“Searching for the Shape”

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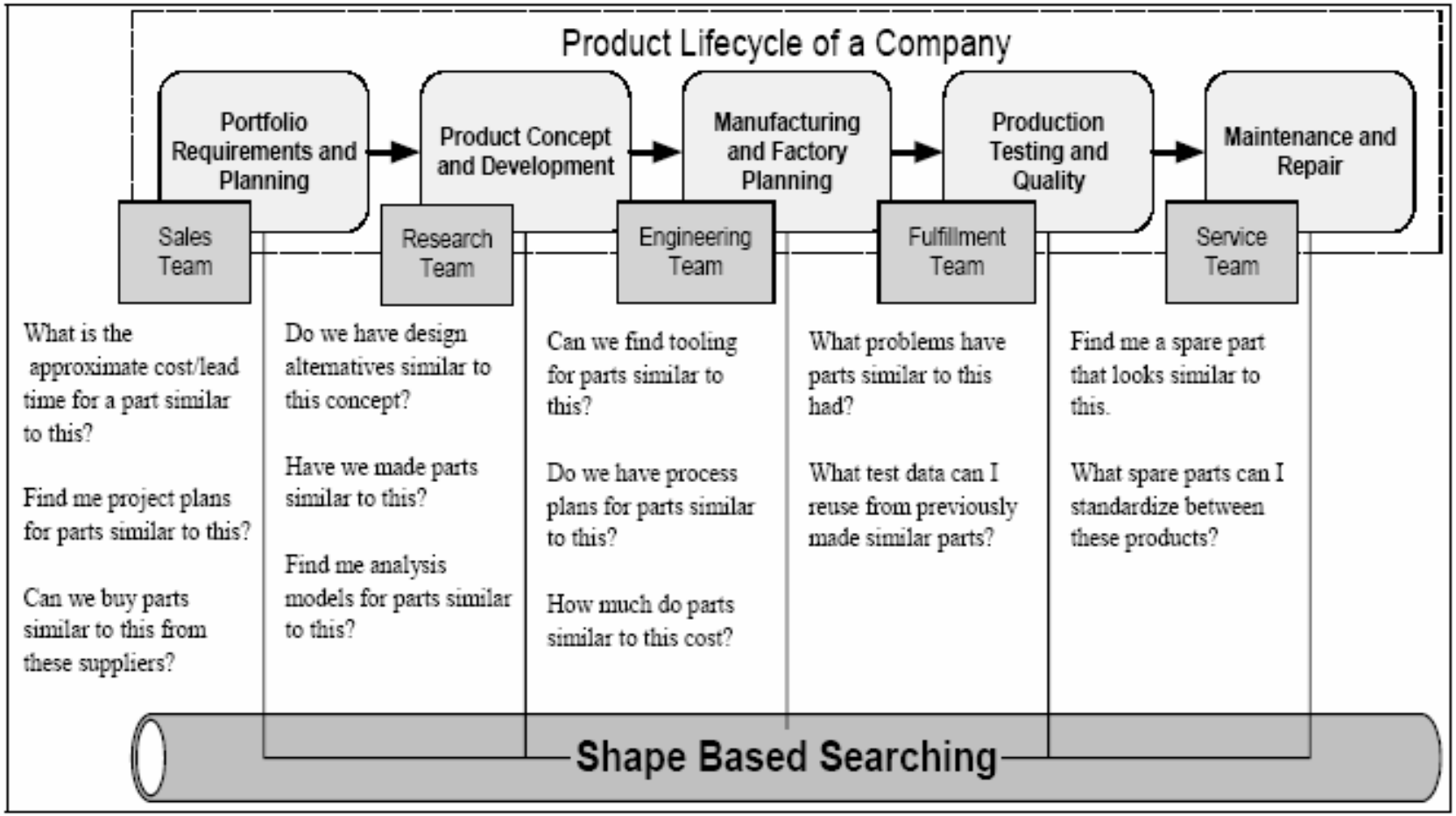
The world we are in…

- Designers spend 60% time searching for right info
- 75% of design activity is design reuse
- 80% of models are created in 3D
- A SME has 30,000 CAD models
- Multimedia activities like Gaming creates even more

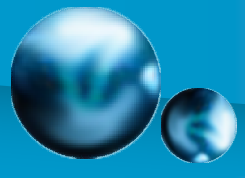
Shape Search Applications



Source: Iyer N., Patwardhan H., Jayanti S and Ramani K. "Dynamic Early Design Advice Using Shape Retrieval", International CIRP Design Seminar, Grenoble, France, May 12-14, 2003.

What is Shape?

- "visible characteristics that make up a particular item" – MW
- ".. All the geometrical information that remains when location, scale & rotational effects are filtered out from an object" – Kendall
- Shape = Geometry + Topology
- Simlarity: overall, scale, pose, domain + task dependent



Shape Descriptor

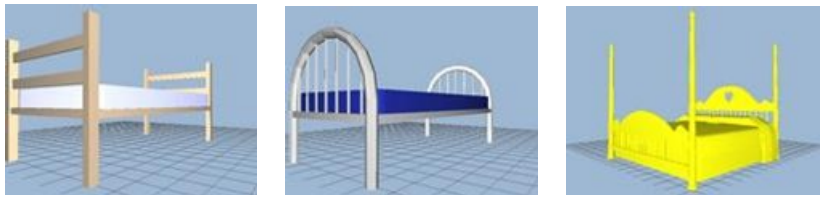
- Scope – must describe all classes
- Uniqueness - one to one mapping
- Stability – stabble w.r.t small changes
- Sensitivity – must capture subtle details
- Efficiency, multi-scale, local
- “Similar shapes should yield similar descriptions”

Engineering vs. Multimedia

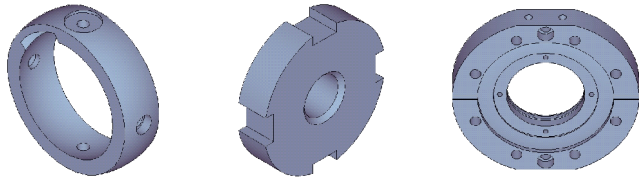
- Engineering
  - high curvatures
  - lots of local features
  - internal features
  - high genus
  - Sheet metal
- Multimedia
  - Free-form
  - pose invariant
  - “assemblies”

Engineering vs. Multimedia

- In engineering, designers look for not only the overall shape but also specific design features
- Function-based classification for the engineering domain is a daunting proposition
- Function based classification does not seem logical because parts with different functions may have similar shape



Multimedia: Similar function; Variable Shape

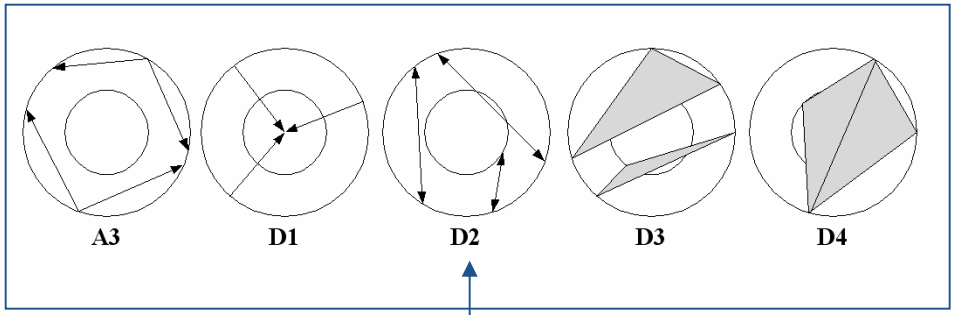


Gimble Ring Lock Nut Flange

Engineering: Similar shape; Varied functions

Shape Representations

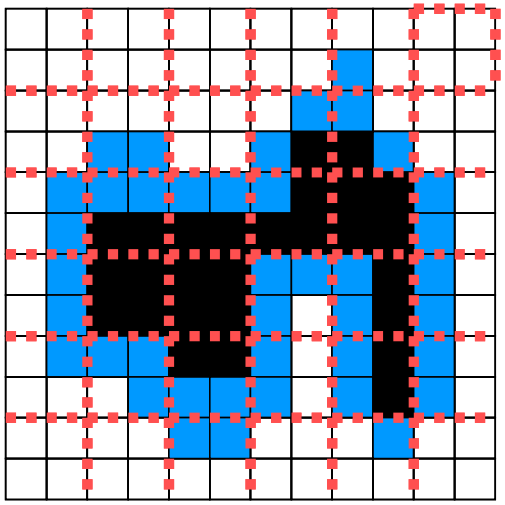
- Shape Distributions (Osada et al. 2002)



Osada, R., Funkhouser, T., Chazelle, B., and Dobkin, D., (2002), "Shape Distributions," ACM Transactions on Graphics, Vol. 21, No. 4, pp.807-832.

- Shape Histograms
  - Solid Angle Histogram

(Kriegel et al. 2003)



Kriegel H.-P., Kröger P., Mashael Z., Pfeifle M., Pötke M., Seidl S., (2003), "Effective Similarity Search on Voxelized CAD Objects", Proceedings of 8th International Conference on Database Systems for Advanced Applications, Kyoto, Japan, pp. 27-36.

Shape Representations

- Spherical Harmonics (Osada et al., 2002)

Any spherical function $f(\theta,\phi)$ can be decomposed as the sum of its harmonics as seen below:

$$f(\theta,\phi) = \sum_{l\geq 0}\sum_{|m|\leq l} a_{lm} Y_l^m(\theta,\phi)$$

$$0 \leq \theta \leq \pi,\ 0 \leq \phi \leq 2\pi$$

where

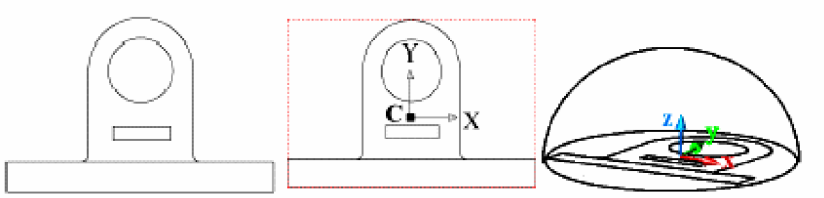
a_{lm} are the Fourier coefficients

$Y_l^m(\theta,\phi)$ are the solutions to the normalized Laplace's equation in spherical coordinates.

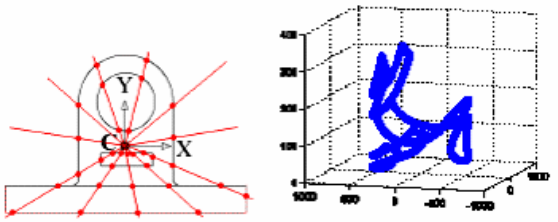
Osada, R., Funkhouser, T., Chazelle, B., and Dobkin, D., (2002), "Shape Distributions," ACM Transactions on Graphics, Vol. 21, No. 4, pp.807-832.

Shape Representations

- 2.5D Spherical Harmonics (Jiantao and Ramani, 2005)
  - Works with 2D drawings as well



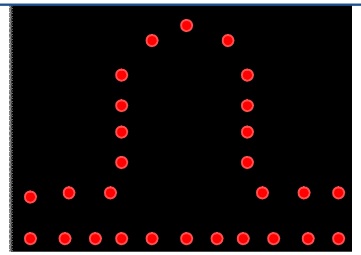
2D view | Bounding Box | Bounding Sphere



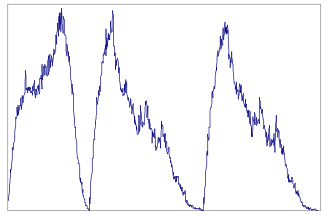
Ray Casting | 3D representation of 2D drawing

(PRECISE)

- Orthogonal Main View (Jiantao and Ramani, 2005)
  - Works with 2D drawings as well



Sample equidistant points on outer contour



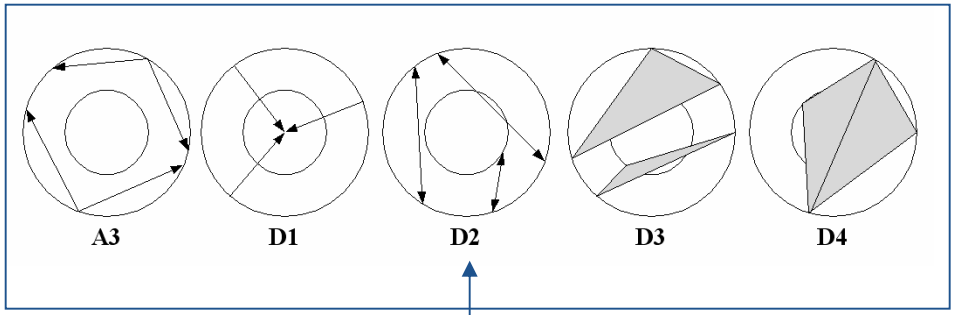
2D shape distribution

(PRECISE)

Jiantao Pu, and Karthik Ramani, (2005), "A 3D Model Retrieval Method Using 2D Freehand Sketches," Proc. Fourth International Workshop on Computer Graphics and Geometric Modeling (CGGM'2005), Emory University, Atlanta, USA, May 22-25, 2005

Some Shape Representations

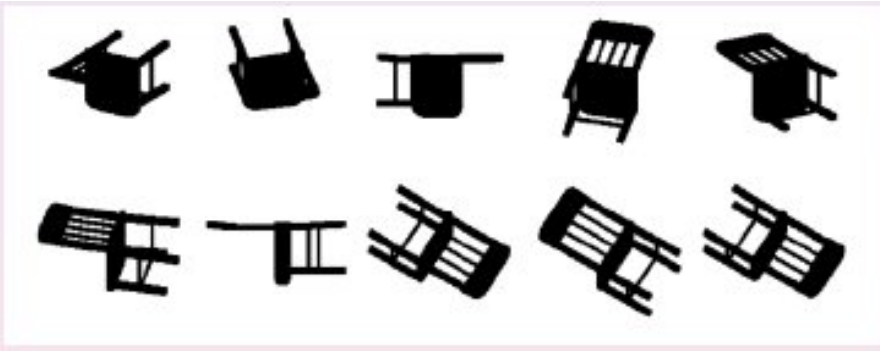
- Convex hull histogram (Kalyanaraman et al. 2004)



Kalyanaraman Y., Boutin, M., and Ramani, K., (2004), "Convex Hull Histograms for Shape Matching," PRECISE Technical Report, PRE-TR-2005-1, Purdue University, West Lafayette IN

- Light Field Descriptor

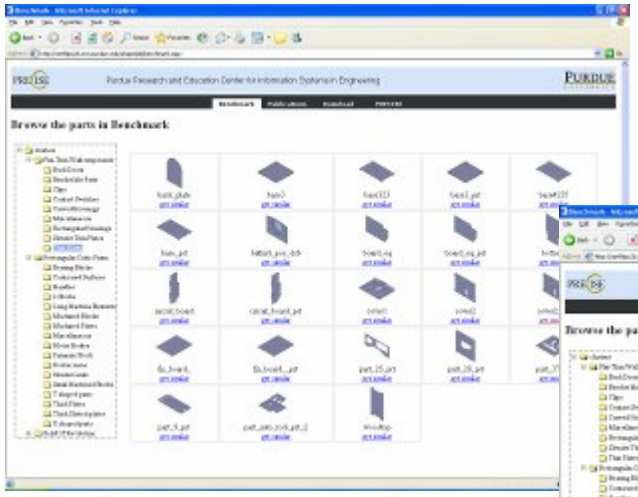
(Chen et al. 2003)



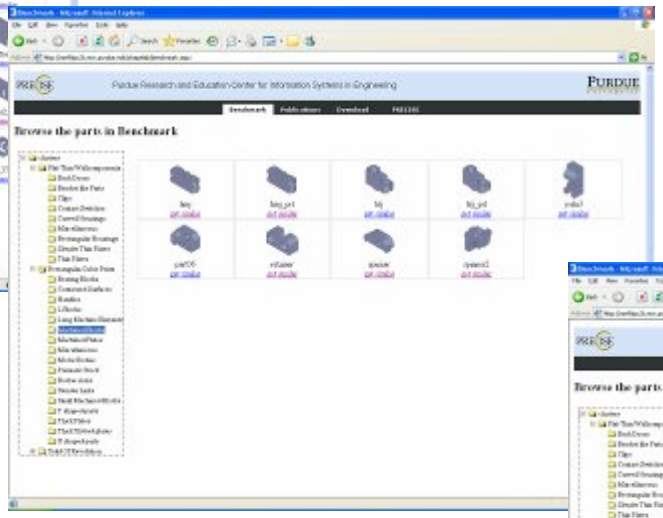
Chen, D.-Y. , Ouhyoung, M., Tian, X.-P., and Shen, Y.-T. , (2003), "On visual similarity based 3D model retrieval." Computer Graphics Forum, pages 223–232, 2003.

Engineering shape Benchmark

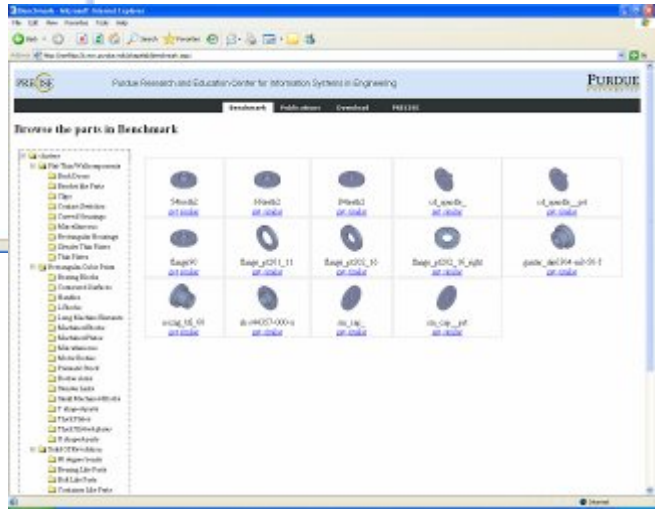
Three Super-Classes



Flat, thin-walled parts

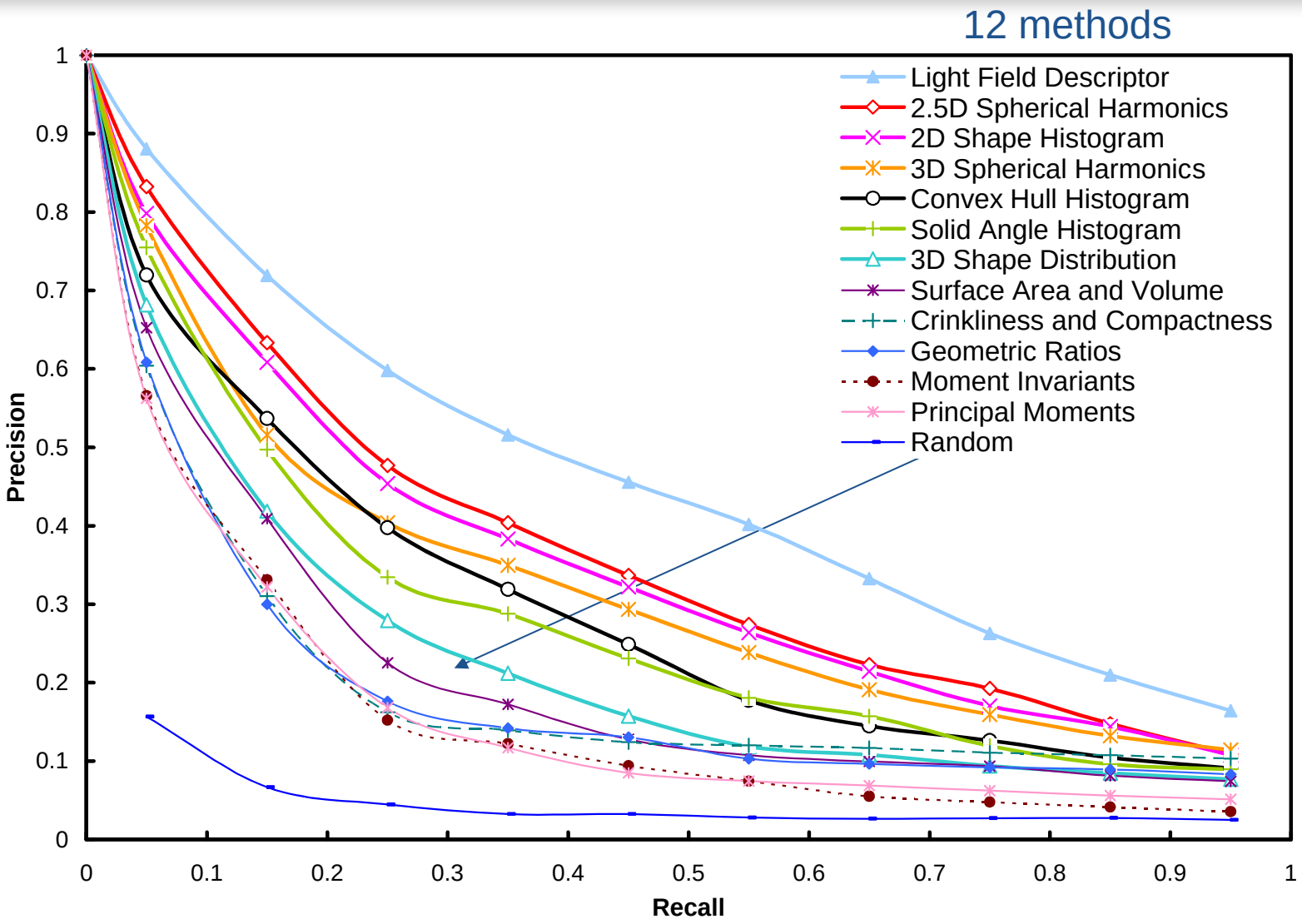


Rectangular, cubic prism parts



Solids of revolution

Overall Precision Recall Curves



Shape: Global | Local | Partial

- Objects can be similar in overall shape – Global
- Objects match at local spots - Local
- Portions of objects can match – partial
- How to enable these abstractions?

“Bring me that horizon…”

- A model = sum of parts + joints
- Decompose the model into segments
- Model as a graph of segments
- Compare, contrast, compose, cluster…
- More info on - http://purdue.edu/shapelab