SHAPE RETRIEVAL ON THE WAVELET DENSITY HYPERSHPERE

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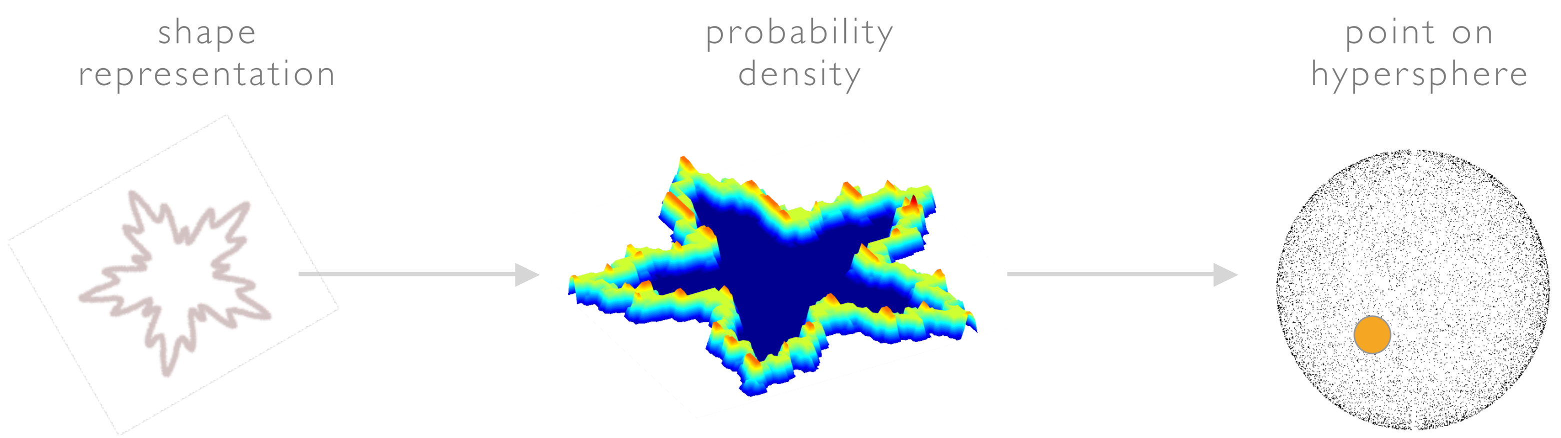
PROBLEM
INTRODUCTION



With the advancement in 3D modeling technology, understanding shape is more important than ever. Shape retrieval is the problem of searching for similar shapes in a database given a query shape, similar to search engines for text.

In our novel approach, we represent shapes as probability densities and use the intrinsic geometry of this space to match similar shapes. Specifically, we expand the square-root of the density in a multiresolution wavelet basis. Under this model, each density (of a corresponding shape) is mapped to a point on unit hypersphere, where the angle between a pair of points can be used as a measure of similarity.

OUR CONTRIBUTIONS

- Improved computational performance of multiresolution wavelet density estimator

- Extended linear assignment metric to support multiresolution densities

- Implemented hierarchical clustering algorithm for spherical data and analyzed algorithmic complexity

- Numerous experimental validations across multiple datasets

APPROACH
WAVELET DENSITY ESTIMATION

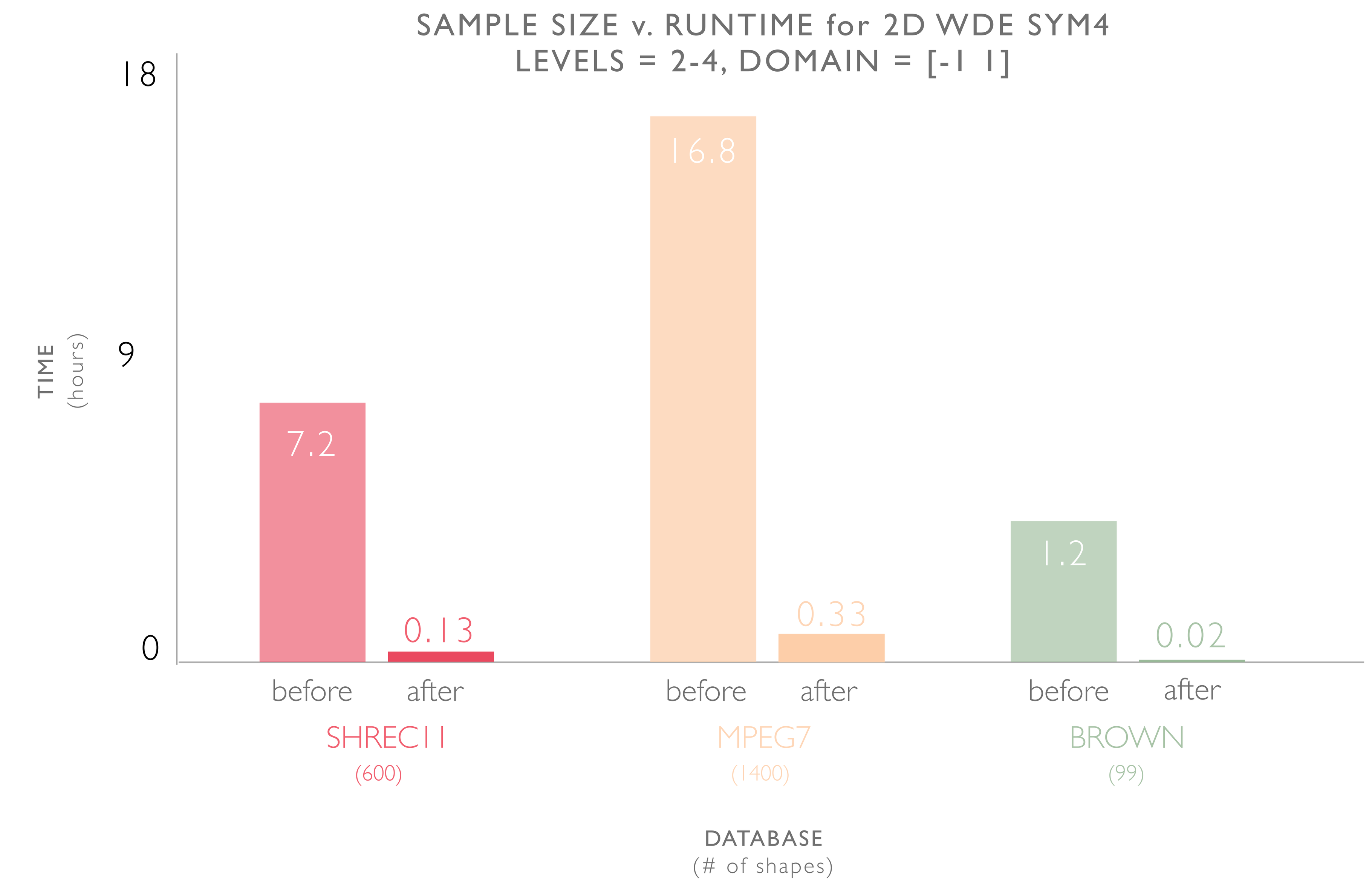
Wavelets are crucial mathematical functions that form an orthonormal basis for probability density functions. Given a point-set representation of a shape, we use a constrained maximum likelihood approach to estimate the coefficients of the wavelet density basis expansion in eq. (1).

$$\sqrt{p(\mathbf{x})} = \sum_{j_0,\mathbf{k}} \alpha_{j_0,\mathbf{k}}\phi_{j_0,\mathbf{k}}(\mathbf{x}) + \sum_{j\geq j_0,\mathbf{k}}^{j_1}\sum_{w=1}^{3}\beta^w_{j,\mathbf{k}}\psi^w_{j,\mathbf{k}}(\mathbf{x}) \qquad (1)$$

APPROACH & RESULTS
2D WDE OPTIMIZATION

Wavelet density estimation (WDE) is a computationally expensive task, but we improved the speed by orders of magnitude through parallelization. We had significant improvements in both initializing the wavelet coefficients and in our negative log likelihood based optimization process.

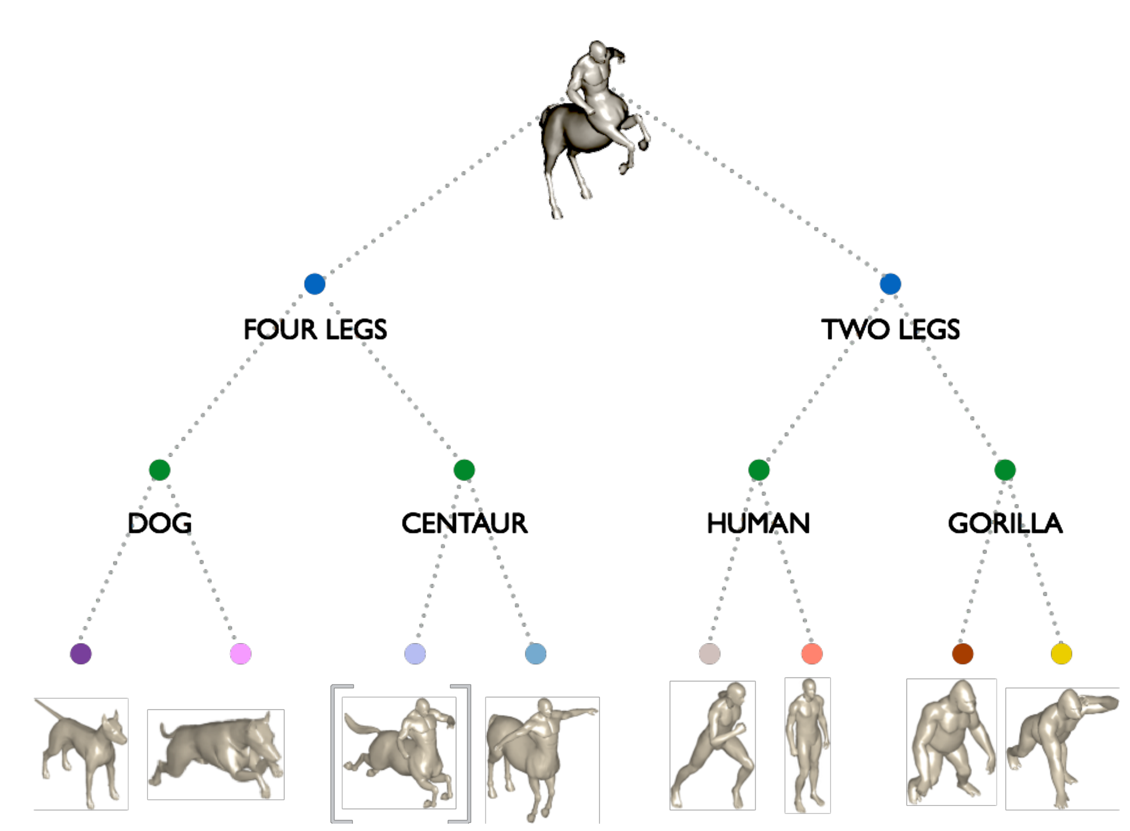
100× FASTER



APPROACH & RESULTS
HIERARCHICAL SHAPE RETRIEVAL

Hierarchical clustering uses different levels of abstraction to group similar shapes together. Because of the hierarchical tree structure, retrieval speed and accuracy are improved.

We used spherical form of *k*-means clustering on the hypersphere for each level of clustering, and create a recursive tree structure where the means of one level form the children of the higher level.



ACCURACY

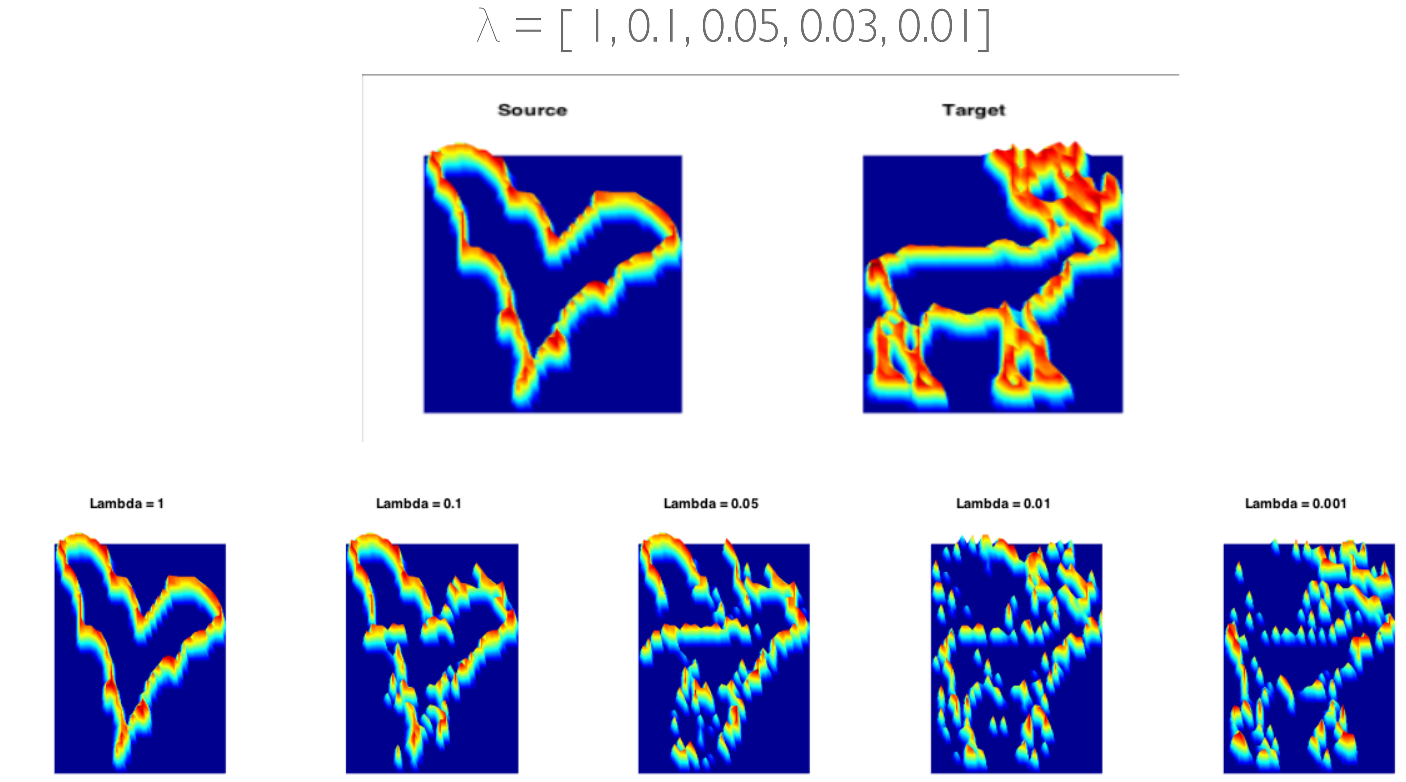
	SHREC11	MPEG7	BROWN
w/o HIERARCHY	20.7%	75.3%	51.8%
w/ HIERARCHY.	99.7%	99.3%	83.0%

APPROACH & RESULTS
LINEAR ASSIGNMENT

Linear assignment warps two shapes closer together to reduce non-rigid differences between them. Because shapes easily warp when they're close together, we reduce the distance between similar shapes while keeping dissimilar shapes far apart. This makes our dissimilarity metric more robust to small deformations, which improve the accuracy of shape retrieval.

We have an objective function that balances warping the shapes together with regularizing the amount of warping allowed. We decrease the amount of warping by increasing the parameter λ.

WARPING FROM SOURCE TO TARGET
λ = [1, 0.1, 0.05, 0.03, 0.01]



ACCURACY

	SHREC11	MPEG7	BROWN
w/o HIERARCHY	xx.x%	xx.x%	xx.x%
w/ HIERARCHY.	xx.x%	xx.x%	xx.x%