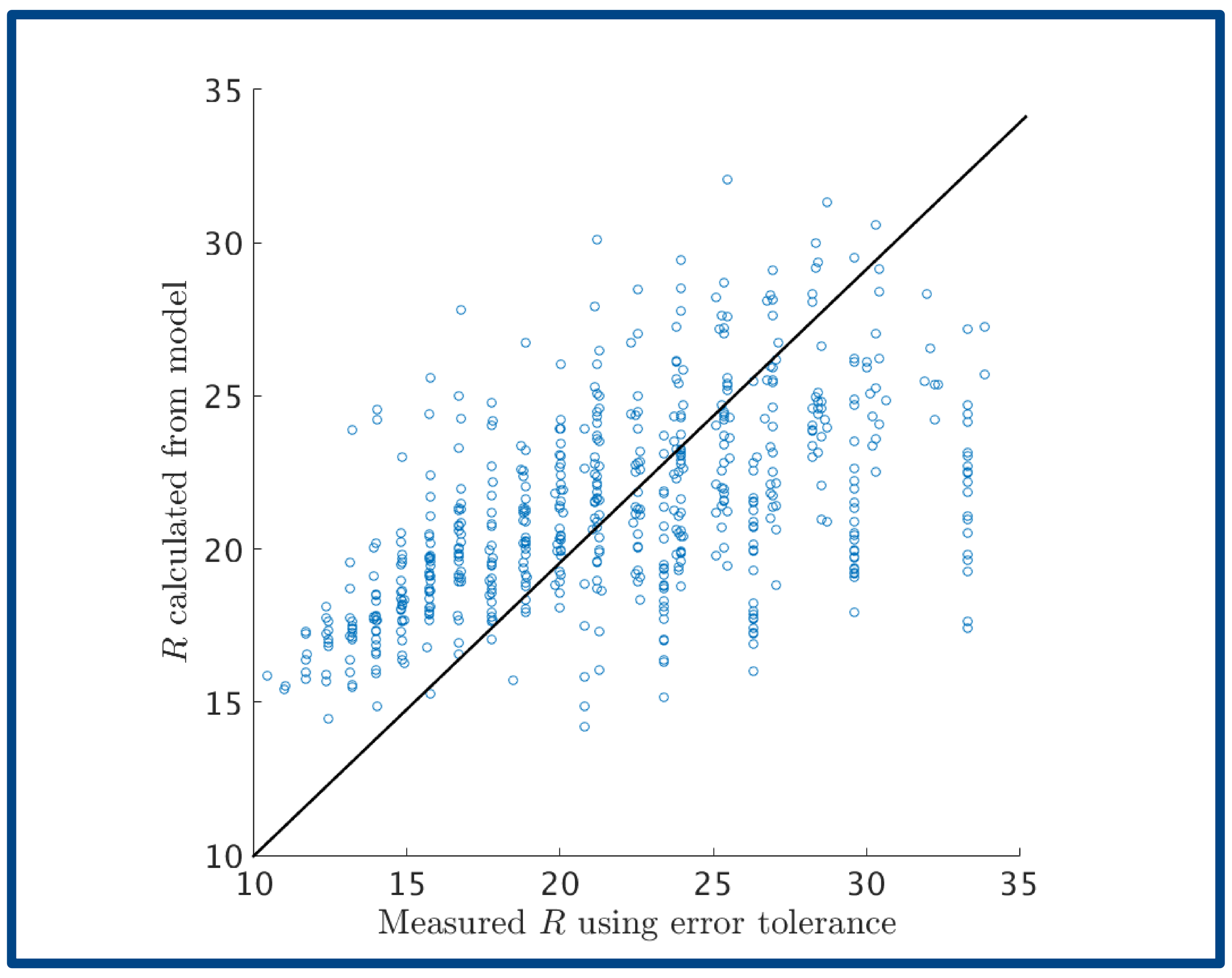
Results and Conclusion



Two functions (~33,000 mesh points per function) compressed and reconstructed using a correlation model and CS. We find that as the function complexity decreases, the optimum R increases.



R calculated from the correlation model is plotted against the measured R. For 1000 functions, the optimal compression ratios are overestimated for small R and underestimated for large R.

- **Future work:** Will aim to fill in the "gaps" between the clusters of R and apply this knowledge to realistic 3D mesh data, as well as try different models for R.
- **References:**

1. Salloum, M., Fabian, N., Hensinger, D.M. and Templeton, J. Compressed Sensing and Reconstruction of Unstructured Mesh Datasets. 5th IEEE Symposium on Large Data Analysis and Visualization (submitted)
2. Donoho, D. L., Tsaig, Y., Drori, I. and Starck, J.L. Sparse solution of underdetermined systems of linear equations by stagewise orthogonal matching pursuit. IEEE Transactions on Information Theory, 58(2):1094–1121, 2012.