SHAPE REPRESENTATIONS

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SHAPE
RETRIEVAL

REFRESHER

QUERY SHAPE

DATABASE

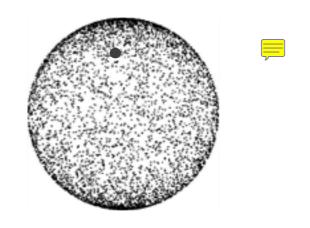# PROBLEM STATEMENT

SHAPE
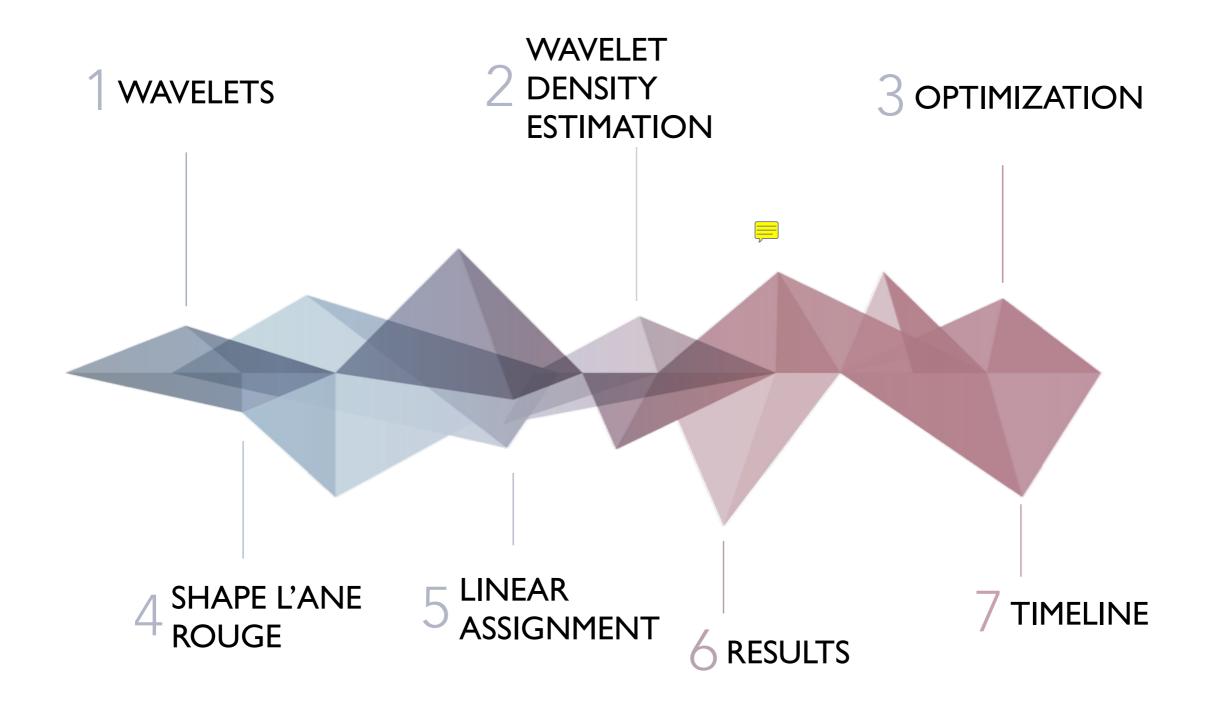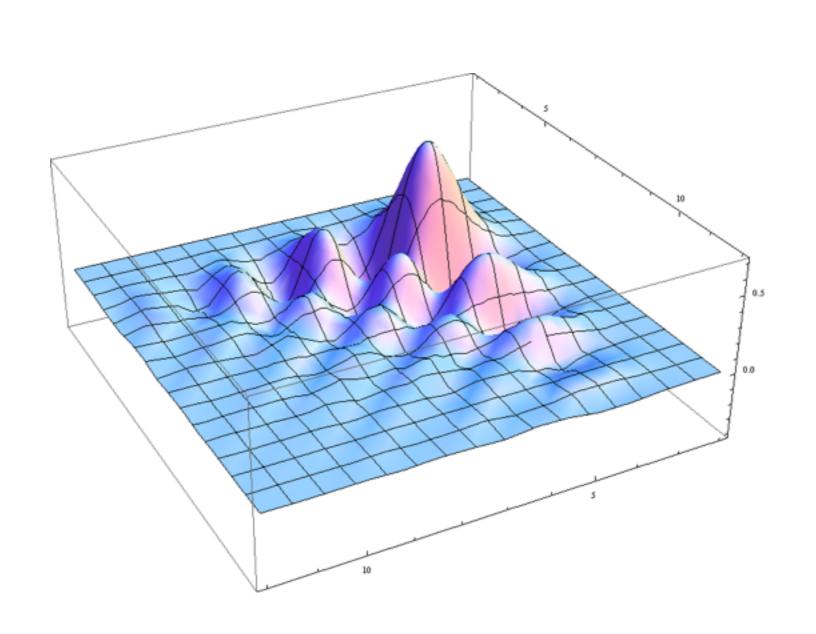REPRESENTATION

1

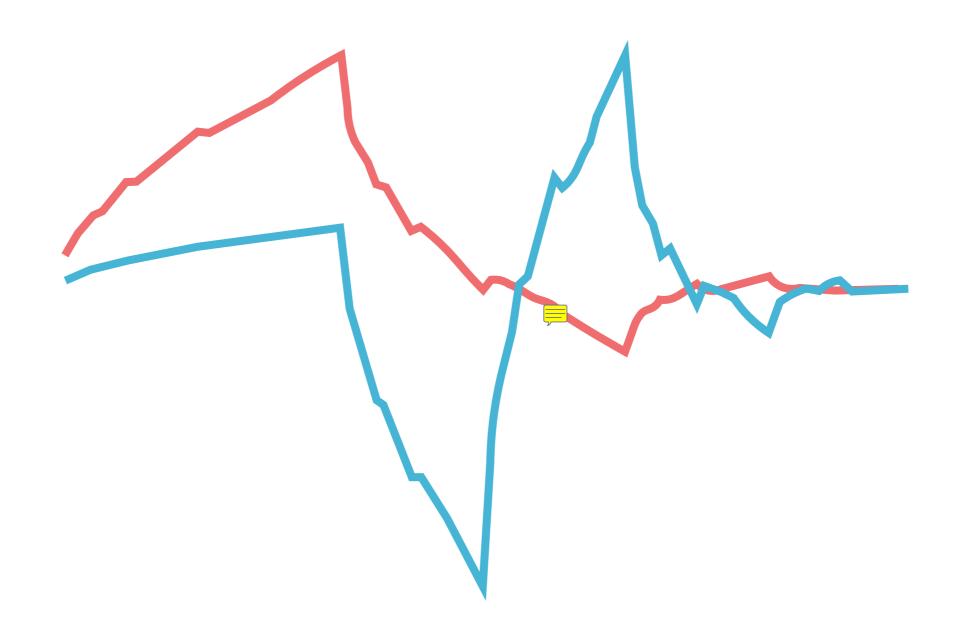FEATURE
REPRESENTATION

2

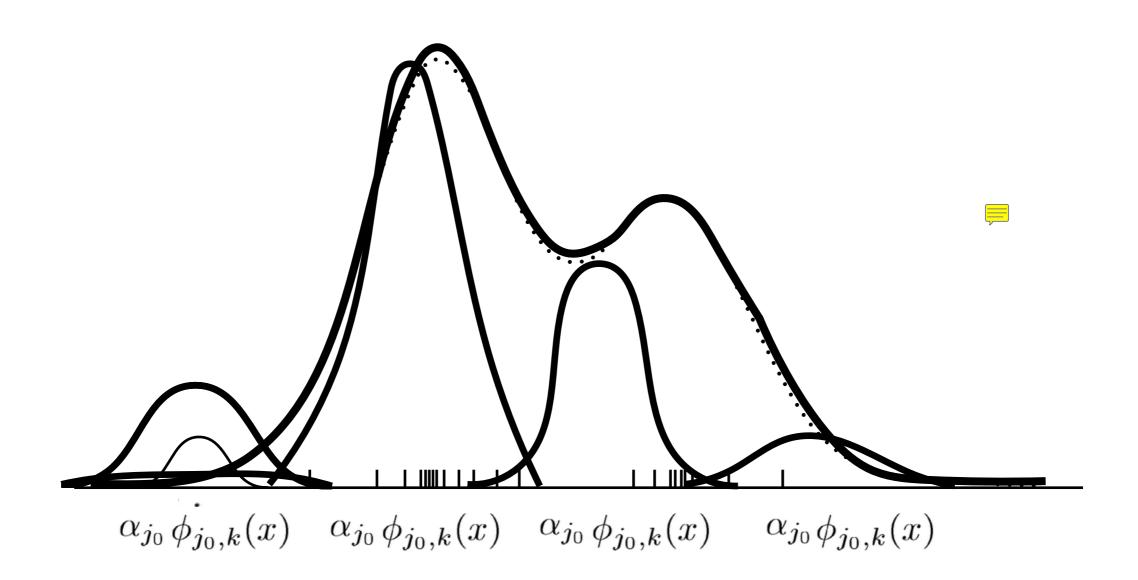RETRIEVAL
MECHANICS

3

ROADMAP FOR FEATURE REPRESENTATION

WAVELETS

WHY WAVELETS

WAVELET DENSITY ESTIMATION

$$\alpha_{j_0}\,\phi_{j_0,k}(x) \qquad \alpha_{j_0}\,\phi_{j_0,k}(x) \qquad \alpha_{j_0}\,\phi_{j_0,k}(x) \qquad \alpha_{j_0}\,\phi_{j_0,k}(x)$$

WAVELETS, FORMALLY

$$\sqrt{p(x)} = \sum_{j_0,k} \underbrace{\alpha_{j_0,k}}_{\substack{\text{Scaling} \\ \text{Coefficient}}} \underbrace{\phi_{j_0,k}(x)}_{\substack{\text{Scaling Basis} \\ \text{Function}}} + \sum_{j \geq j_0,k}^{\infty} \underbrace{\beta_{j,k}}_{\substack{\text{Wavelet} \\ \text{Coefficient}}} \underbrace{\psi_{j,k}(x)}_{\substack{\text{Wavelet Basis} \\ \text{Function}}}$$

Father

Mother

$$\alpha_{j_o,\mathbf{k}} = \frac{1}{N} \frac{\sum_{i=1}^{N} \phi_{j_o,\mathbf{k}}(\mathbf{x})}{\sqrt{p(\mathbf{x})}}$$

$$\psi_{j,\mathbf{k}}^{2}(\mathbf{x}) = 2^{j} \psi \int \frac{}{\sqrt{p(x)}} \phi_{j_0,k}(x)dx$$

$$\psi_{j,\mathbf{k}}^{3}(\mathbf{x}) = 2^{j} \psi \, \mathcal{E}\left[\frac{\phi_{j_0,k}(x)}{\sqrt{p(x)}}\right].$$
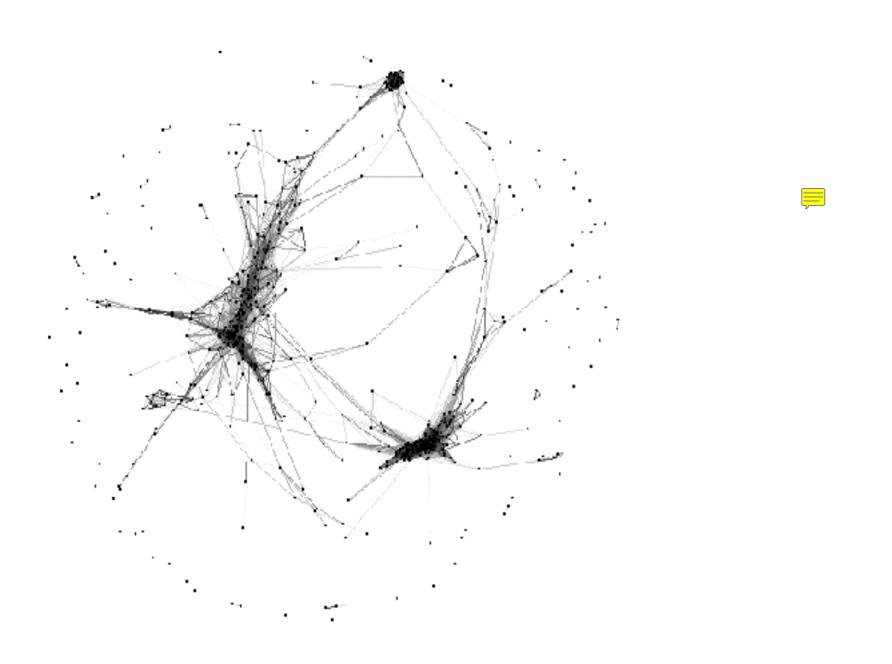
WAVELET DENSITY ESTIMATION

NEGATIVE LOG LIKELIHOOD

$$-\log p(X; \{\alpha_{j_0,k}, \beta_{j,k}\}) = -\frac{1}{N} \log \prod_{i=1}^{N} \left[\sqrt{p(x_i)} \right]^2$$
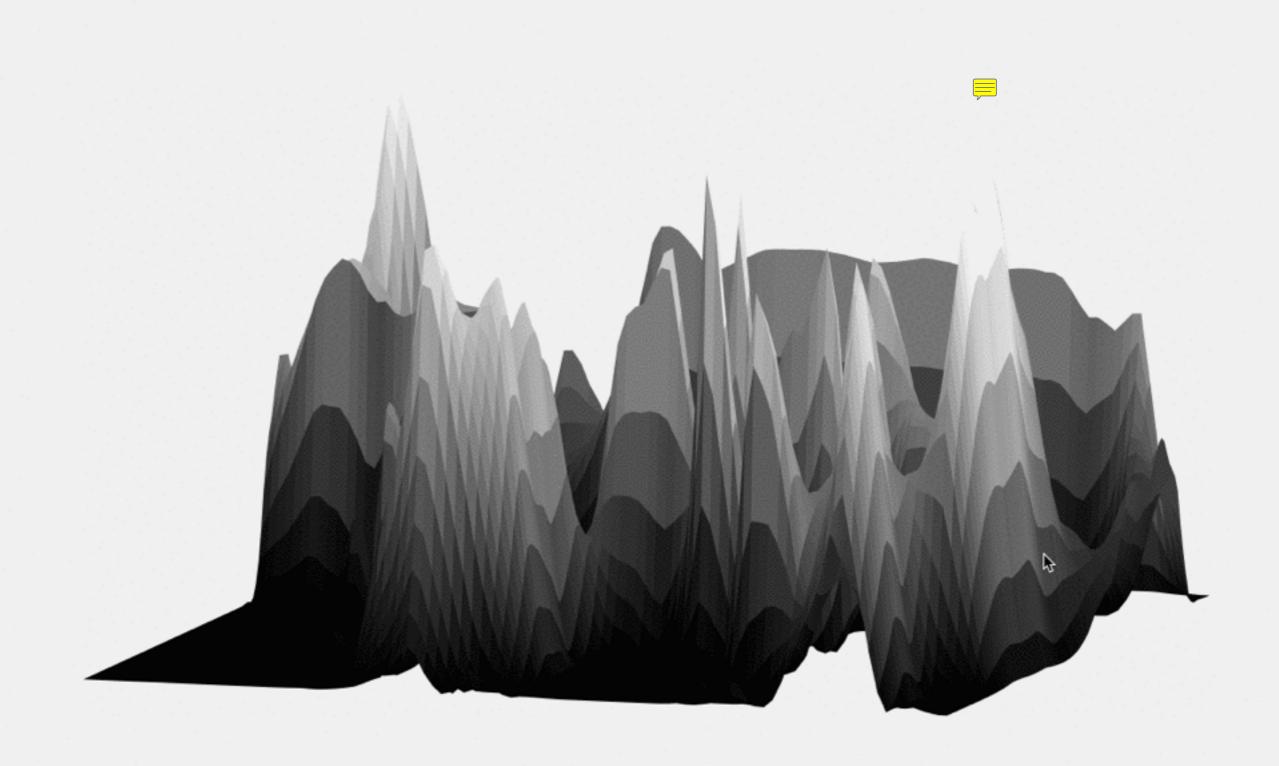
$$= -\frac{1}{N} \sum_{i=1}^{N} \log \left[\sum_{j_0,k} \alpha_{j_0,k} \phi_{j_0,k}(x_i) + \sum_{j \geq j_0,k}^{j_1} \beta_{j,k} \psi_{j,k}(x_i) \right]^2$$

$$\sum_{j_0,k} \alpha_{j_0,k}^2 + \sum_{j \geq j_0,k}^{j_1} \beta_{j,k}^2 = 1.$$
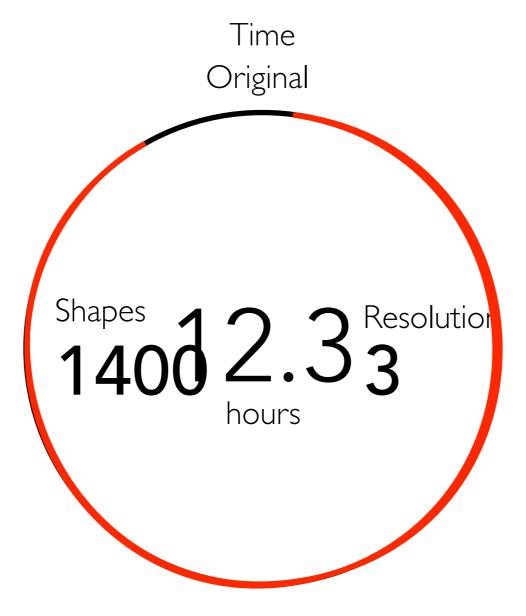
WAVELET DENSITY ESTIMATION

WDE OPTIMIZATION ⏱

Time
Original

Database

MPEG7

Shapes
1400

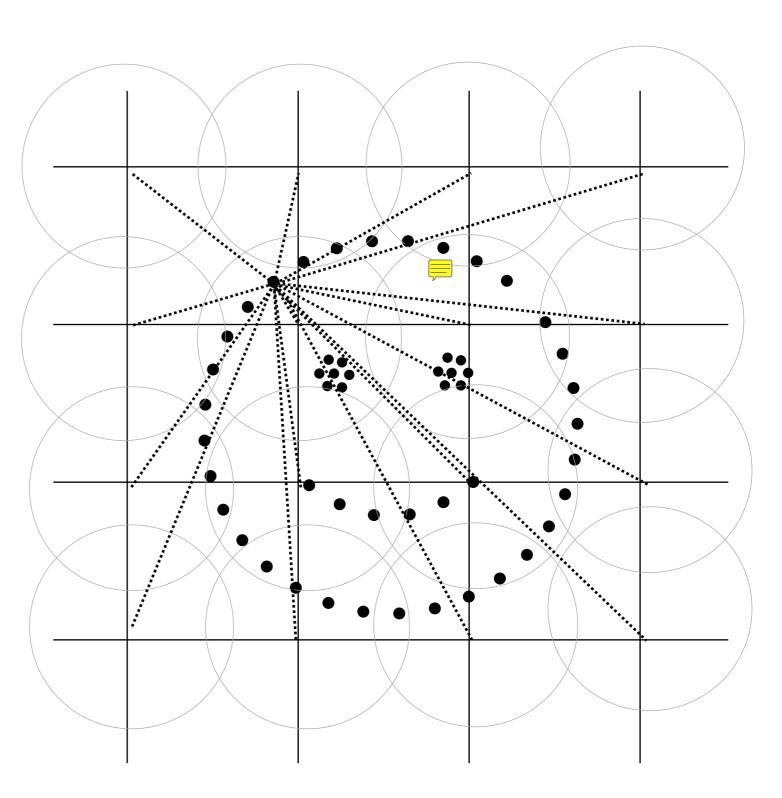12.3
hours

Resolution
3

Translations
576

WDE OPTIMIZATION
INITIALIZE COEFFICIENTS PROBLEM

$$\alpha_{j_o,\mathbf{k}} = \frac{1}{N} \frac{\sum_{i=1}^{N} \phi_{j_o,\mathbf{k}}(\mathbf{x})}{\sqrt{p(\mathbf{x})}}$$
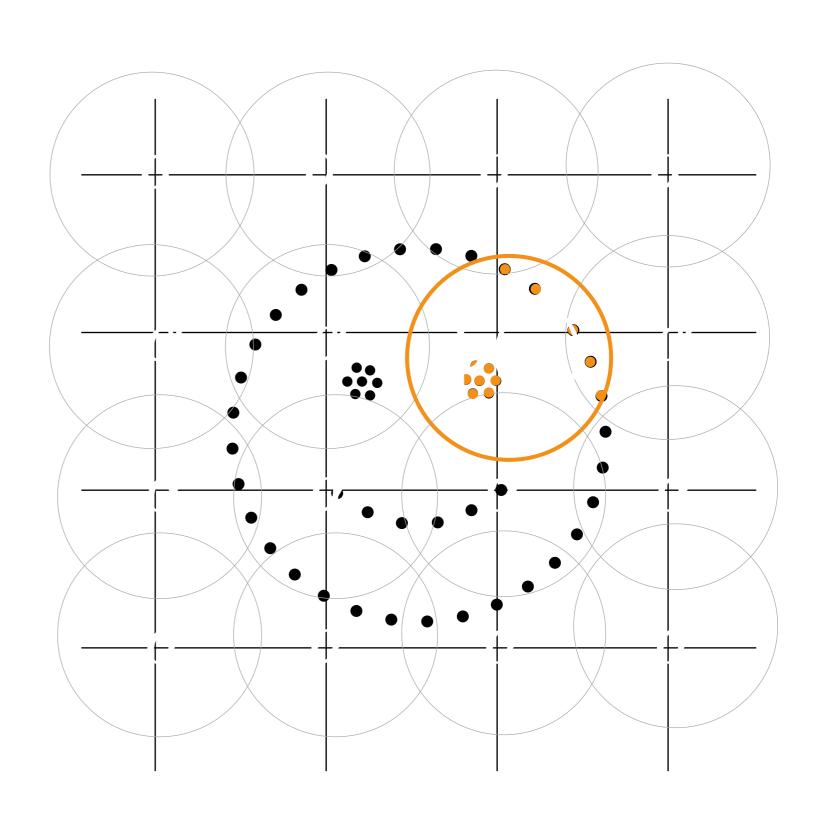
576 wavelet functions

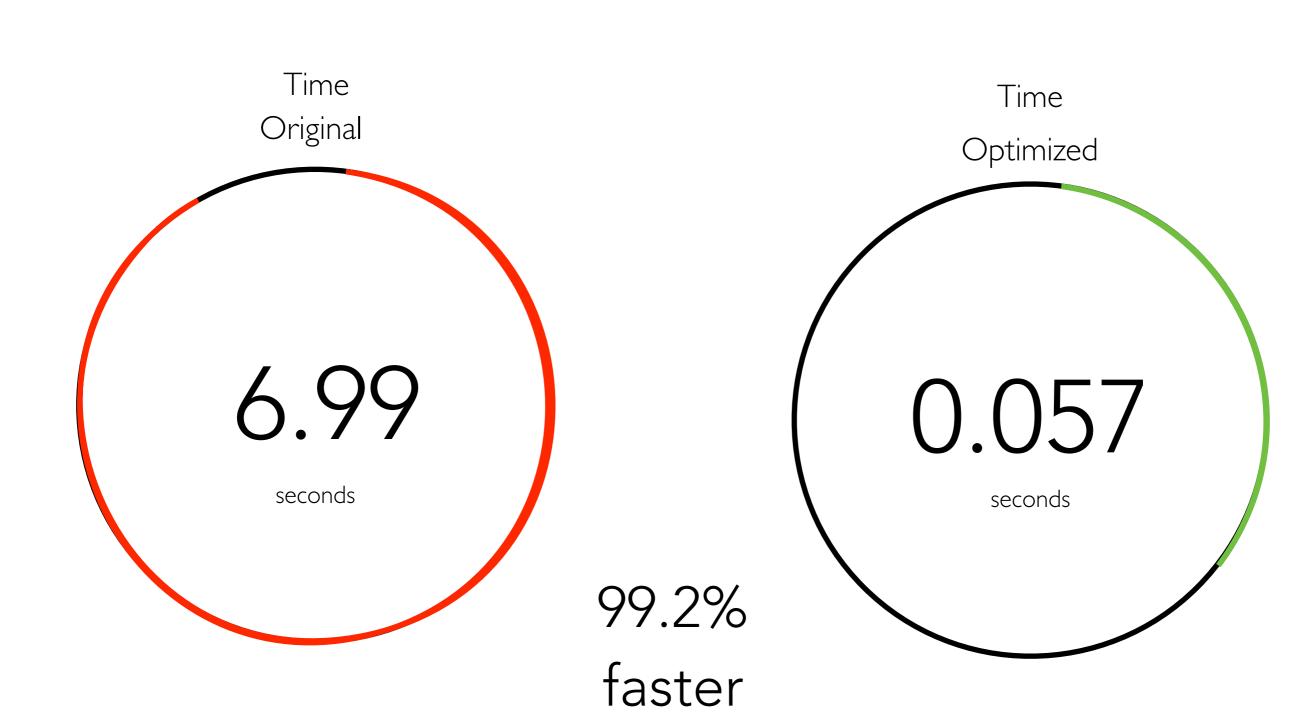$\times$ 4007 samples

2,308,032 operations

WDE OPTIMIZATION
INITIALIZE COEFFICIENTS SOLUTION

$$\alpha_{j_o, \mathbf{k}} = \frac{1}{N} \frac{\sum_{i=1}^{N} \phi_{j_o, \mathbf{k}}(\mathbf{x})}{\sqrt{p(\mathbf{x})}}$$
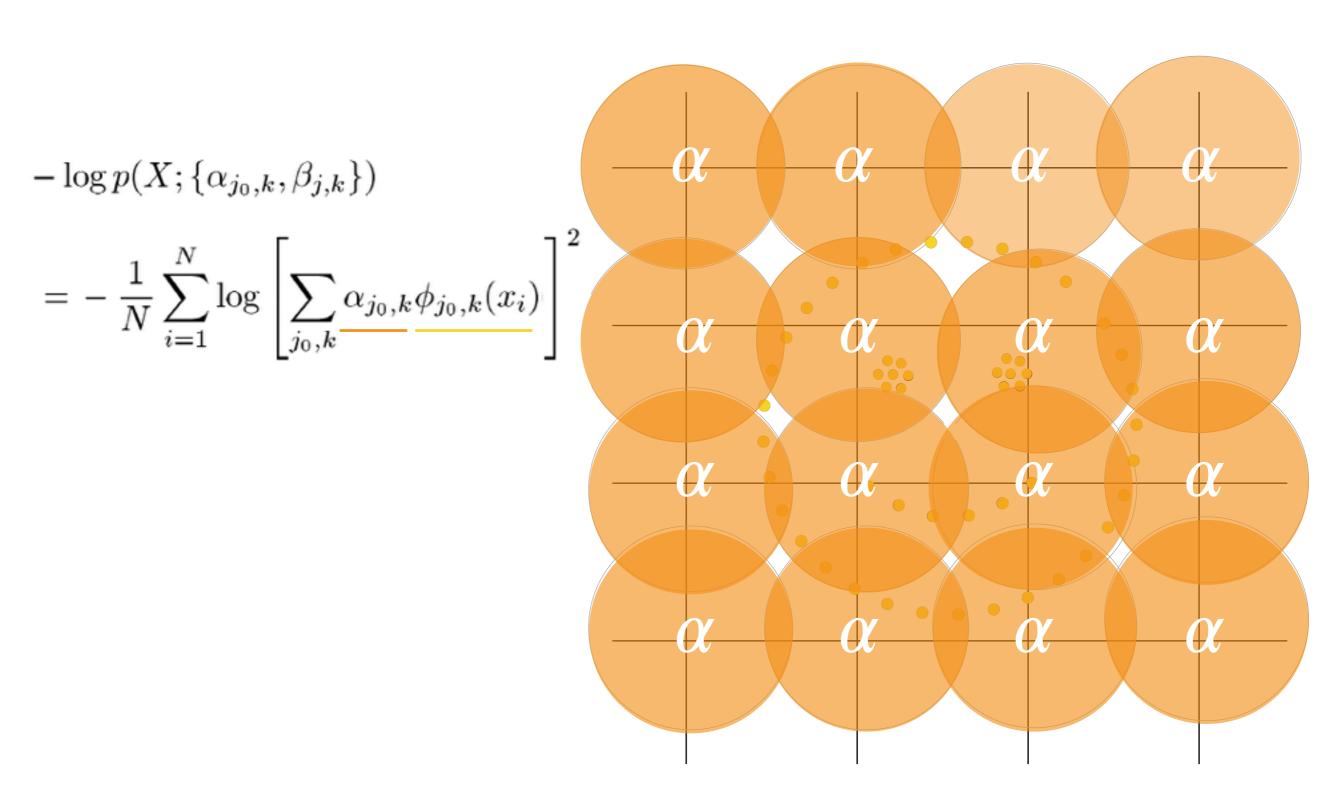
WDE OPTIMIZATION
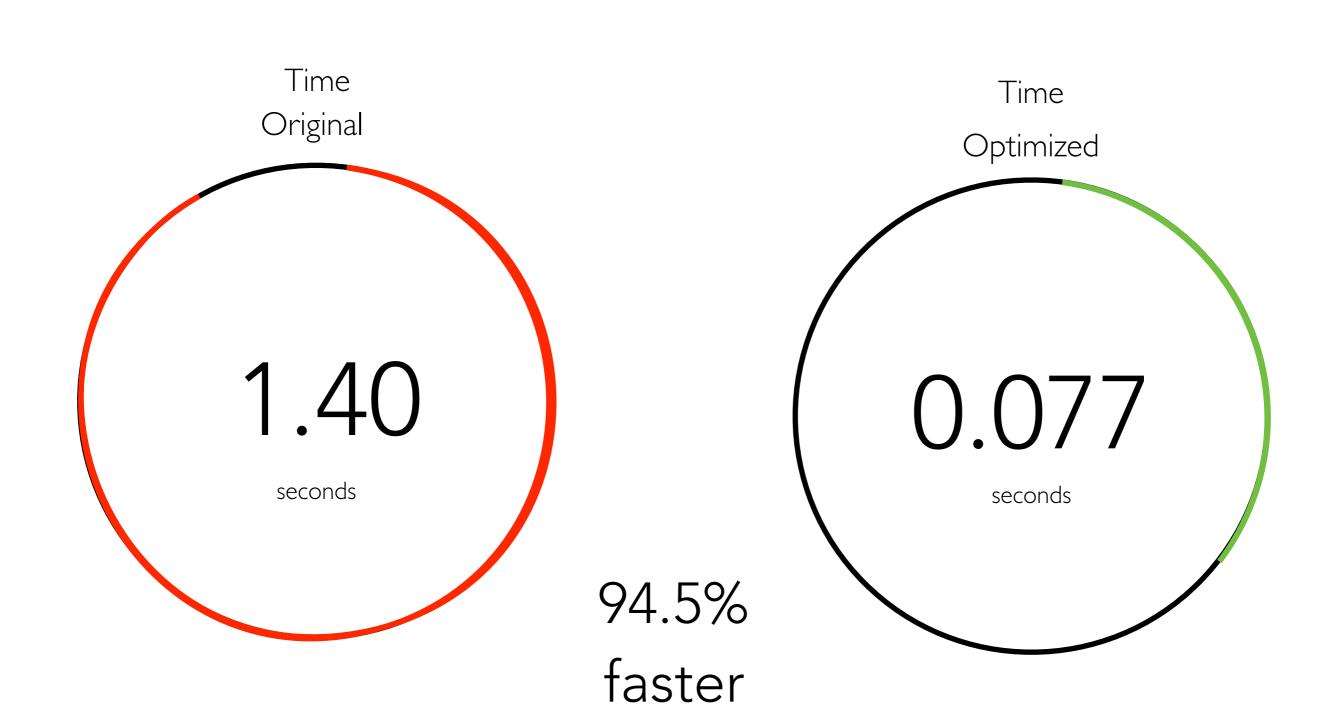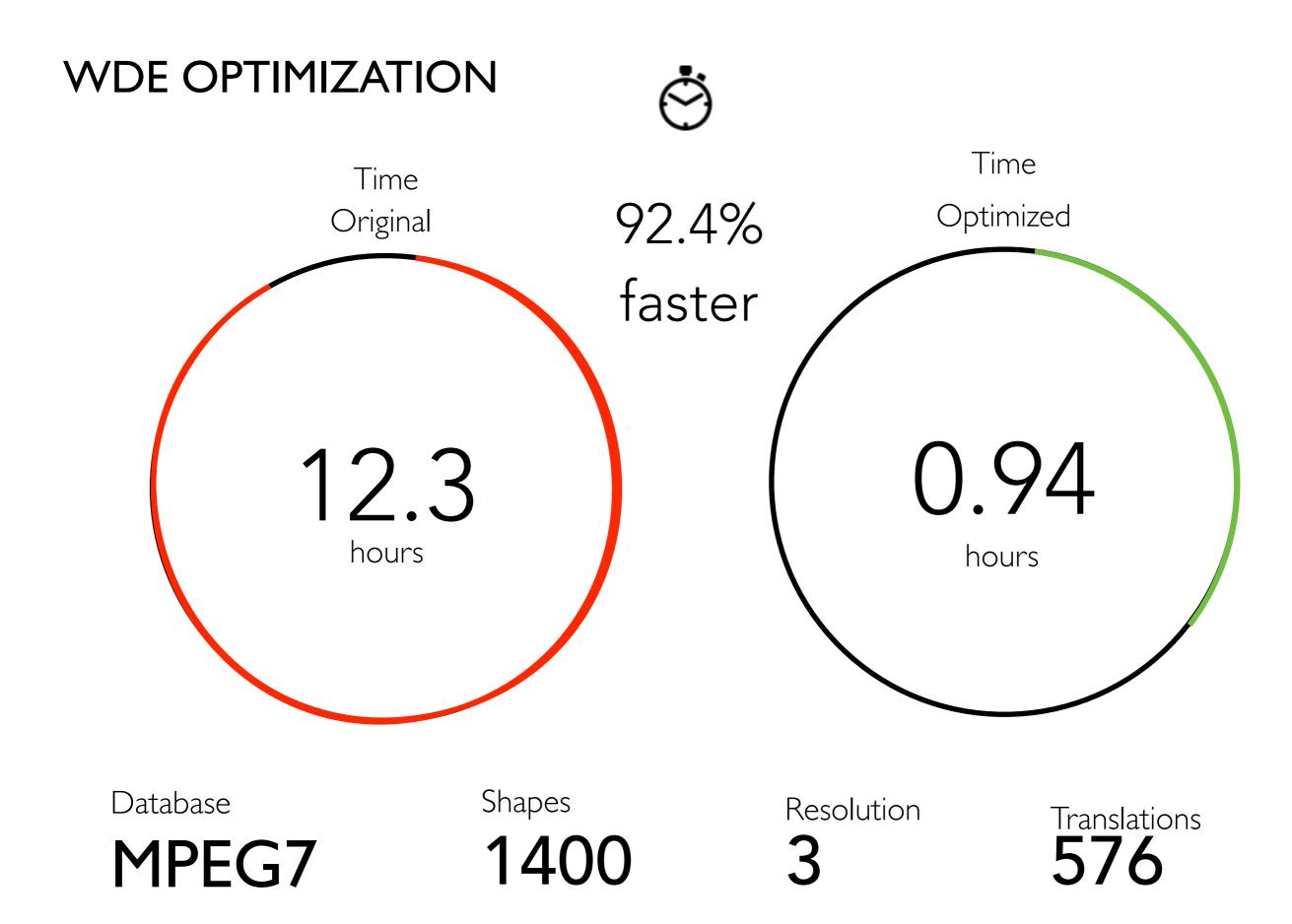## INITIALIZE COEFFICIENTS

Time
Original

6.99

seconds

Time
Optimized

0.057

seconds

99.2%
faster

WDE OPTIMIZATION
NEGATIVE LOG LIKELIHOOD SOLUTION

$$-\log p(X; \{\alpha_{j_0,k}, \beta_{j,k}\})$$

$$= -\frac{1}{N} \sum_{i=1}^{N} \log \left[\sum_{j_0,k} \alpha_{j_0,k} \phi_{j_0,k}(x_i) \right]^2$$

WDE OPTIMIZATION
NEGATIVE LOG LIKELIHOOD

Time
Original

1.40

seconds

Time
Optimized

0.077

seconds

94.5%
faster

WDE OPTIMIZATION

Time
Original

12.3

hours

92.4%
faster

Time
Optimized

0.94

hours

Database	Shapes	Resolution	Translations
MPEG7	1400	3	576

SHAPE L'ANE ROUGE

SHAPE L'ANE ROUGE

SHAPE L'ANE ROUGE

SHAPE L'ANE ROUGE

$$\begin{bmatrix} 0.0000 & 0.0000 & 0.0000 \\ 0.0000 & 0.0000 & 0.0000 \\ 0.0000 & 0.0000 & 0.0000 \\ 0.0000 & 0.0361 & 0.0000 \\ 0.0000 & 0.0000 & 0.0000 \\ 0.0000 & 0.0000 & 0.0000 \\ 0.0000 & 0.0000 & 0.0472 \end{bmatrix}$$

SHAPE L'ANE ROUGE

SHAPE L'ANE ROUGE

LINEAR ASSIGNMENT

SHAPE L'ANE ROUGE

$$s\ X, Y\ | = |Y|$$

$$C : X \times Y \to \mathbb{R}$$

$$X \to Y$$

SHAPE L'ANE ROUGE
JONKER-VOLGENANT

$$C = -(\boldsymbol{c_1} \otimes \boldsymbol{c_2}) + D$$

SHAPE L'ANE ROUGE
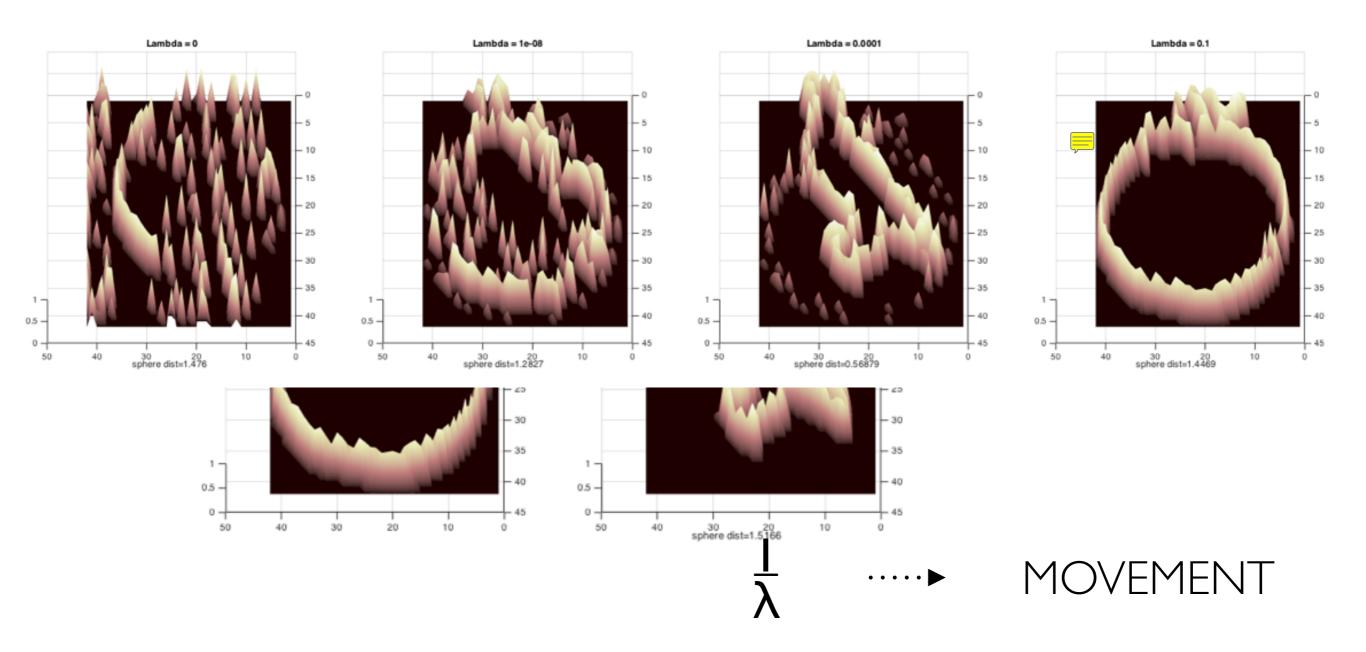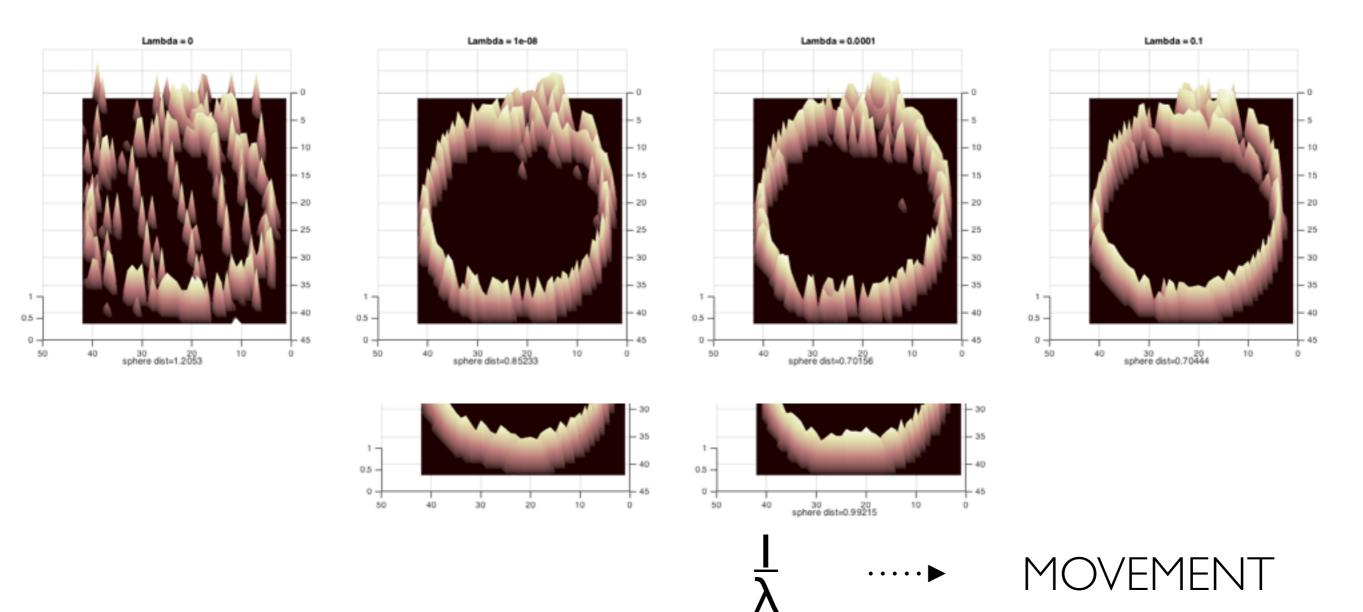
OPTIMIZATION FOR JONKER-VOLGENANT

SHAPE L'ANE ROUGE
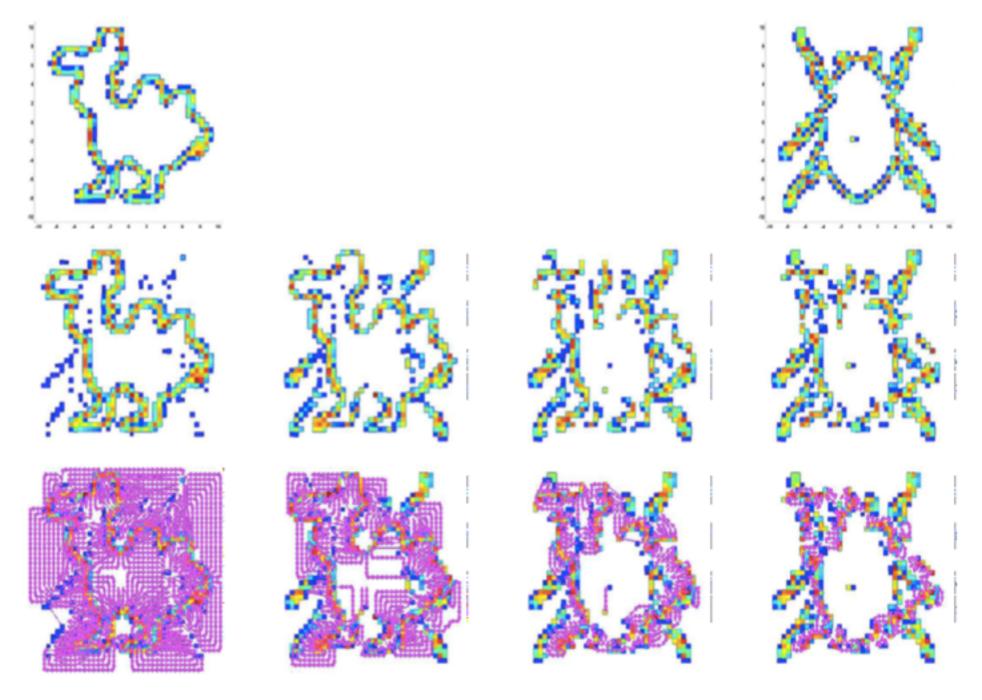
DIFFERENT SHAPE WARP

$$\frac{1}{\lambda} \quad \cdots\cdots\blacktriangleright \quad \text{MOVEMENT}$$

SHAPE L'ANE ROUGE

SAME SHAPE WARP

$$\frac{1}{\lambda} \quad \cdots\cdots\blacktriangleright \quad \text{MOVEMENT}$$

FUTURE RESEARCH

- Optimization
  - Optimize multi-resolution
  - Extend to different dimensions
- Shape L'Ane Rouge
  - Optimize λ
  - Test on datasets
- Find better feature representations
- Investigate high-dimension visualization

FEATURE REPRESENTATION

THANK YOU