

3D Shape Attributes

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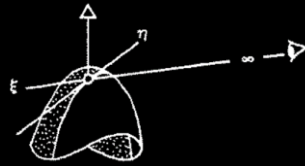
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Perceiving 3D in Images



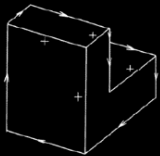
Contours
Koenderink
1984



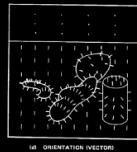
Volumes
Biederman
1987



Rooms
Hedau et al.
2009



Polyhedra
Roberts
1963



Intrinsic Images
Barrow et al.
1978



Qual. Orient
Hoiem et al.
2005



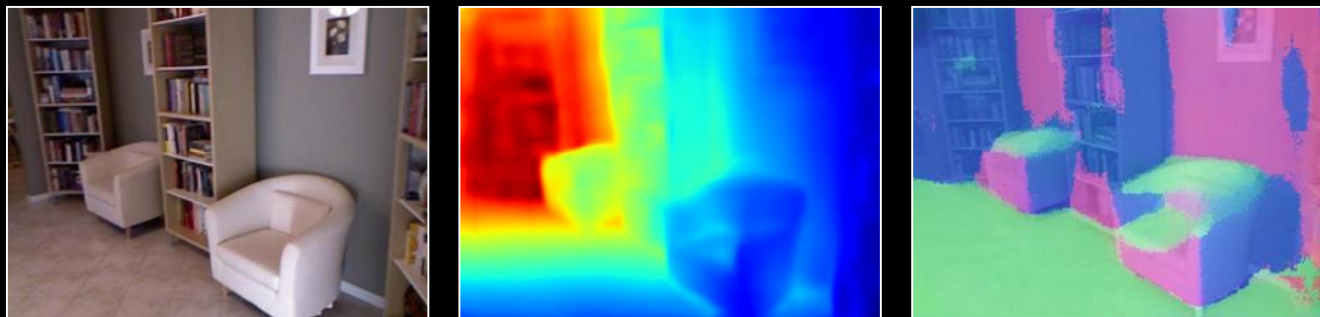
Depth
Saxena et al.
2005

Recent Work

Category specific reconstruction



Metric 2.5D Maps (Depth, Normals)



Category specific reconstruction: Hedau et al. '09, Lim '13, '14, Vicente & Carreira '14, Kar '15, Blanz and Vetter '99, etc.

Metric map recovery: Saxena et al. '07, Barron et al. '11 – '15, Karsch '12, Fouhey '13, '14, Eigen '14, '15, Ladicky '14 & '14, Liu '14, Baig '15, Wang '15, Bansal '16, etc.



Goal: 3D Shape Attributes

Input: Image

Output: 3D Shape Attributes
(Qualitative, higher-order shape,
largely viewpoint independent)



Not planar

Smooth surface

1 point of contact

Not point contact

Has hole



Not thin structures

...

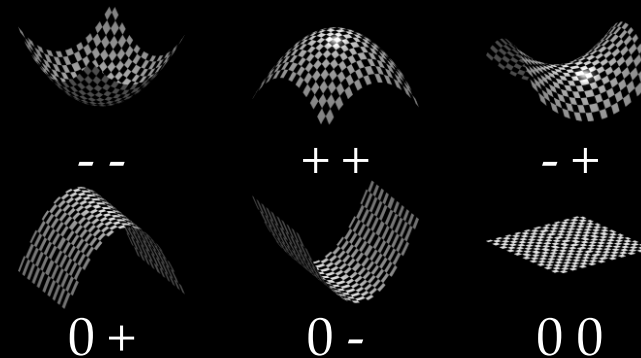
Historical Inspiration

Qualitative 3D shape of generic objects

Biederman's
Geons

Geon	CROSS SECTION			
	Edge Straight S Curved C	Symmetry Rot & Ref ++ Ref + Asymm -	Size Constant ++ Expanded - Exp & Cont --	Axis Straight + Curved -
	S	++	++	+
	C	++	++	+

Koenderink &
van Doorn's
shape categories



3D Shape Attributes

Curvature
(4 Total)



Planar
Surfaces



Cylindrical
Surfaces

Contact
(2 Total)



Point or
Line



Multiple

Occupancy
(6 Total)



Thin
Structures



Has
Hole

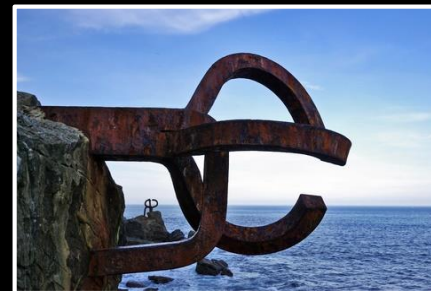
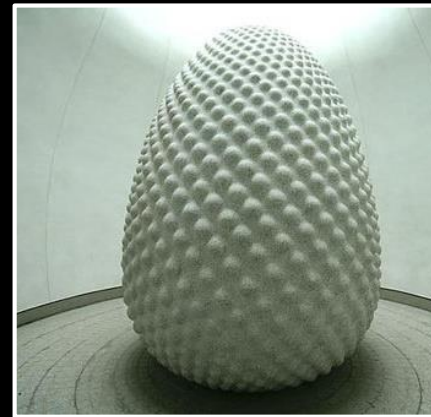
Potential Data Sources

Ordinary Objects



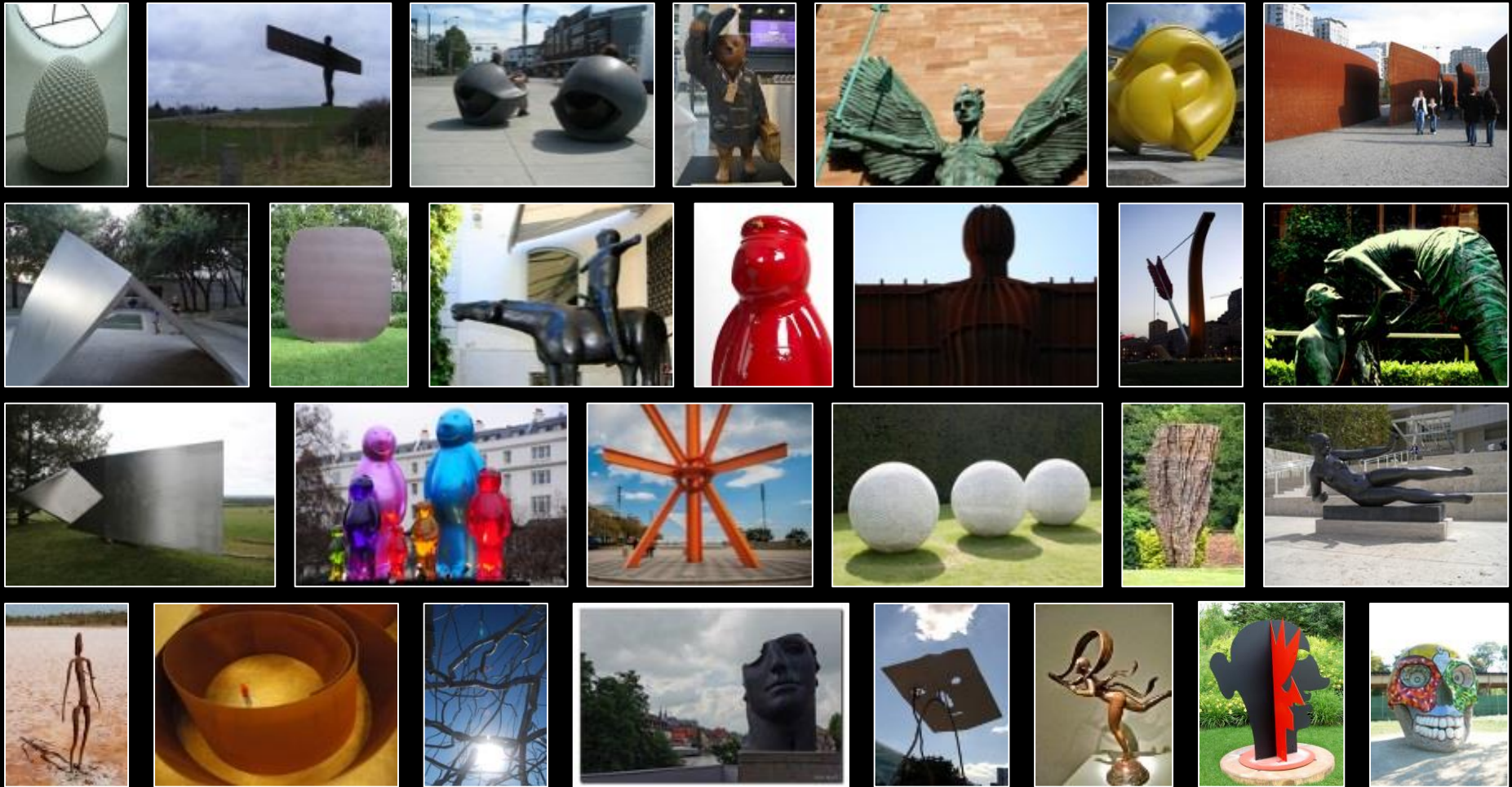
Limited shape diversity
Category/shape correlation

Modern Sculpture



Great shape diversity
Categories we can't describe

Data



Examples

Positives: Has Planar Surfaces



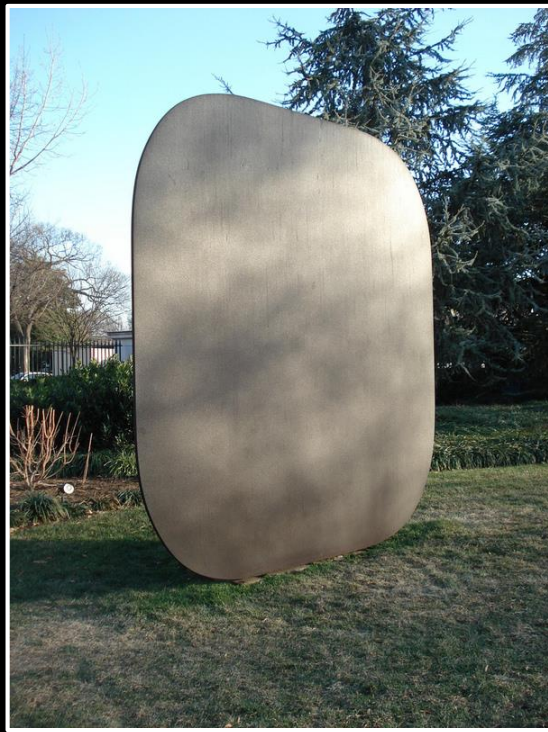
Examples

Negatives: Has Planar Surfaces



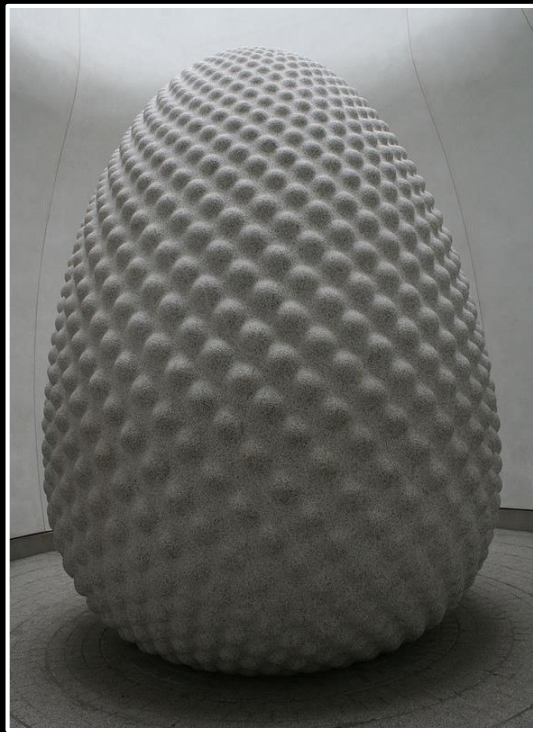
Examples

Positives: Has Point/Line Contact



Examples

Negatives: Has Point/Line Contact



Examples

Positives: Has Thin Structures

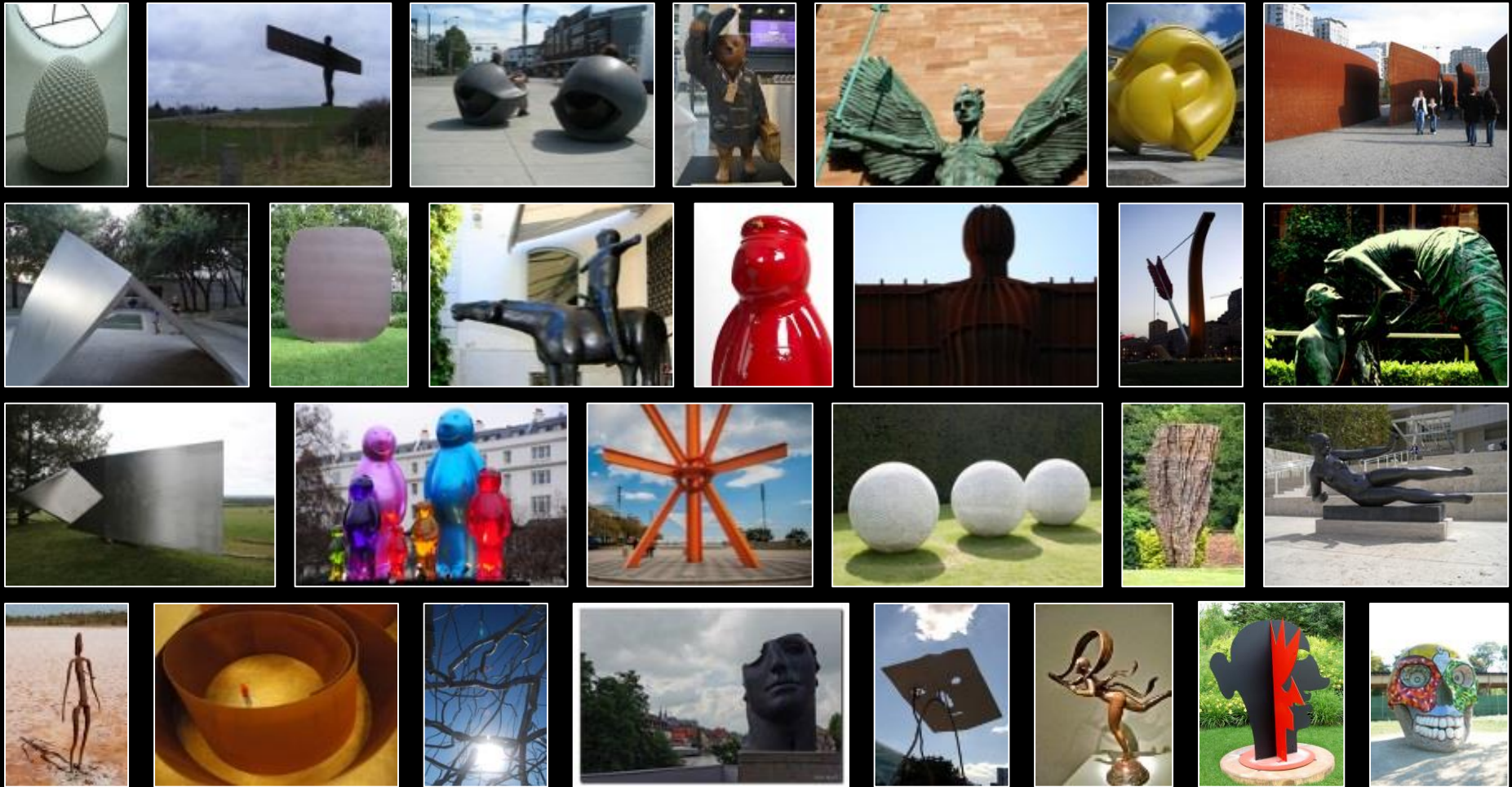


Examples

Negatives: Has Thin Structures



Data



Data Organization



flickr

Data Organization

242 Artists

A. Calder

⋮

H. Moore

⋮



flickr

Data Organization



Red Feather



Five Swords



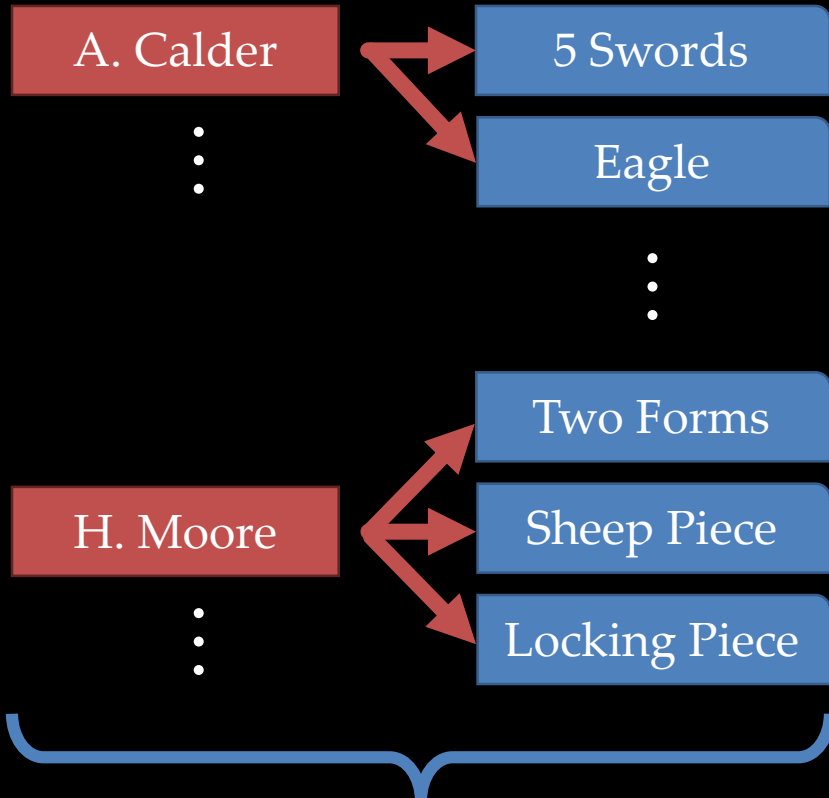
Mountains and Clouds

By Alexander Calder

Data Organization

242 Artists

2197 Works



flickr

Data Organization

London



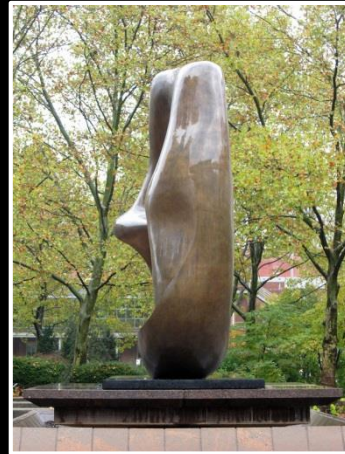
Malaga



Yorkshire



Princeton



Columbus

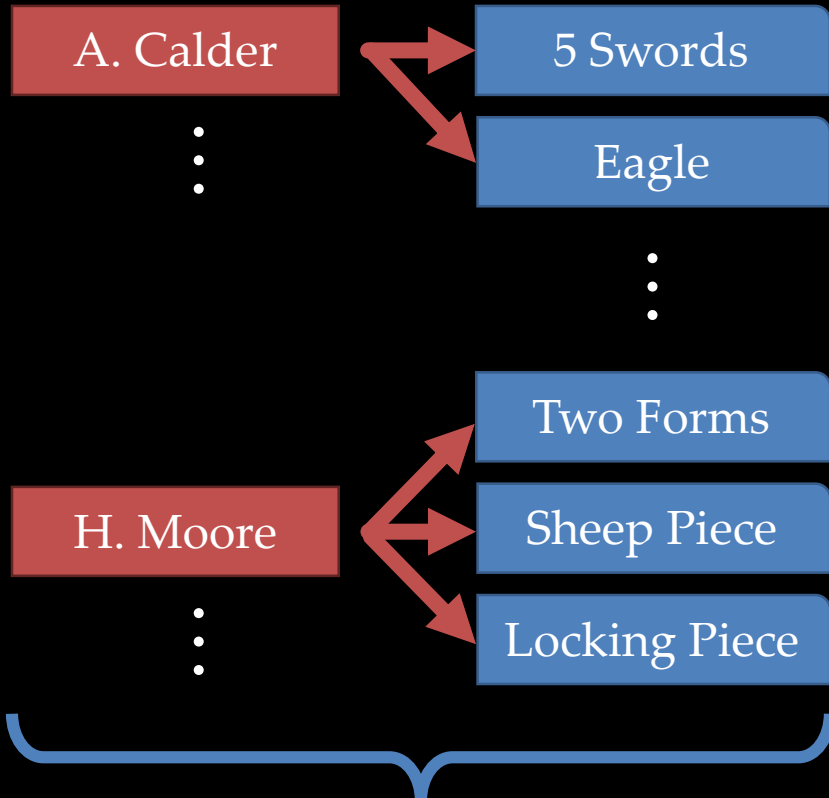


Toronto

Data Organization

242 Artists

2197 Works



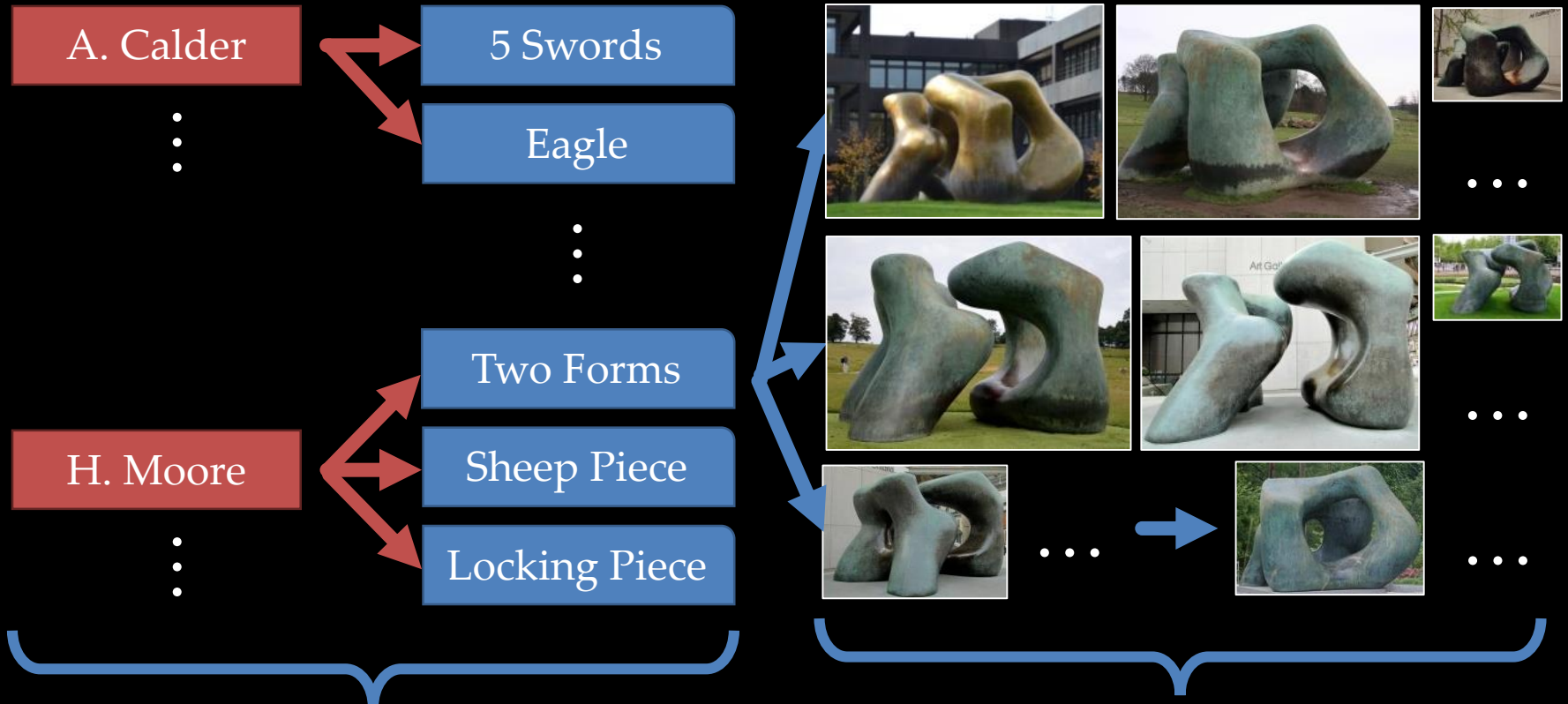
flickr

Data Organization

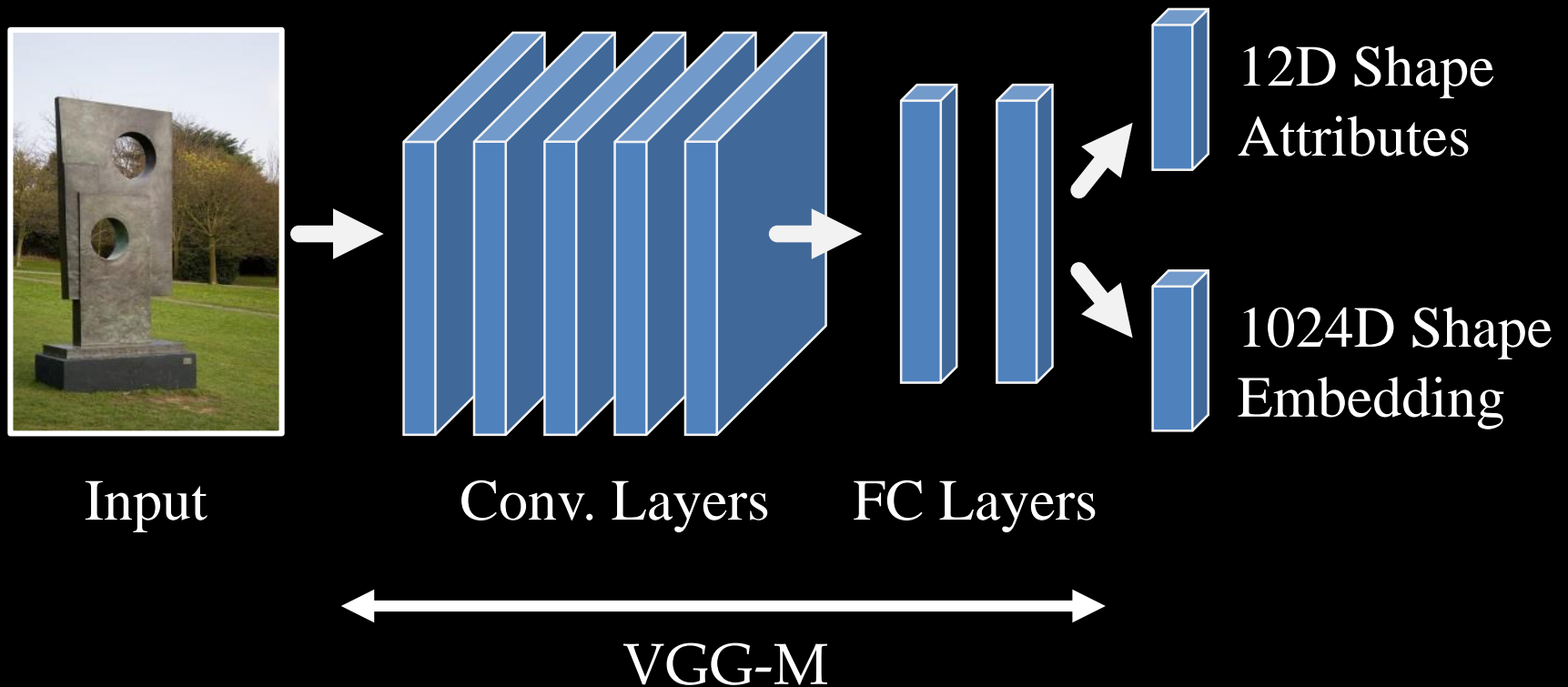
242 Artists

2197 Works

143K Images in 9352 Viewpoint Clusters

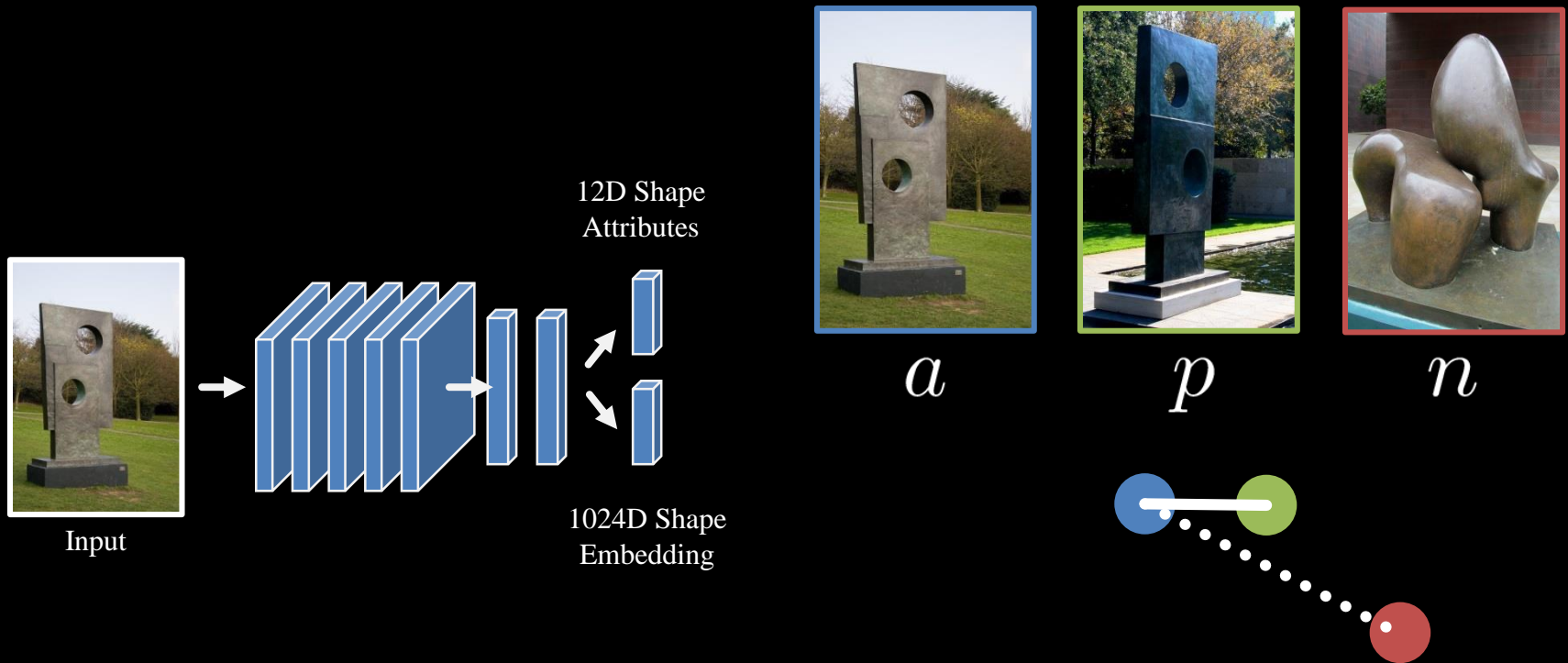


Method



Triplet loss as in Schults and Joachims '04, used in Schroff et al. '14, Wang et al. '15, Parkhi et al. '15

Method



$$L(a, p, n) = \max(\overline{D(a, p)} - \overline{D(a, n)} + \alpha, 0)$$

Triplet loss as in Schults and Joachims '04, used in Schroff et al. '14, Wang et al. '15, Parkhi et al. '15

Experiment Goals

- How well does it do on sculptures?
- Are we picking up on 3D properties?
- Does it generalize to ordinary objects?

Qualitative Results On Test Set

Most

Point/Line Contact

Least



...



Most

Thin Structures

Least



...



Baselines



Planar = Yes

Holes = Yes

...

2+ Contacts = No

...

- SIRFS (Barron et al. '15)
- CNN (Eigen et al. '14)

- KDES+SVM (Bo et al. '11)
- HHA+CNN (Gupta et al. '14)

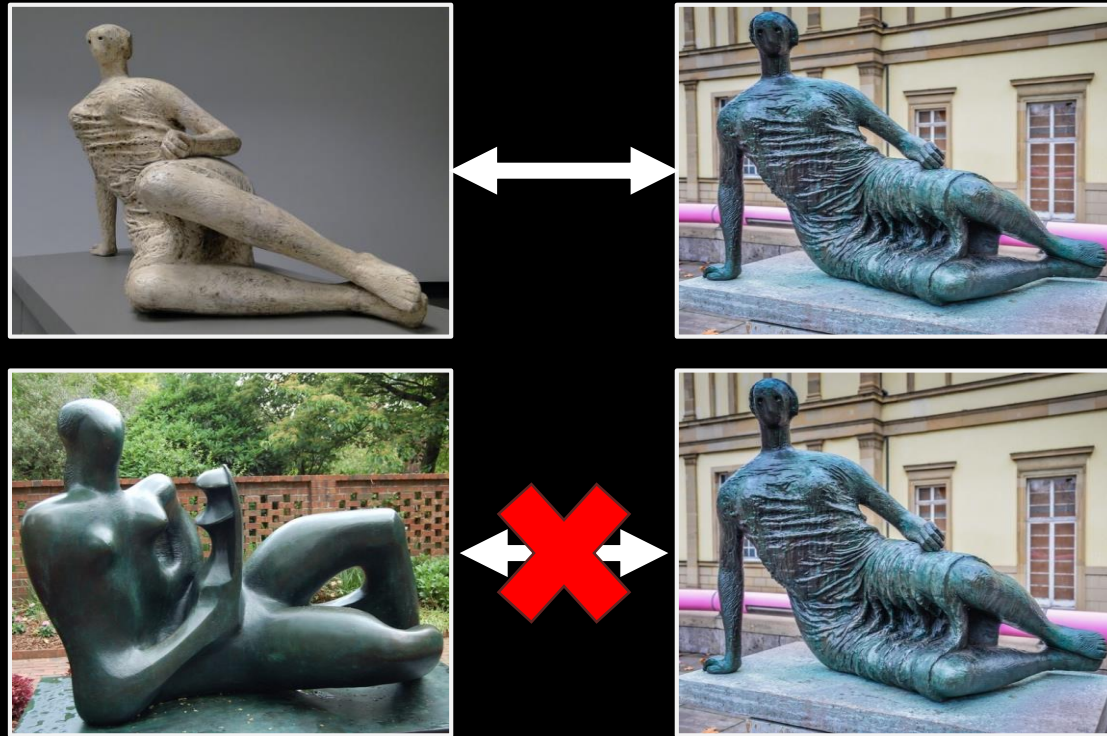
Quantitative Results

Criterion: area under ROC curve

Image → Shape → Attribute				Image → Attribute
Eigen '14		Barron '15		Ours
KDES	HHA	KDES	HHA	
58.5	61.2	59.4	62.5	<u>72.3</u>

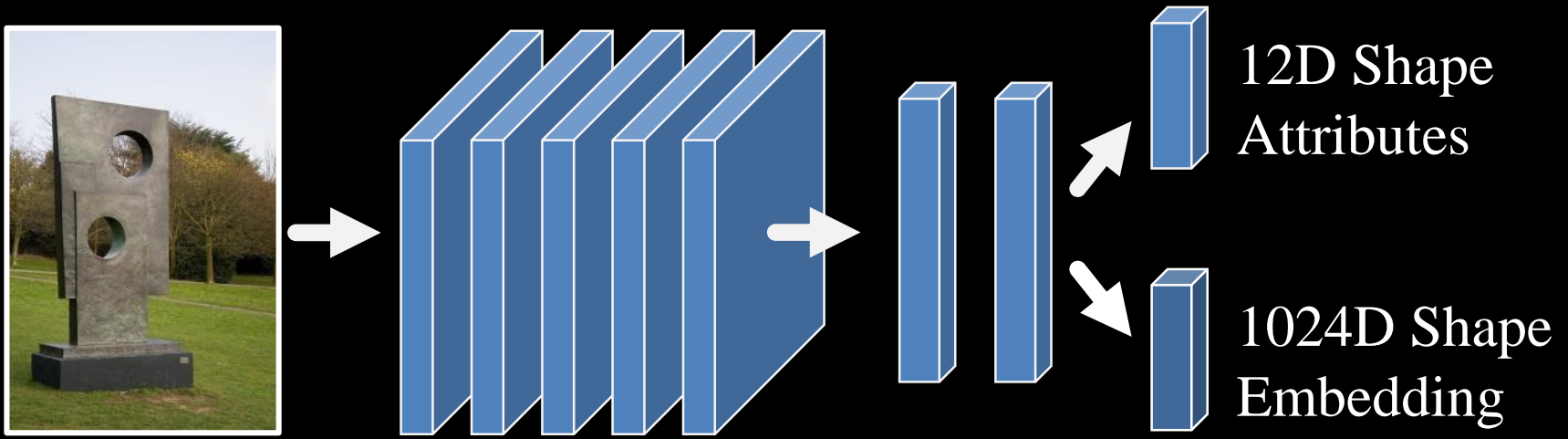
Performance especially good on questions involving aggregation of a local judgment: planarity (82.8%), empty (87.0%) , thin structure (85.8%)

Mental Rotation



- Classify pairs with distance between descriptors
- Artworks often at different locations, of different materials

Mental Rotation Results

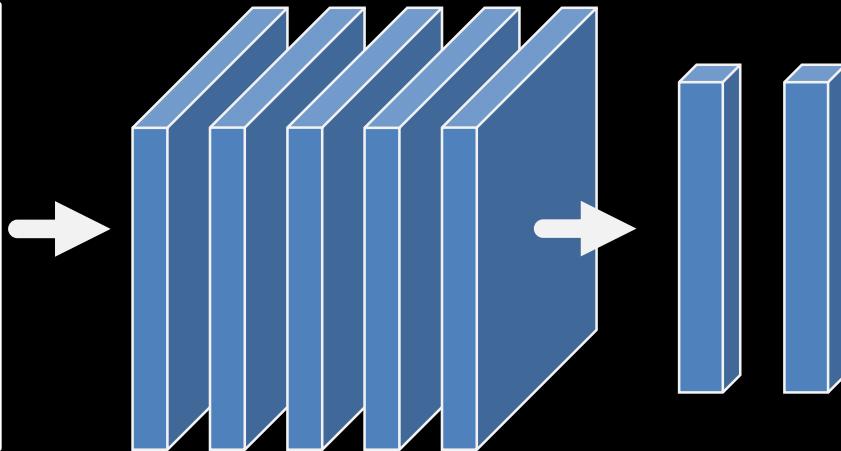


Mental Rotation Results

AUC of ROC using fc7

Imagenet Initialization	+Attribute Loss	+Both Losses
80.0%	82.5%	86.9%

12D attributes vector
outperforms IFV+SIFT



12D Shape
Attributes



1024D Shape
Embedding

PASCAL VOC Results

Most



...

Planarity



Least



Most



...

Planarity



Least



Conclusions

3D Shape
Attributes



Sculpture
Dataset



Experiments

Sculptures



Mental Rotation

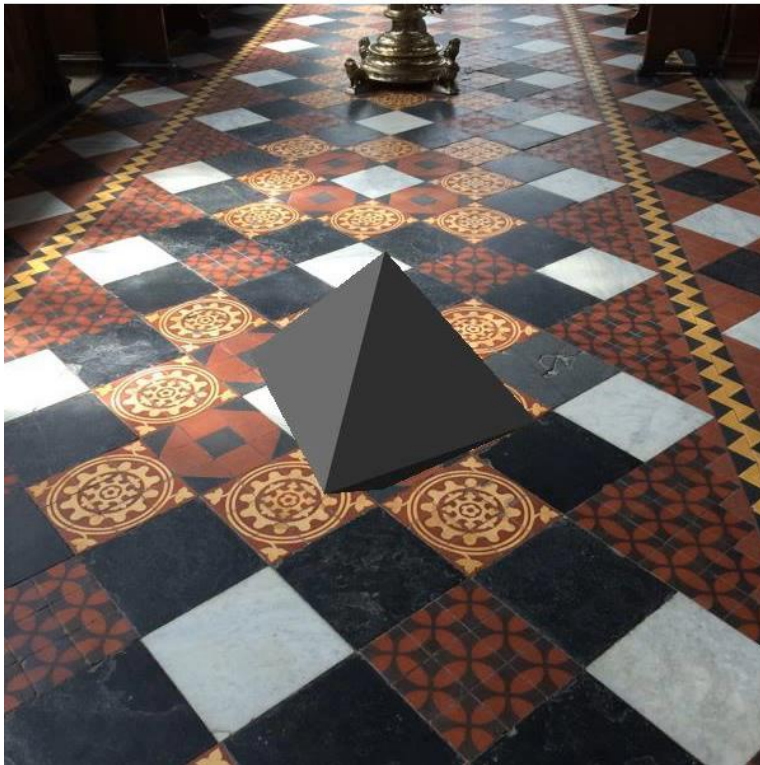


PASCAL VOC



Thank You

Input Stimulus



$P(\text{Has No Planarity})$

