Retrieval on Parametric Shape Collections

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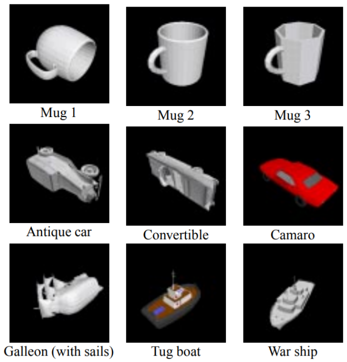
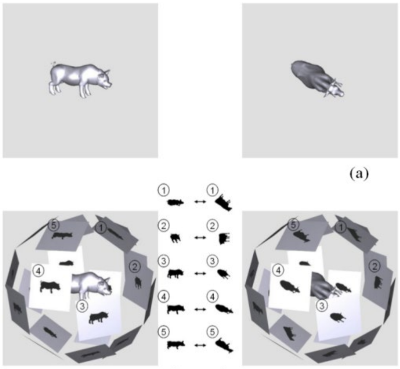
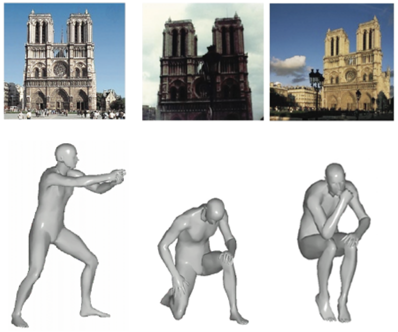
Shape Retrieval



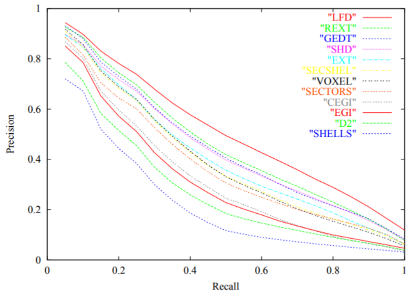
[Osada et al. 2001]



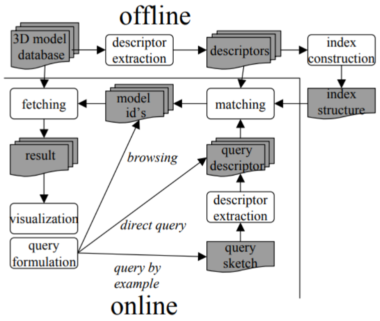
[Chen et al. 2003]



[Brownstein et al 2011]



[Shilane et al. 2004]



[Veltkamp.et al 2008]

Eurographics
3Dor

[SHREC 2013 - 2017]

Parametrization

parameters → **Parametric Shape** →

Advantages:

- constrains manipulations
  - e.g., fabrication-oriented constraints
- reduces the search space

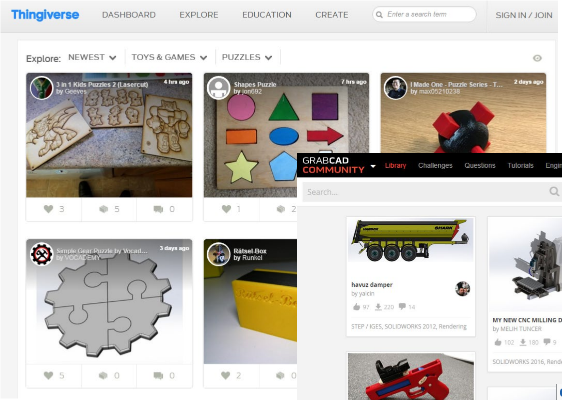
Available Collections

SolidWorks

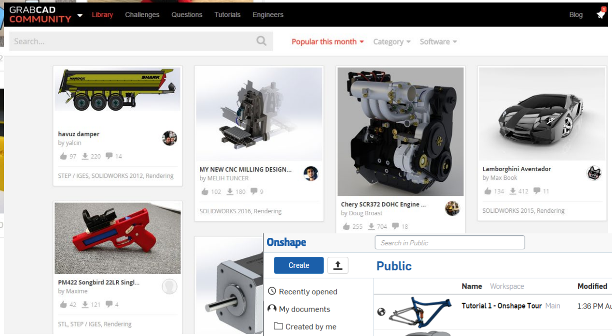
creo™ 1.0

OpenScad

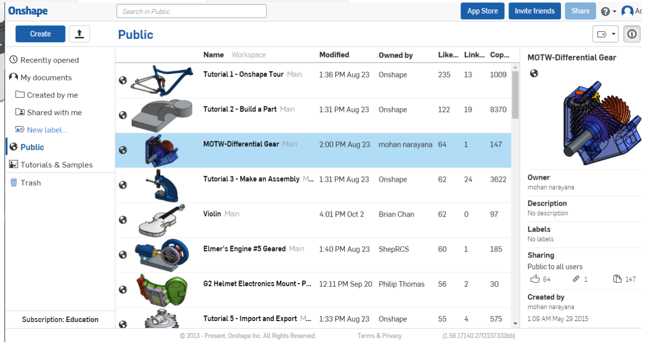
Onshape



Thingiverse

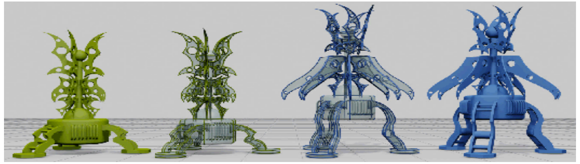


GrabCAD

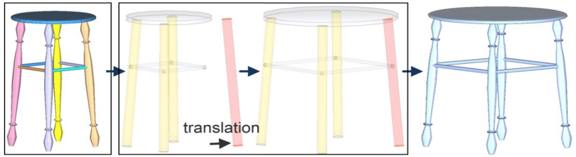


Onshape's Repository

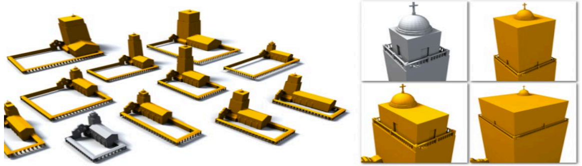
Parametrization Techniques



[Gal et al 2009]



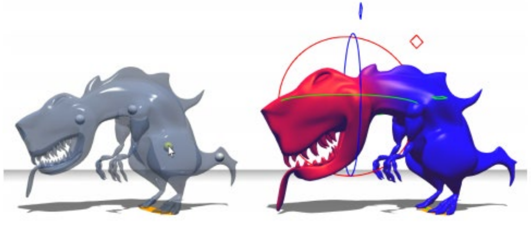
[Zeng et al 2011]



[Bokeloh et al 2012]

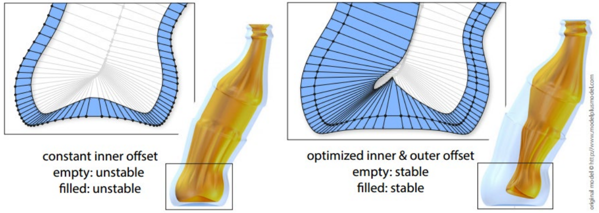
Application Examples:

Linear Blend Skinning



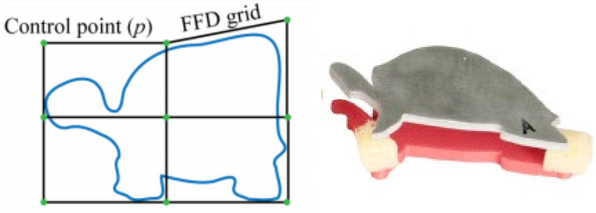
[Prevost et al. 2014]

Offset Surfaces



[Musialski et al. 2015]

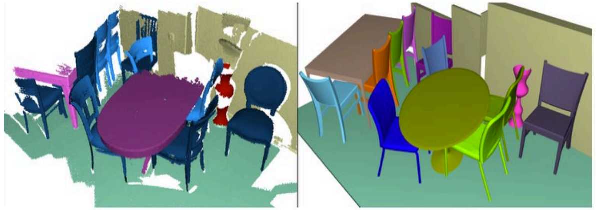
Cages



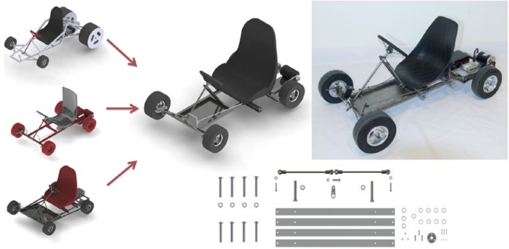
[Bharaj et al. 2015]

Data-Driven Modeling

[Xu et al 2013]



[Nan et al 2012]



[Schulz et al. 2014]

[Xu et al 2011]

[Shen et al 2012]

[Yang et al. 2015]

Parametric Shape Collections

Retrieval in Parametric Shape Collections

Query

Parametric Shape Collection

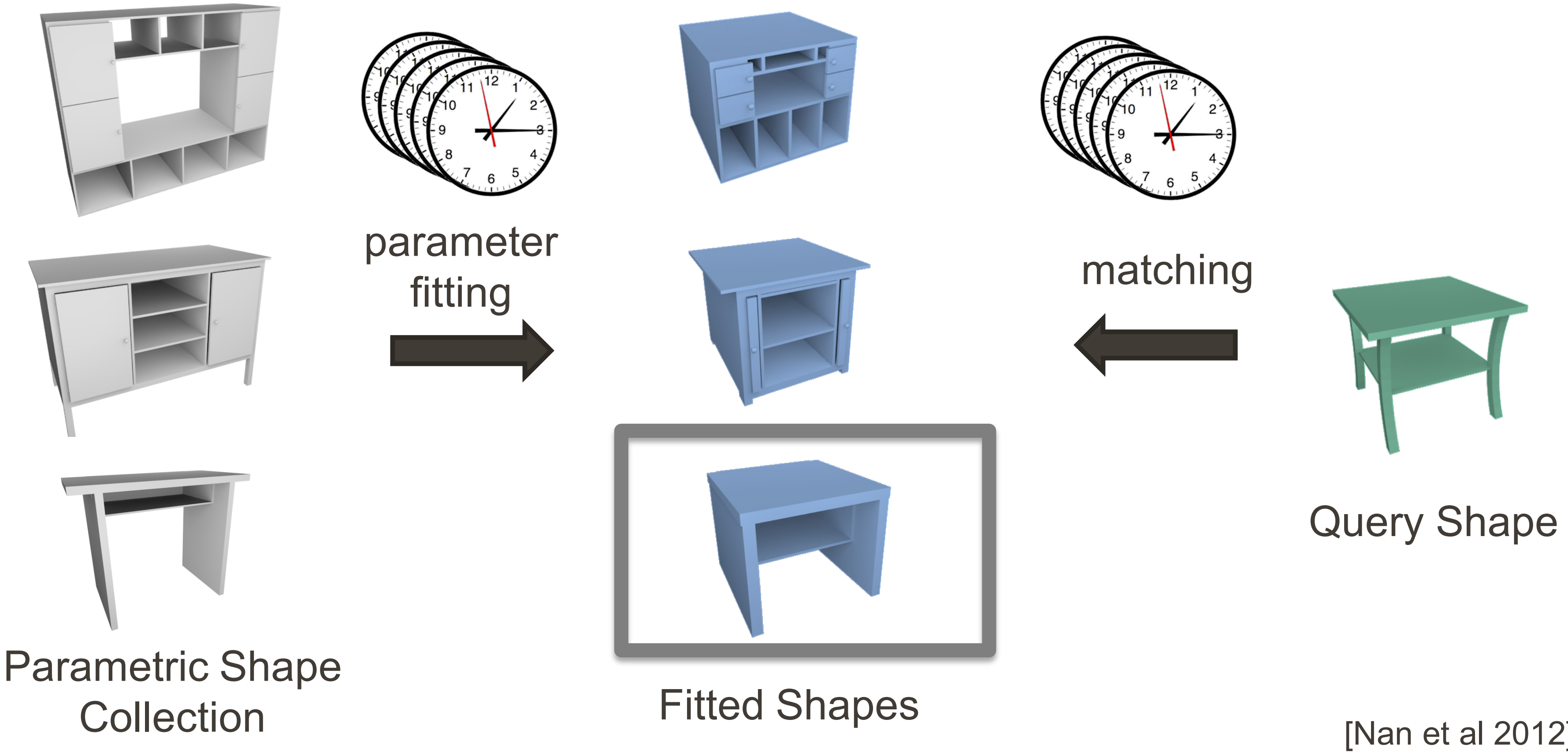
Typical Pipeline

Parametric Shape Collection

?

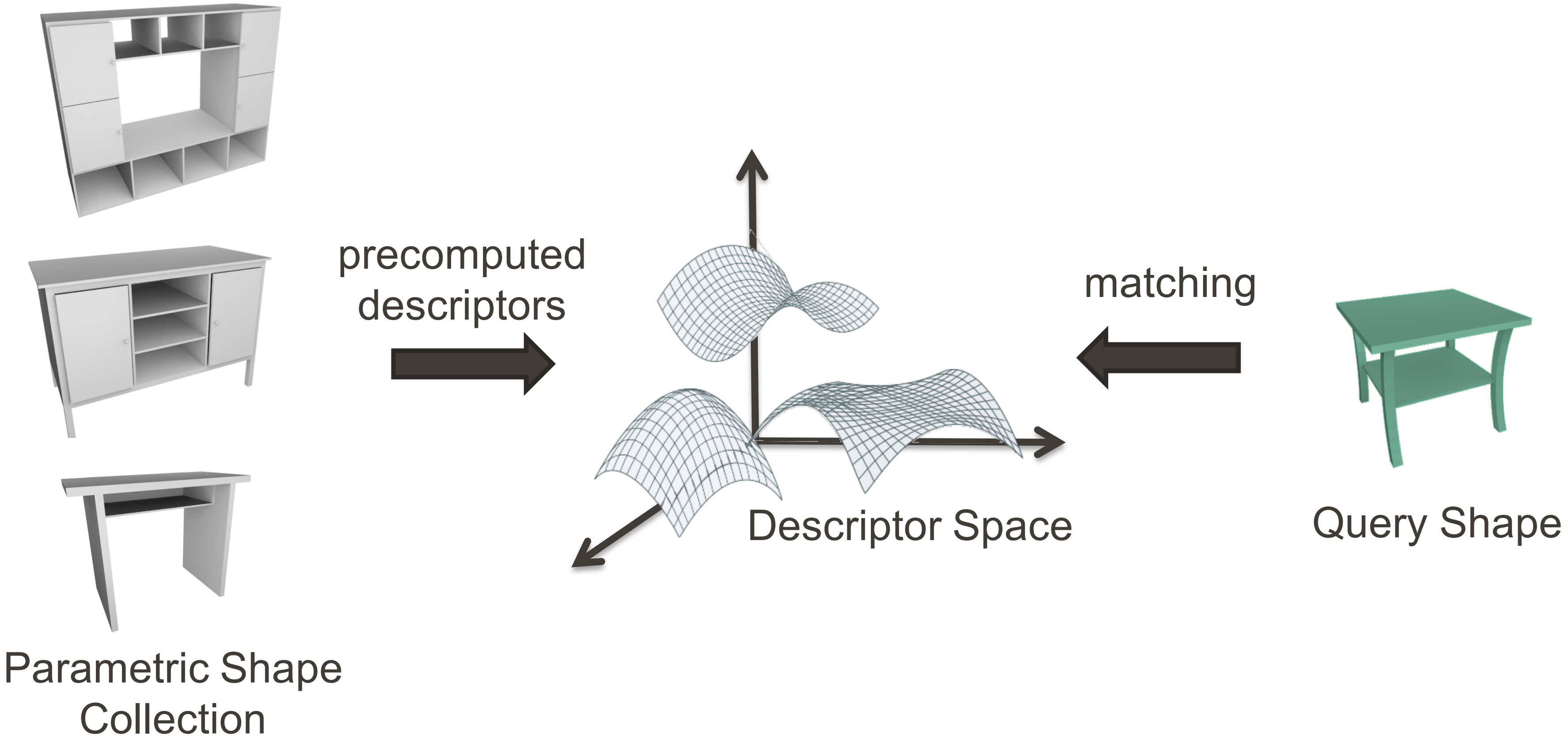
Query Shape

Typical Pipeline *Fit-First*

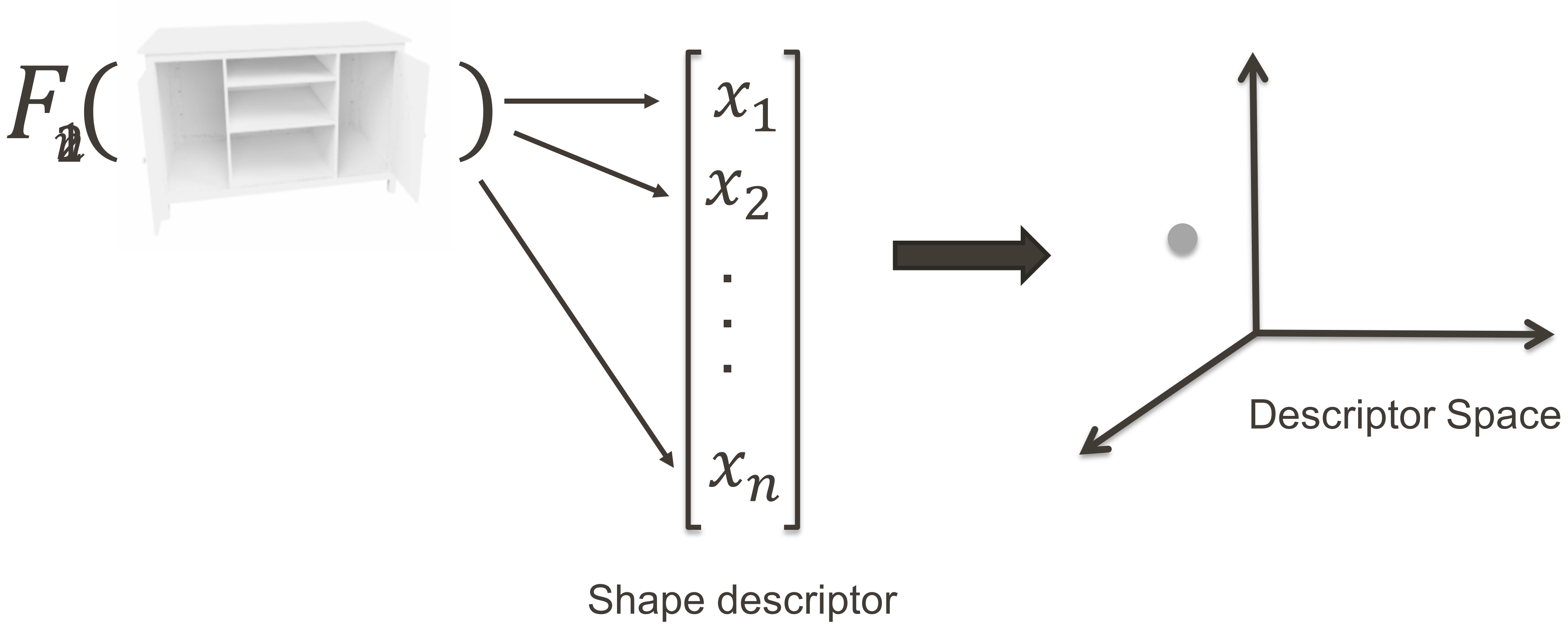


[Nan et al 2012]

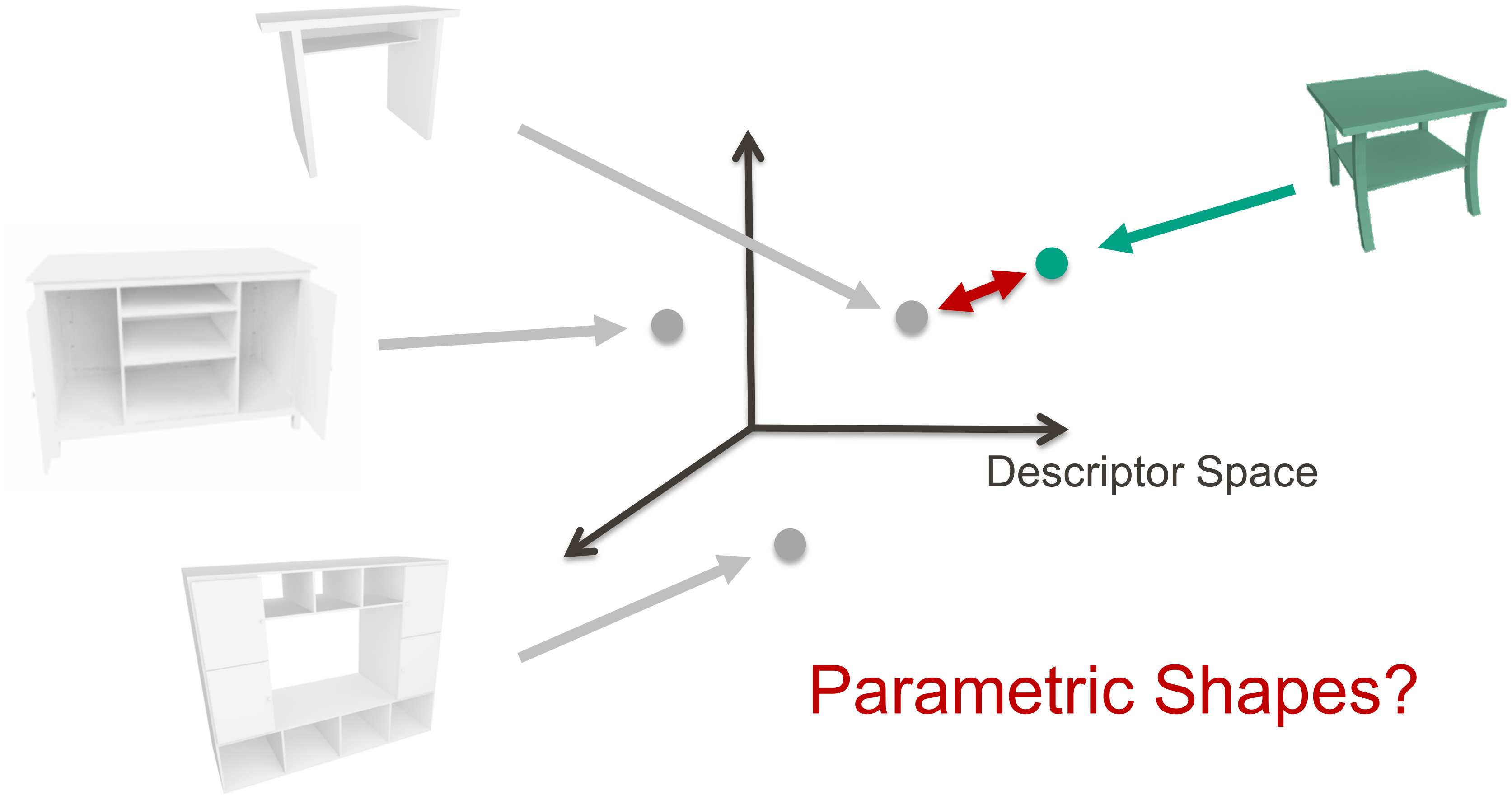
Our Approach



Retrieval Using Descriptors

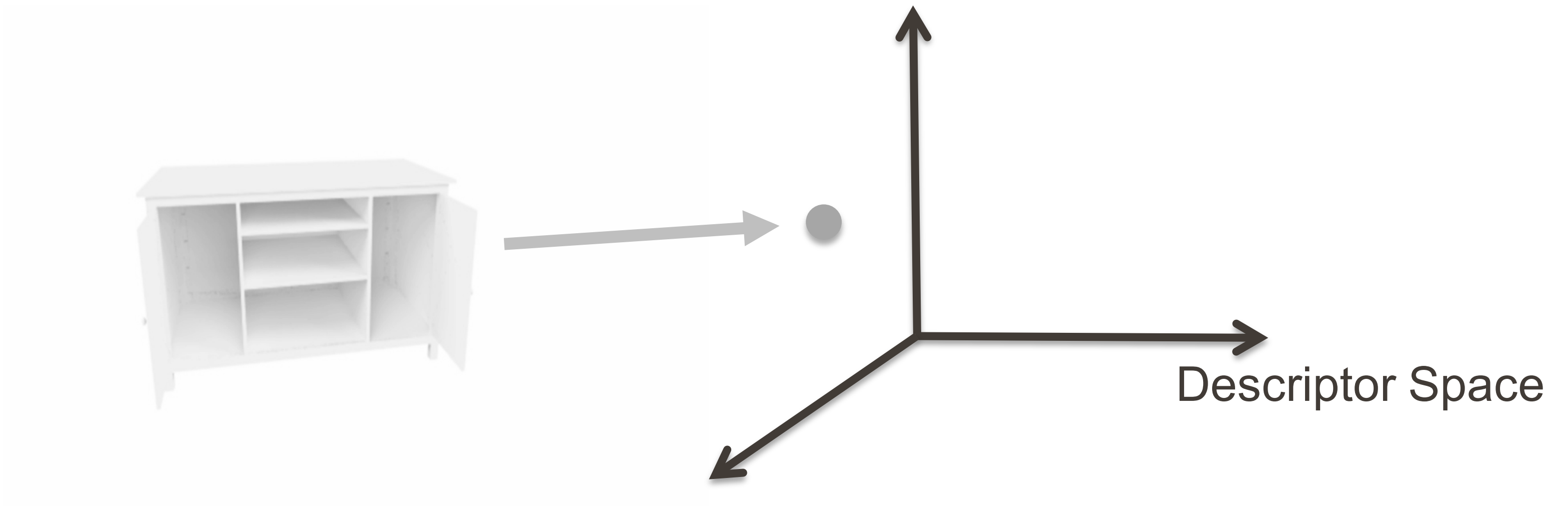


Shape Retrieval with Descriptors

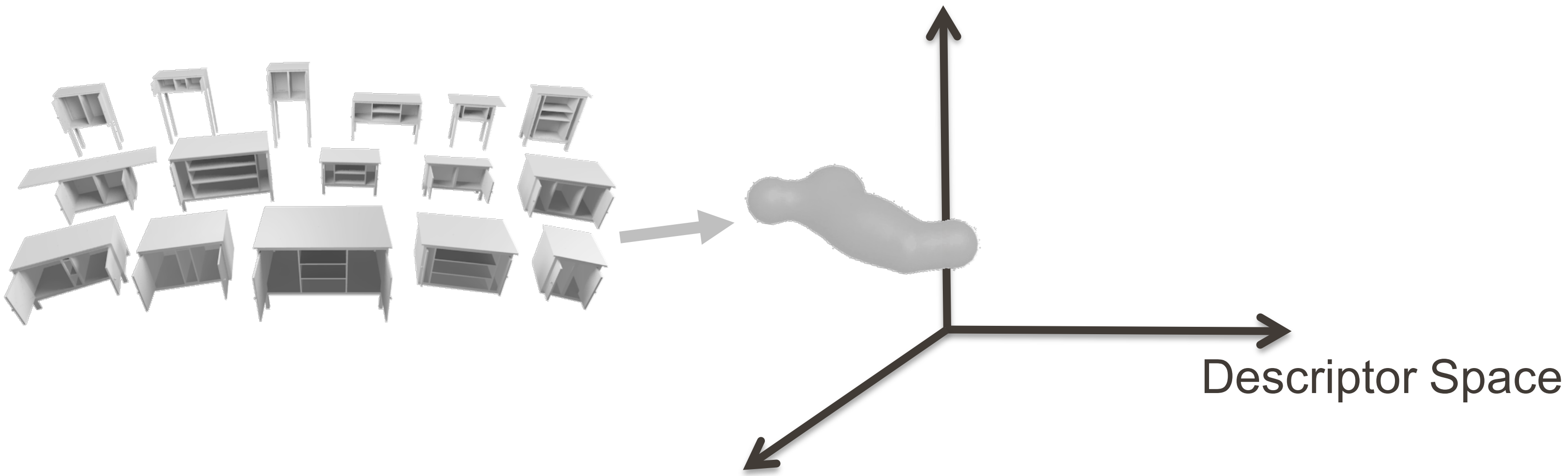


Parametric Shapes?

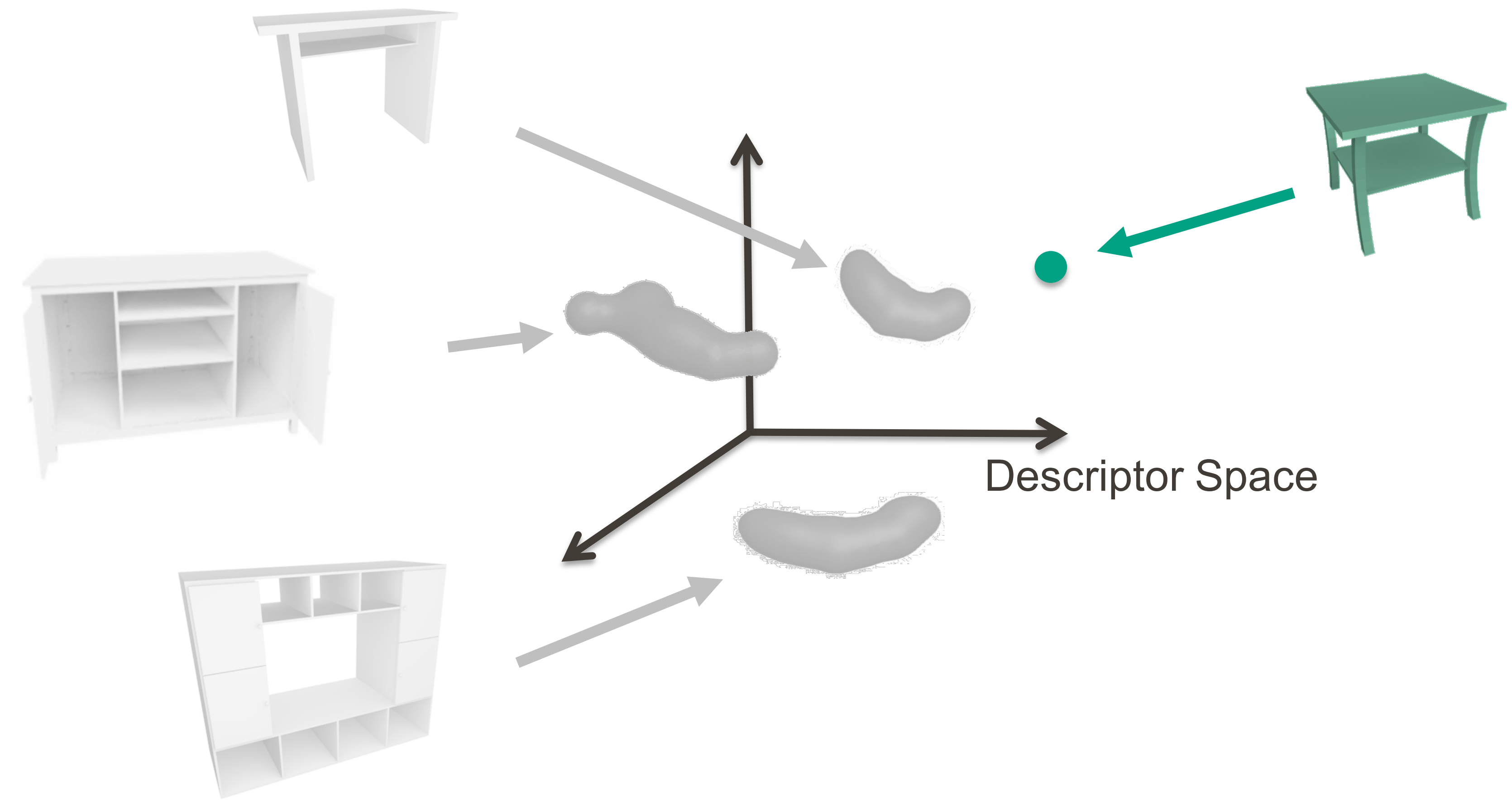
Parametric Shape Retrieval with Descriptors



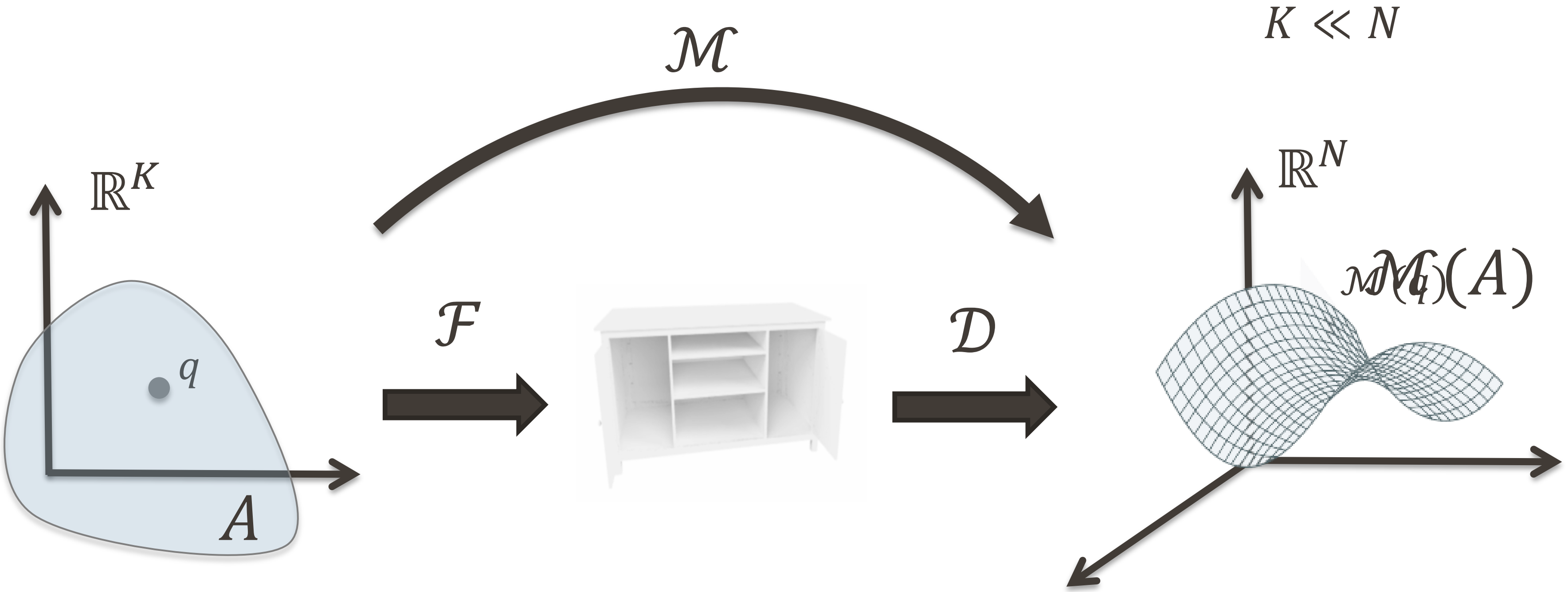
Parametric Shape Retrieval with Descriptors



Parametric Shape Retrieval with Descriptors



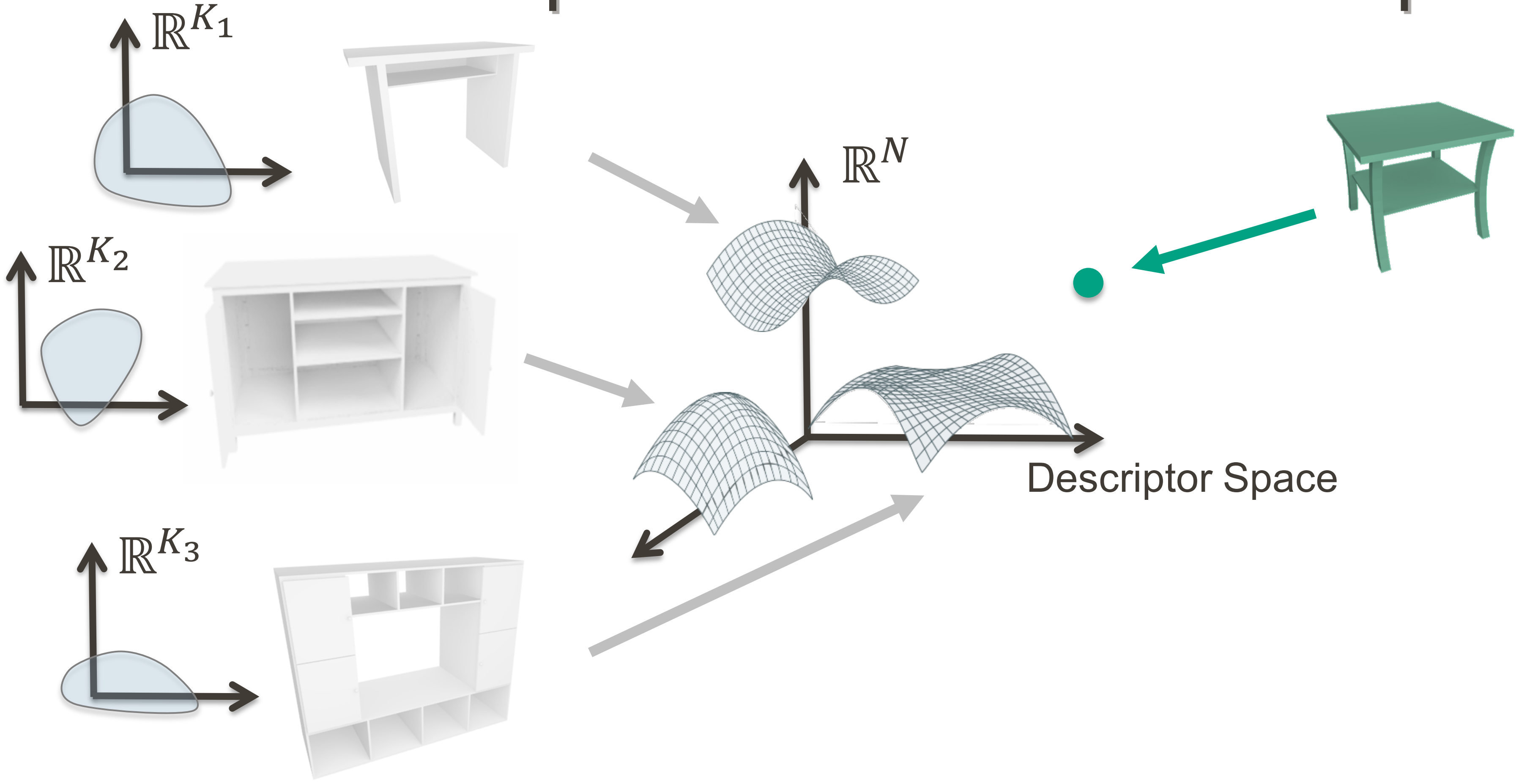
Regions in Descriptor Space



Parameter Space

Descriptor Space

Parametric Shape Retrieval with Descriptors



Approach

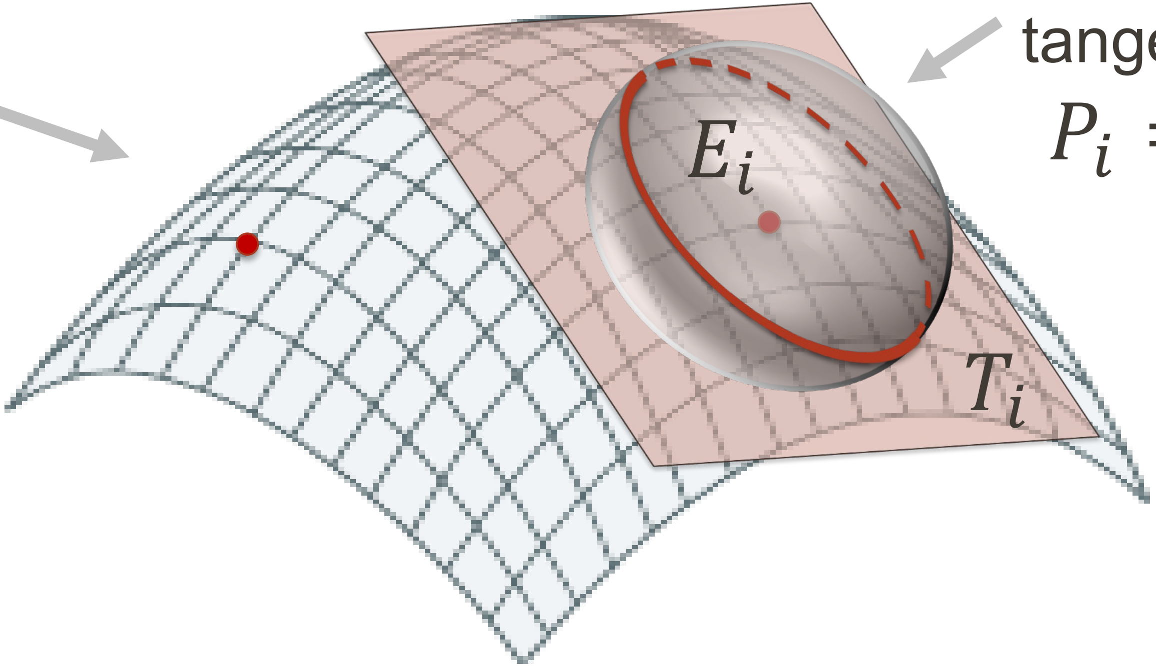
$$\mathcal{M}(A) \longrightarrow \overline{\mathcal{M}(A)} = \{ P_1, \dots, P_K \}$$

point

$P_i = p_i$

bounded tangent space

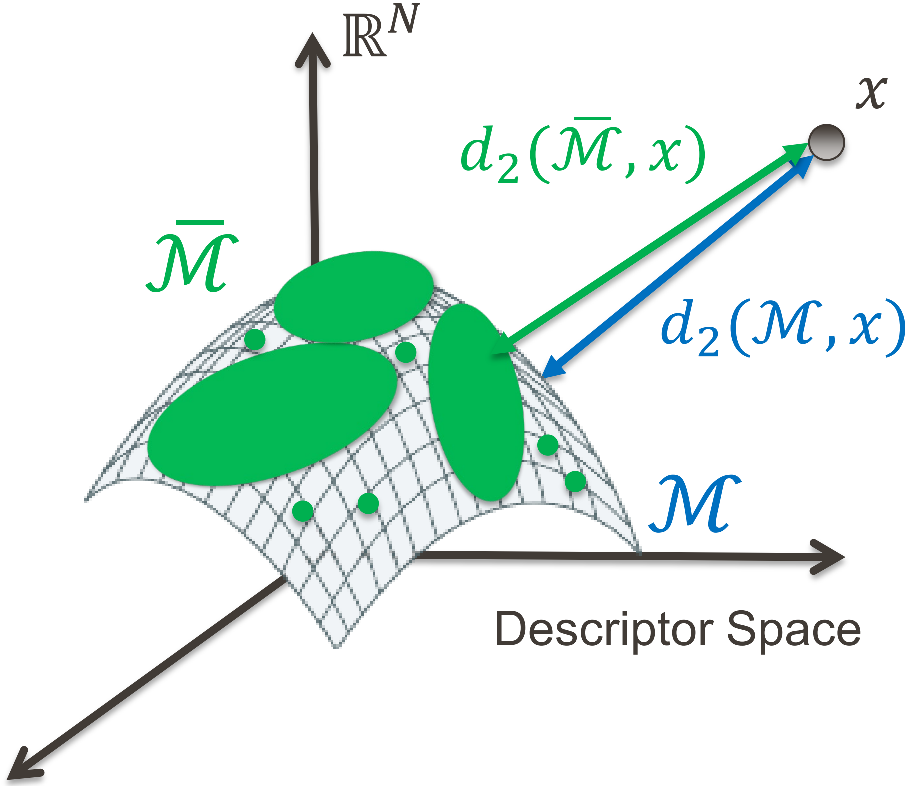
$P_i = T_i \cap \mathrm{E}_i$



Technical Contribution

Algorithm for efficiently representing parametric shapes with these primitives to allow accurate retrieval.

Accuracy Criteria



$$d_2(\bar{\mathcal{M}}, x) \approx d_2(\mathcal{M}, x)$$

$$|d_2(\bar{\mathcal{M}}, x) - d_2(\mathcal{M}, x)| \leq \delta$$

user specified

Coverage and Tightness

$$|d_2(\bar{\mathcal{M}}, x) - d_2(\mathcal{M}, x)| \leq \delta \qquad \forall x \in \mathbb{R}^N$$

⇓

Coverage Property

$$d_2(\bar{\mathcal{M}}, y) \leq \delta \qquad \forall y \in \mathcal{M}$$

Tightness Property

$$d_2(\mathcal{M}, y) \leq \delta \qquad \forall y \in \bar{\mathcal{M}}$$

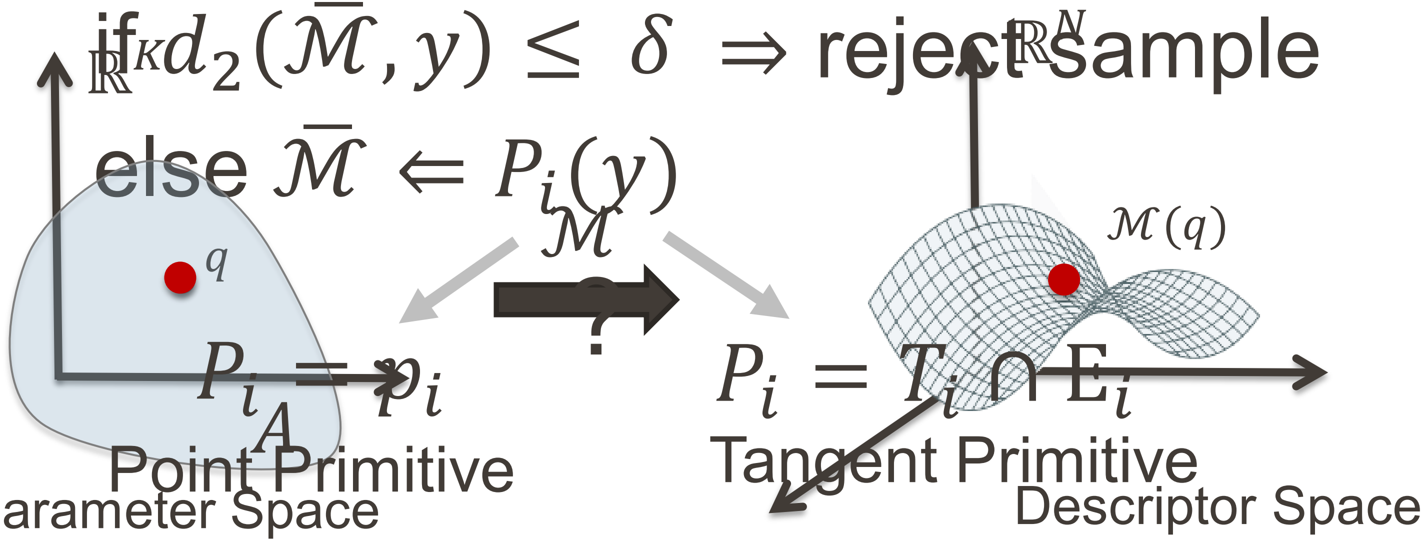
Algorithm

Initialize $\bar{\mathcal{M}} = \emptyset$

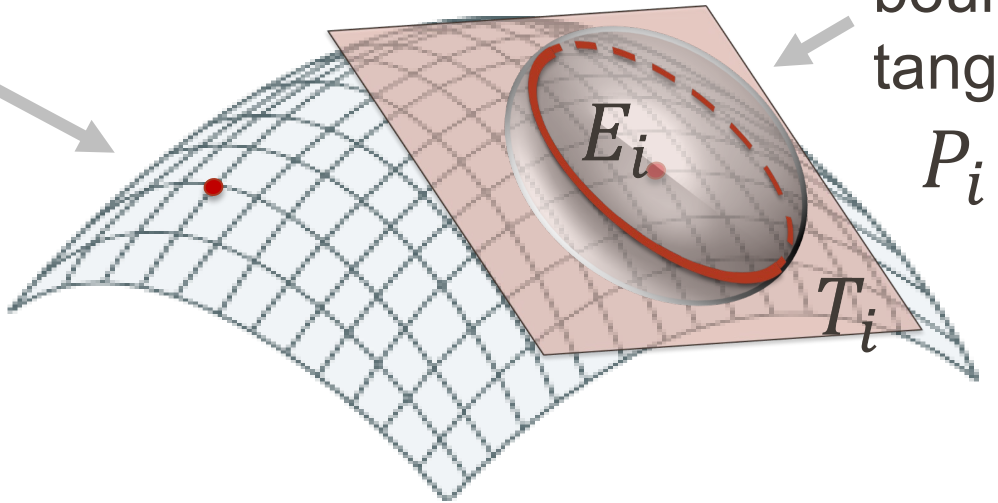
Sample $y \in \mathcal{M}$

if $d_2(\bar{\mathcal{M}}, y) \le \delta \Rightarrow$ reject sample

else $\bar{\mathcal{M}} \Leftarrow P_i(y)$



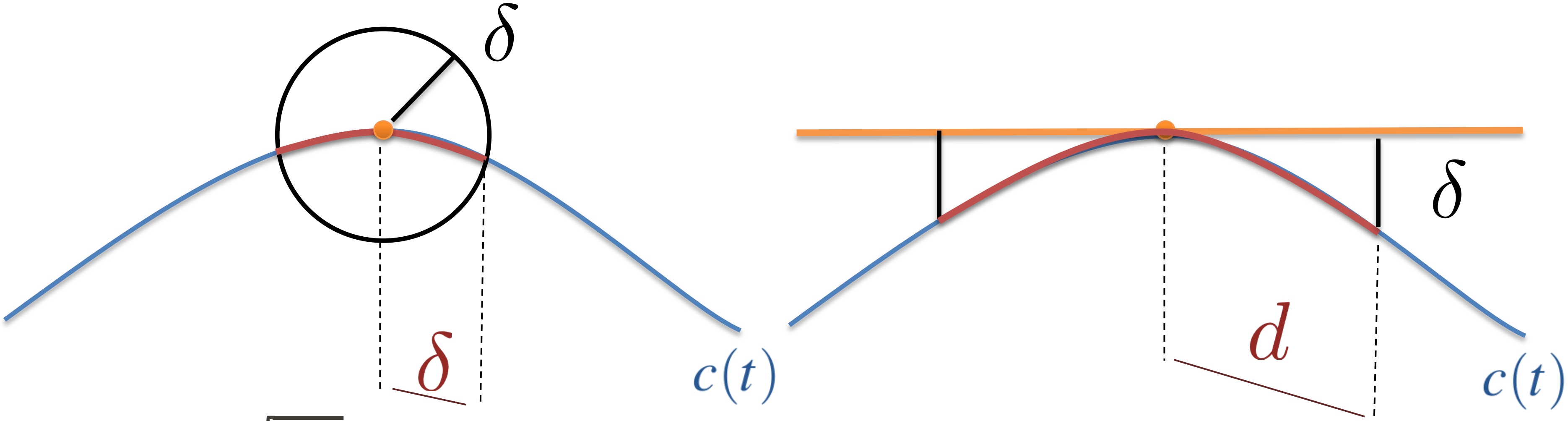
Choosing Between Primitives



cost of tangent = $(K+1)$ cost of point

coverage of tangent > $(K+1)$ coverage of points

Coverage of Points and Tangents



$$\frac{d}{\delta} = \sqrt{\frac{2}{\delta\kappa}}$$

← curvature

Criteria for Primitive Selection

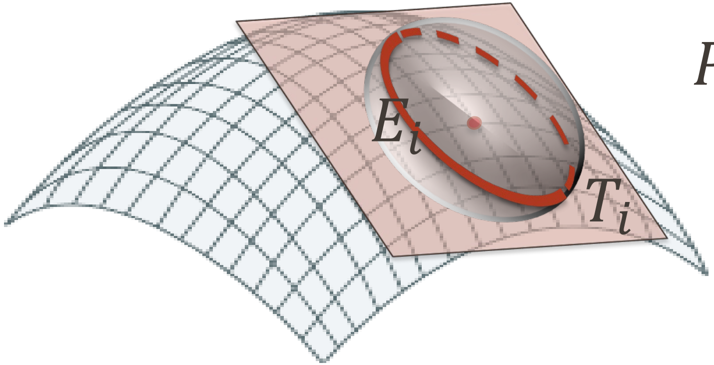
One-Dimensional Case

Use tangents if: $\kappa \leq \frac{2}{\delta(K+1)^2}$

Multi-Dimensional Case

Use tangents if: $\kappa^{max} \leq \frac{2}{\delta(K+1)^{\frac{2}{K}}}$

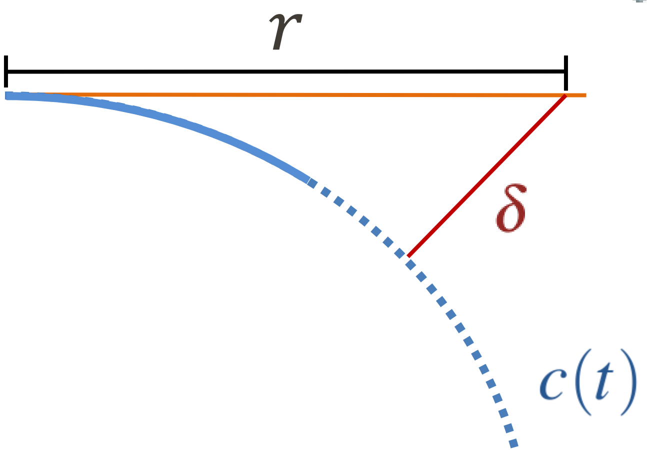
Bounding Tangent Primitives



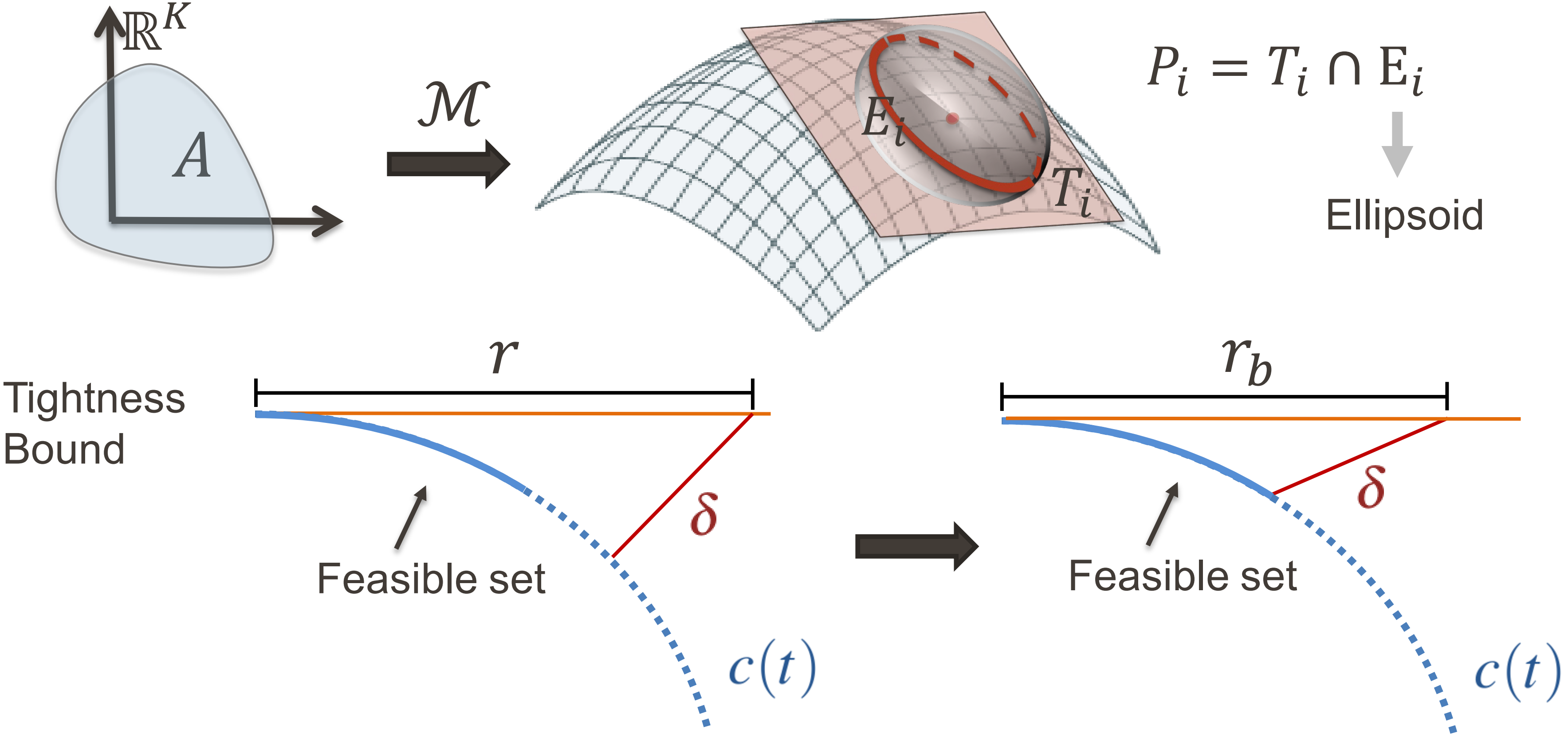
$P_i = T_i \cap \mathrm{E}_i$

Hyperphere of radius r

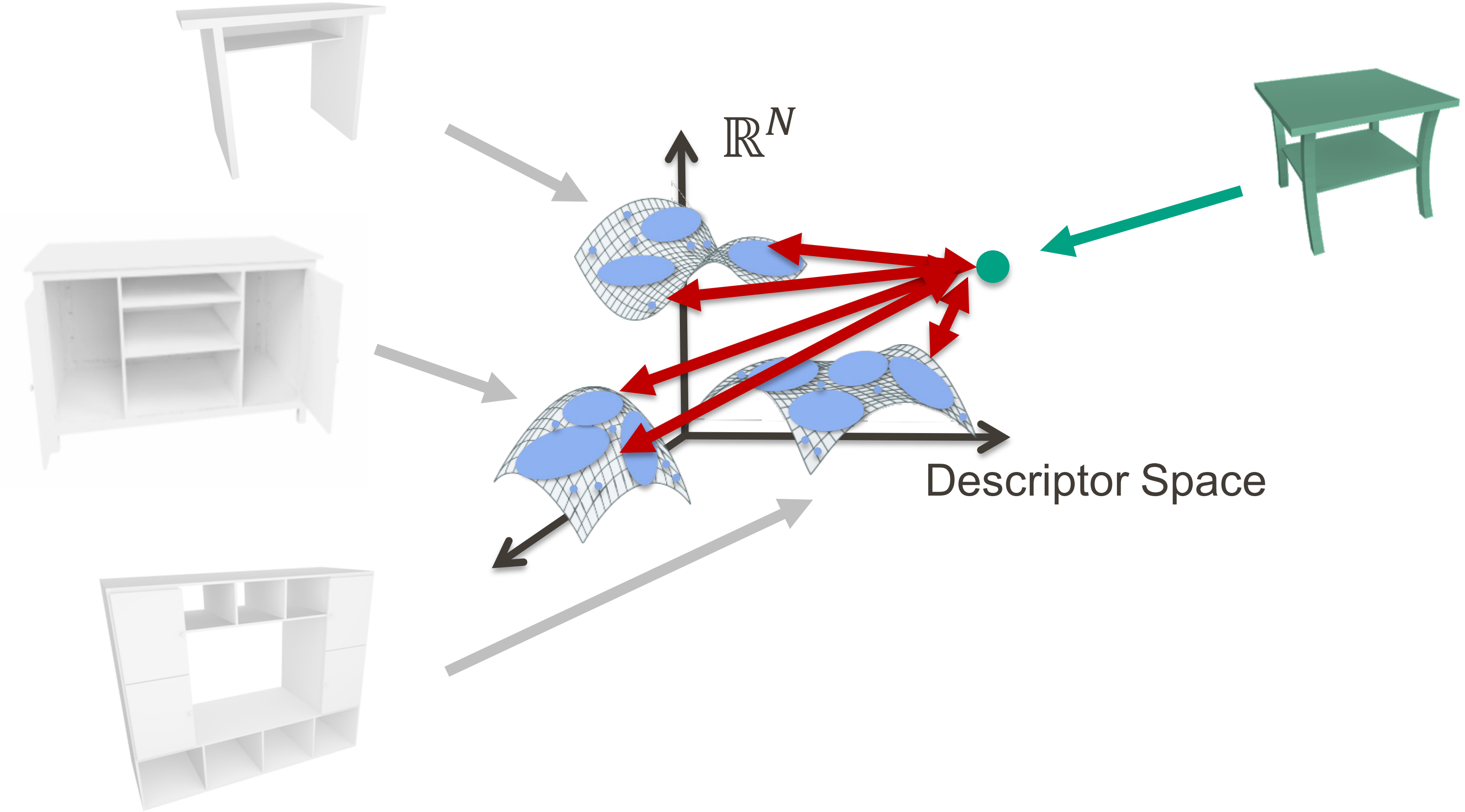
Tightness Bound



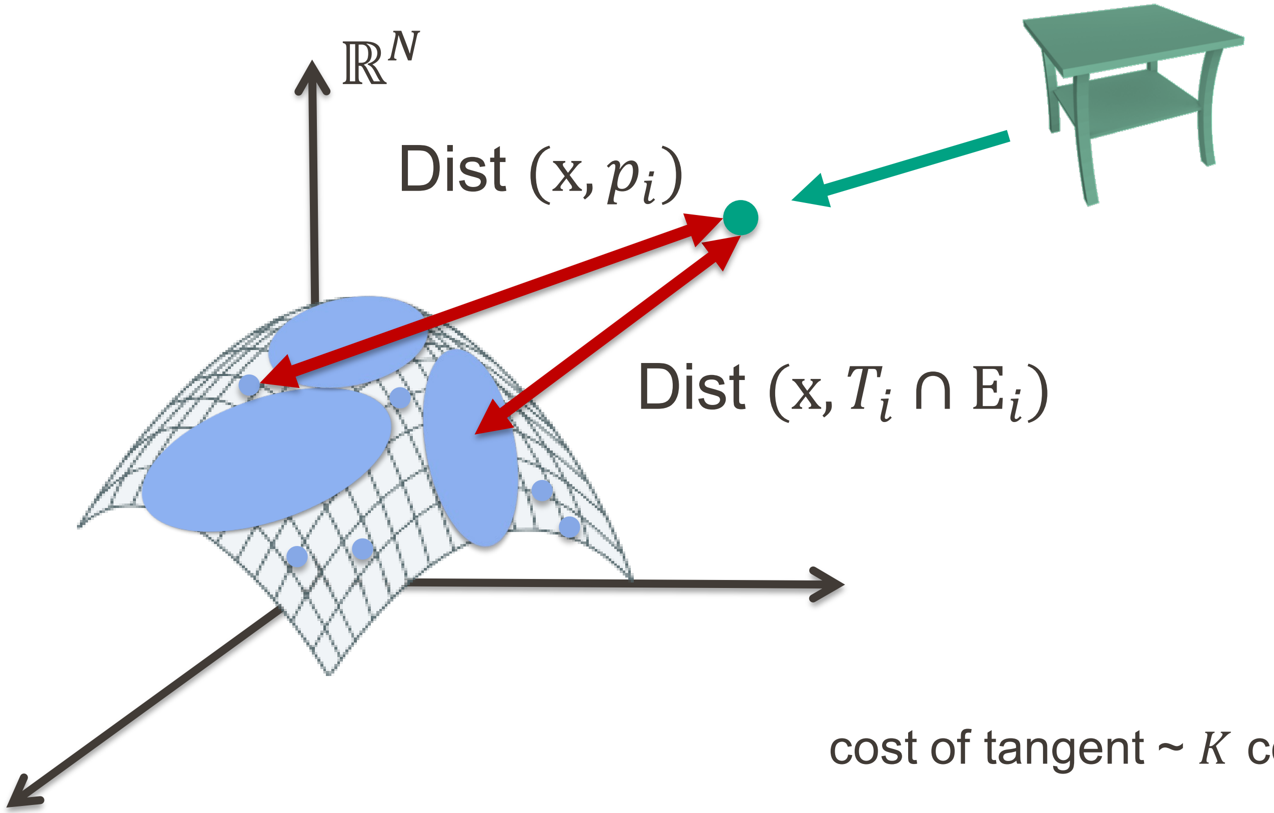
Handling the Feasible set A



Our Approach: Retrieval

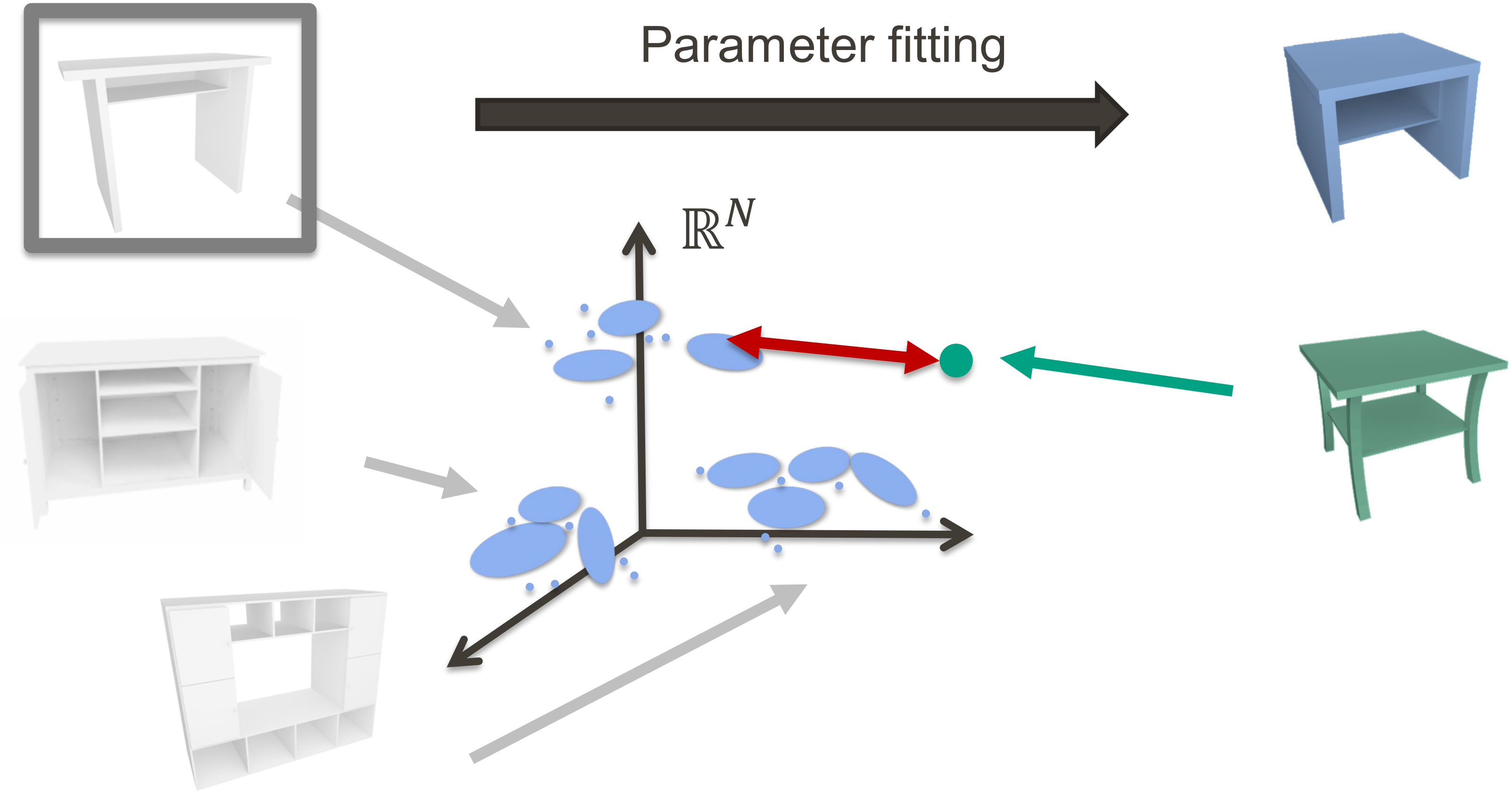


Retrieving the Parametric Shape



cost of tangent ~ K cost of point

Parameter Fitting



Evaluations

Experiments: Data

Number of parameters: 2-9

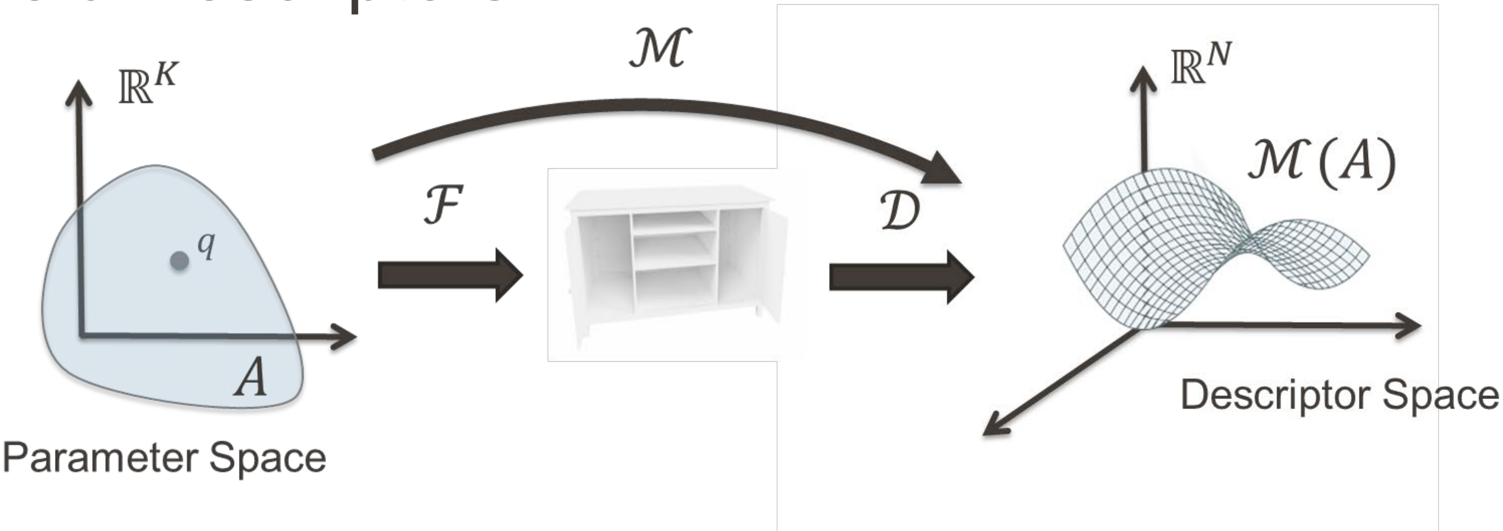
Category	Number of Models
lamps	17
boats	11
chairs	15
planes	9
carts	10
tables	15

Experiments: Descriptors

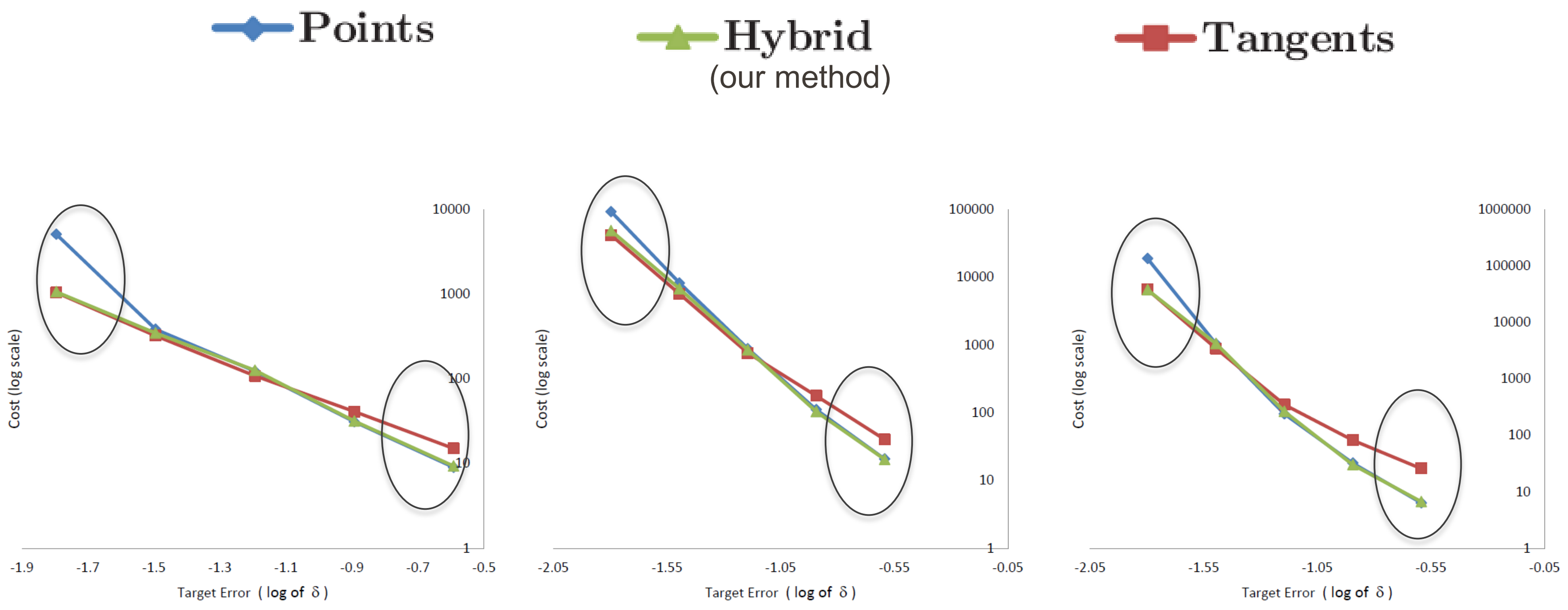
D2 Shape Distribution

VOXEL Shape Histogram

Light Field Descriptors

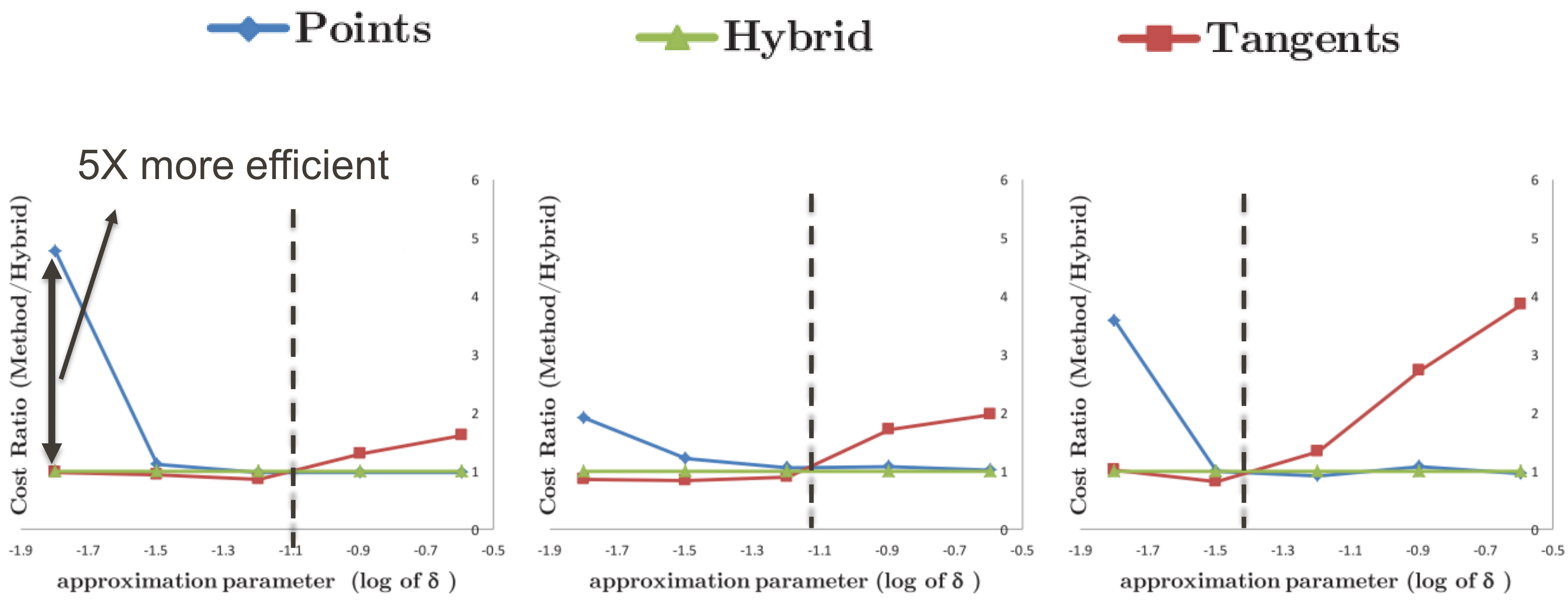


Manifold Representation: Efficiency



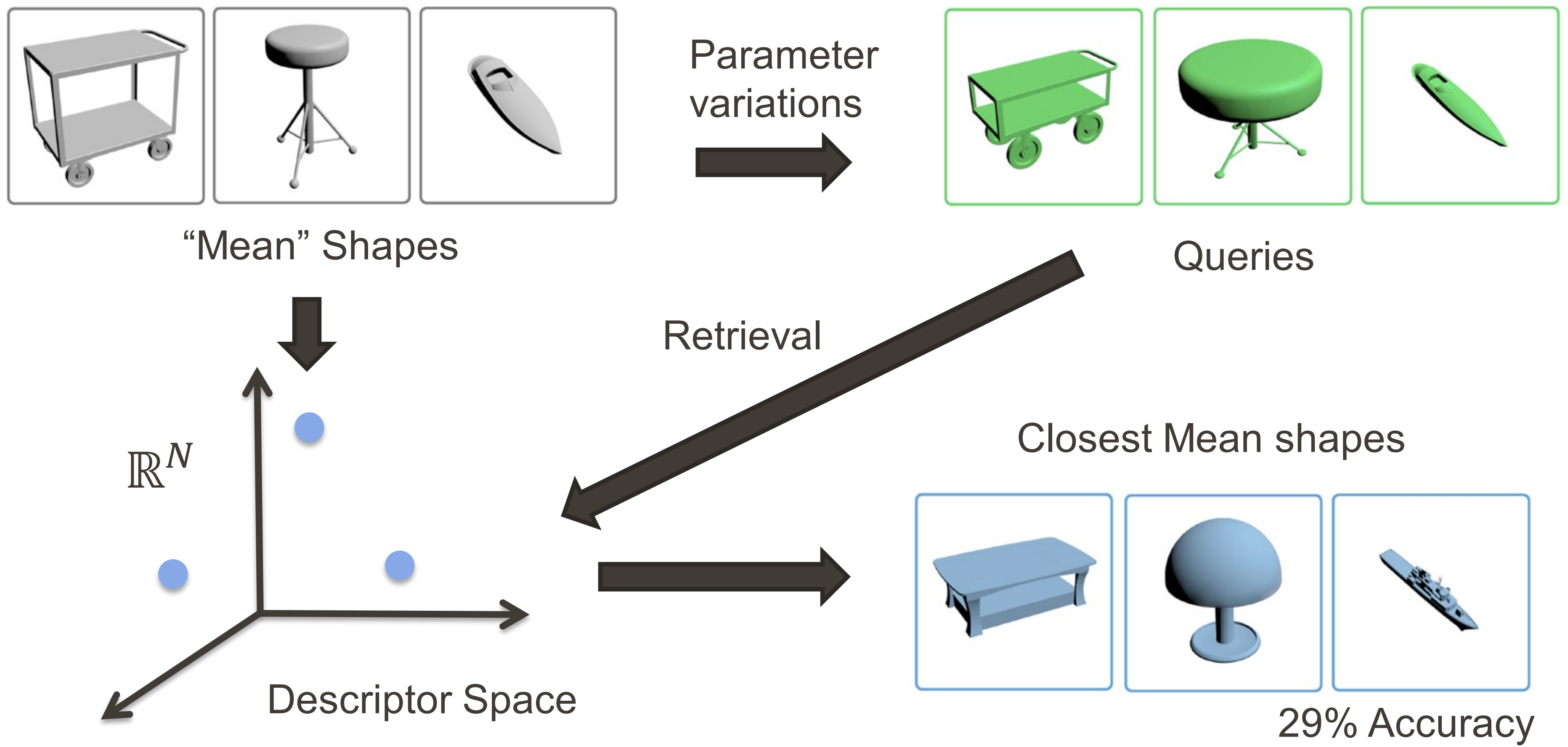
$K = 3$ $K = 5$ $K = 7$

Manifold Representation: Efficiency

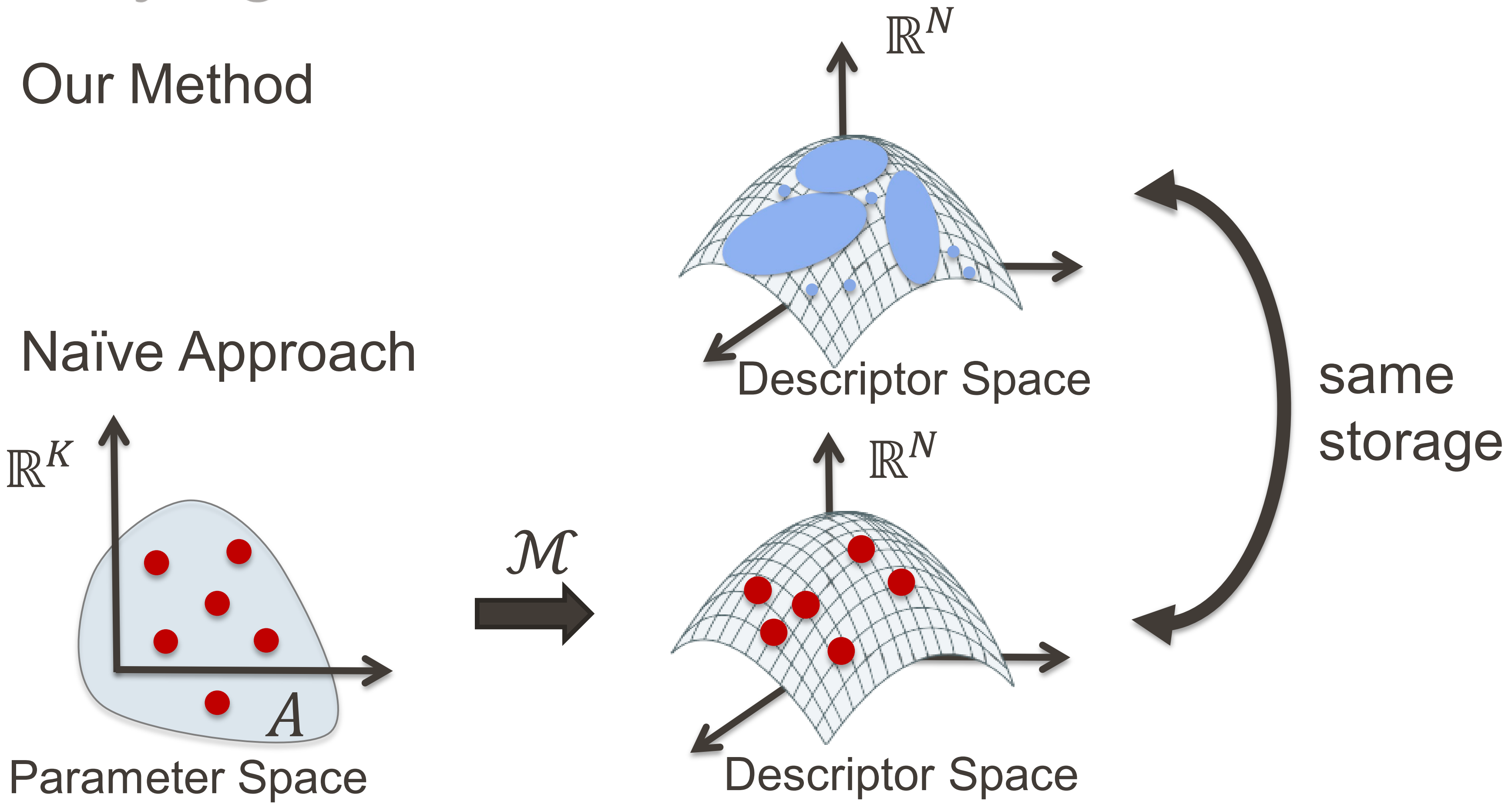


$K = 3$ $K = 5$ $K = 7$

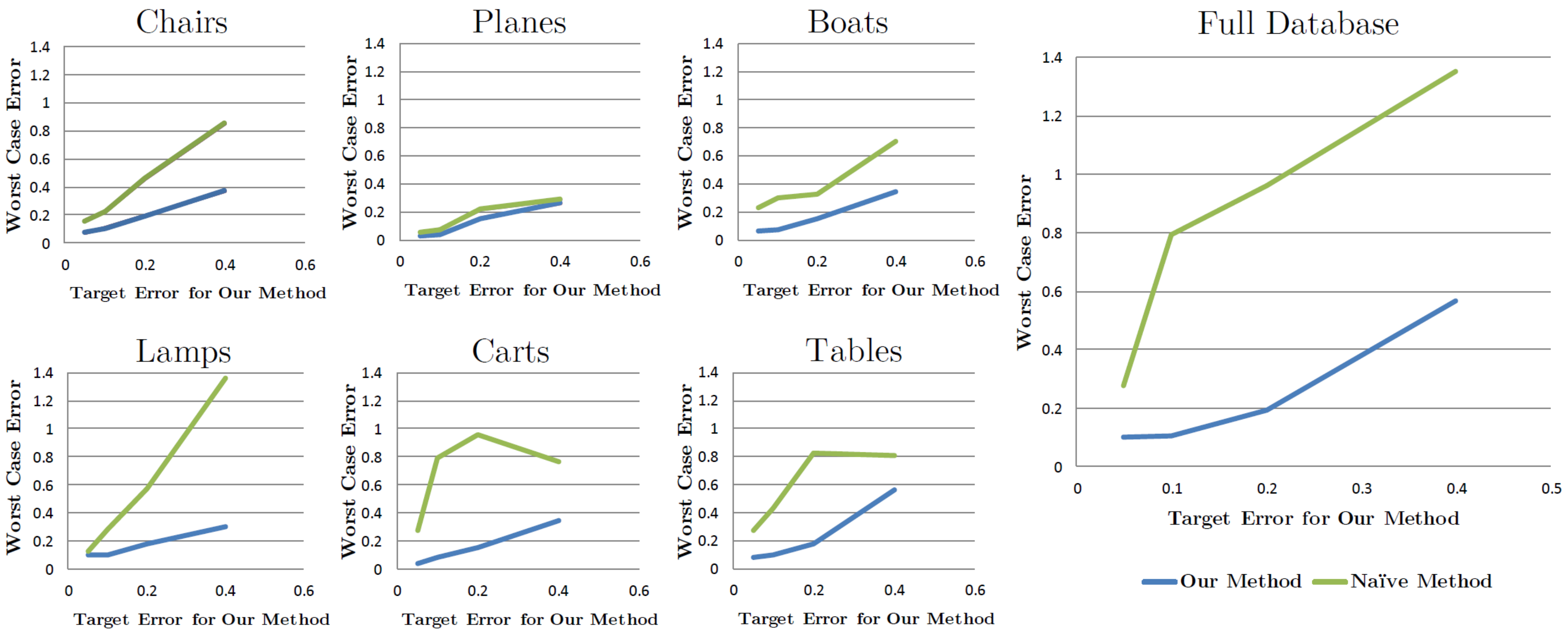
Querying Parametric Variations



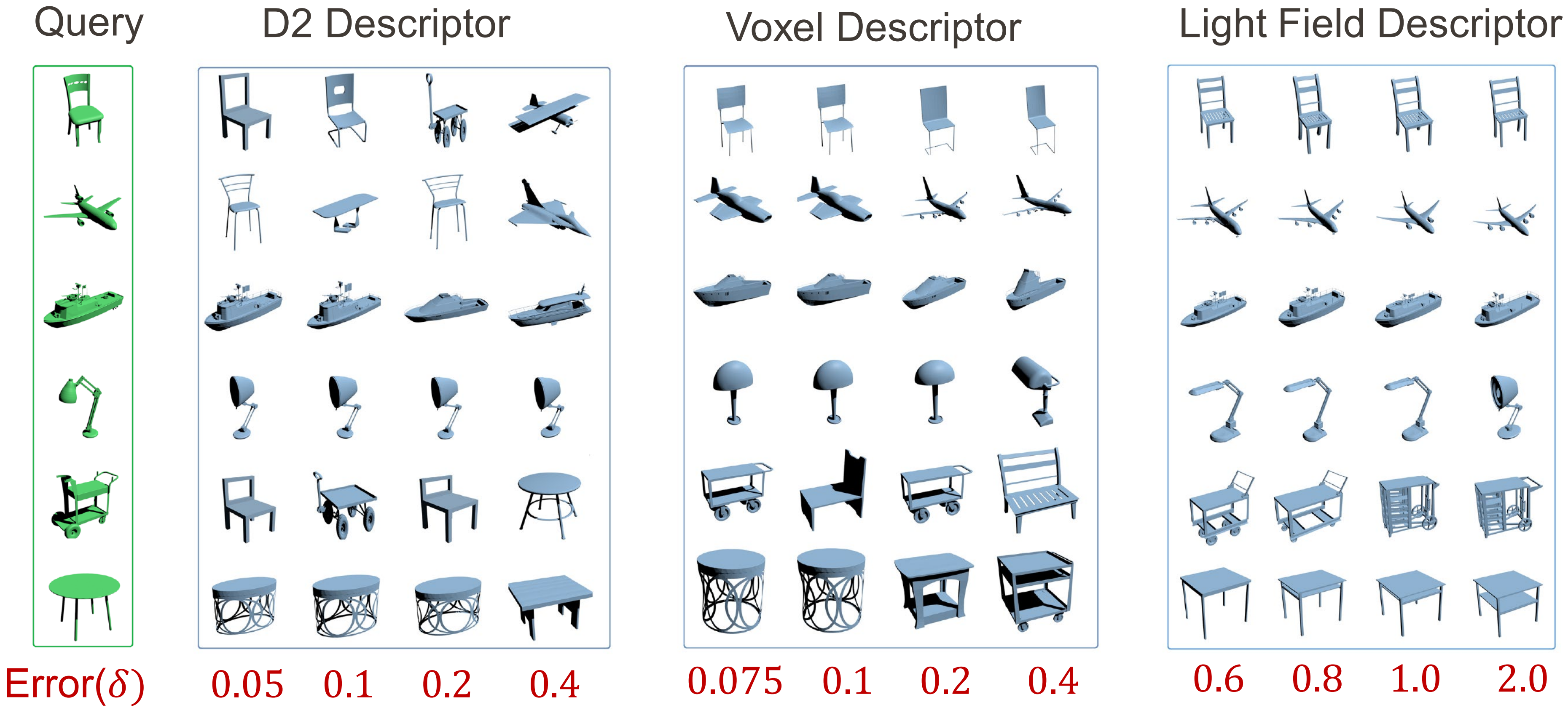
Querying Parametric Variations



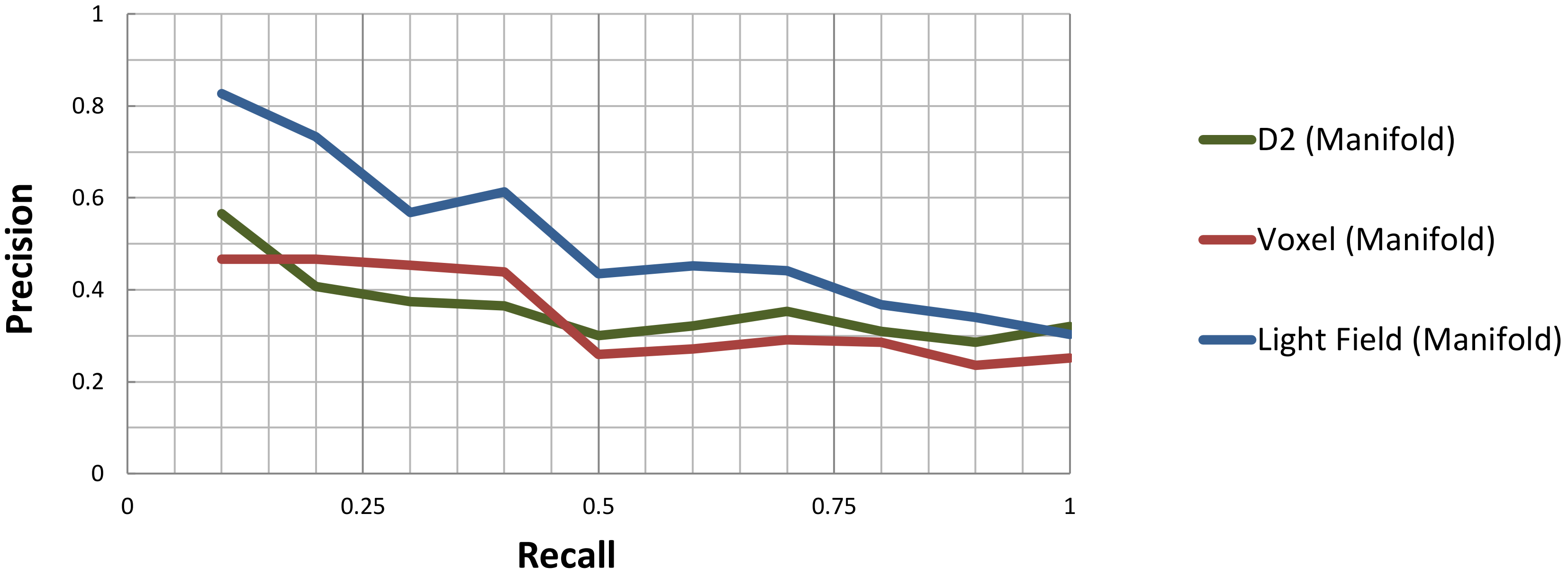
Comparison with Naïve Method



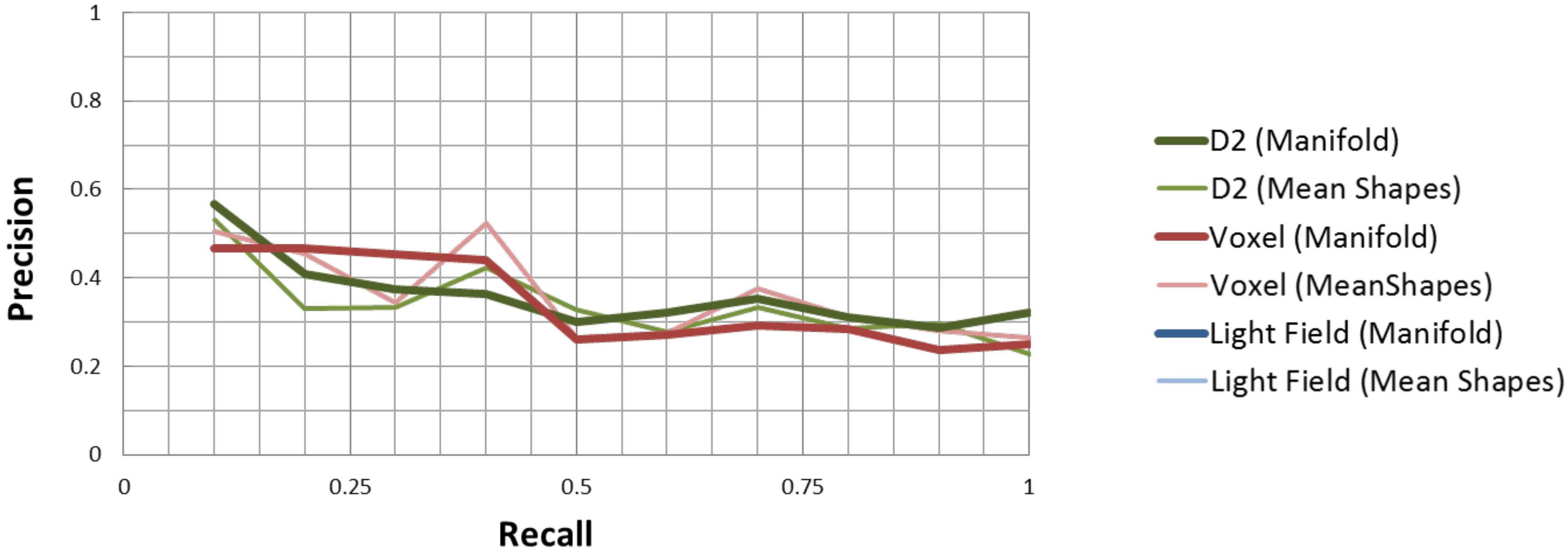
Querying Shapes from Online Repositories



Classification



Classification



High Quality Descriptors ⇒ improves precision/recall

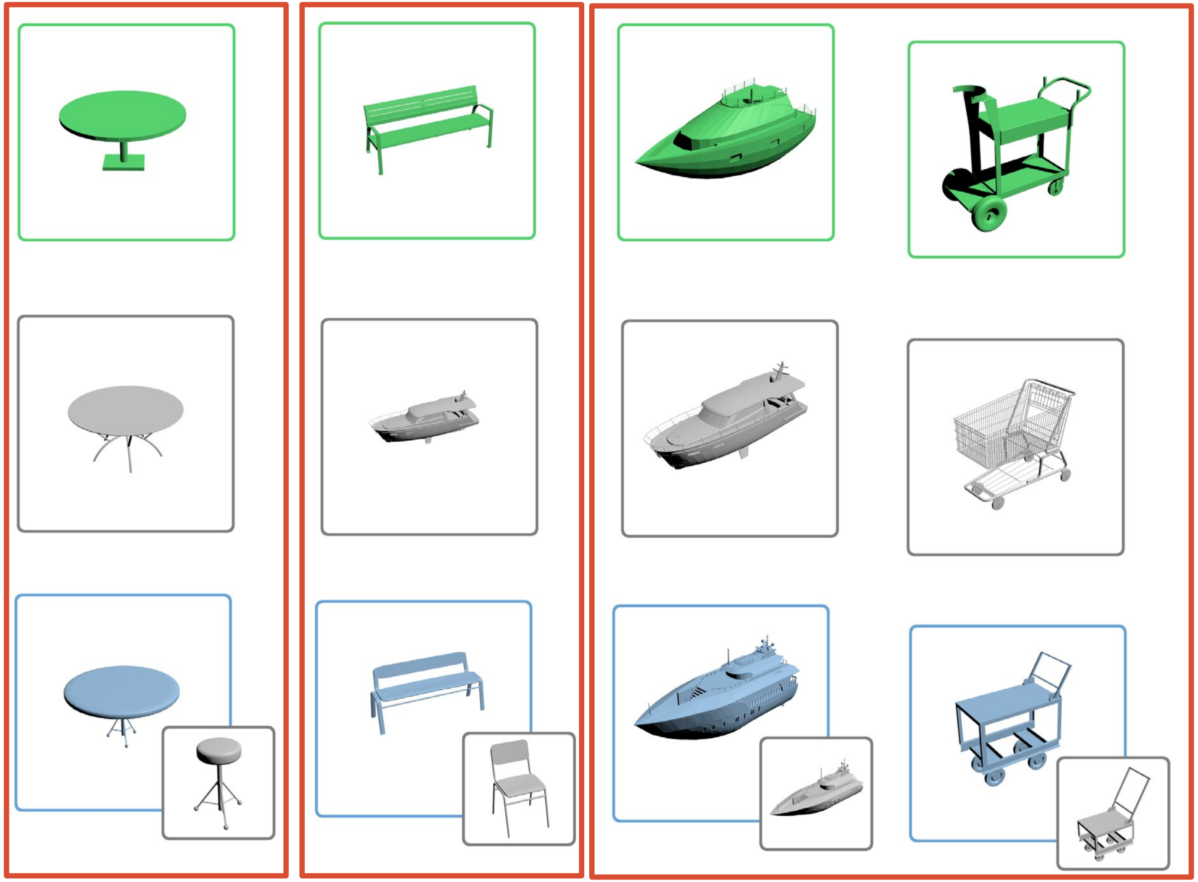
Low Quality Descriptors ⇒ additional complexity cannot be captured (noise)

Beyond Classification

Query

Closest mean shape

Closest parametric
Shape(our Method)



Limitation and Future work

- Scalability (number of parameters)

Limitation and Future work

- Scalability (number of parameters)
- Supporting Discrete Variations

Limitation and Future work

- Scalability (number of parameters)
- Supporting Discrete Variations
- Retrieval Methods

Conclusion

First approach for efficient retrieval on a collection of parametric shapes

Acknowledgements

Charles K. Smart

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Megan C. Chao

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Thank you!

Data available at :
http://people.csail.mit.edu/aschulz/paramShapeRetrieval