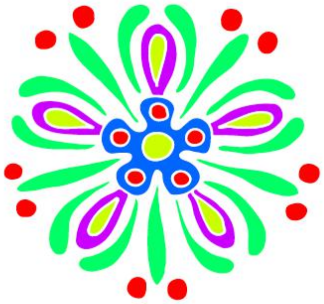
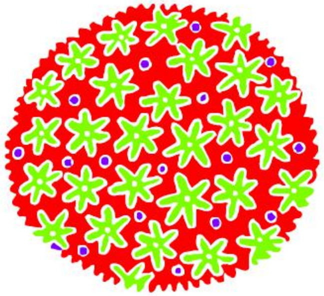
Learning to Group Discrete Graphical Patterns

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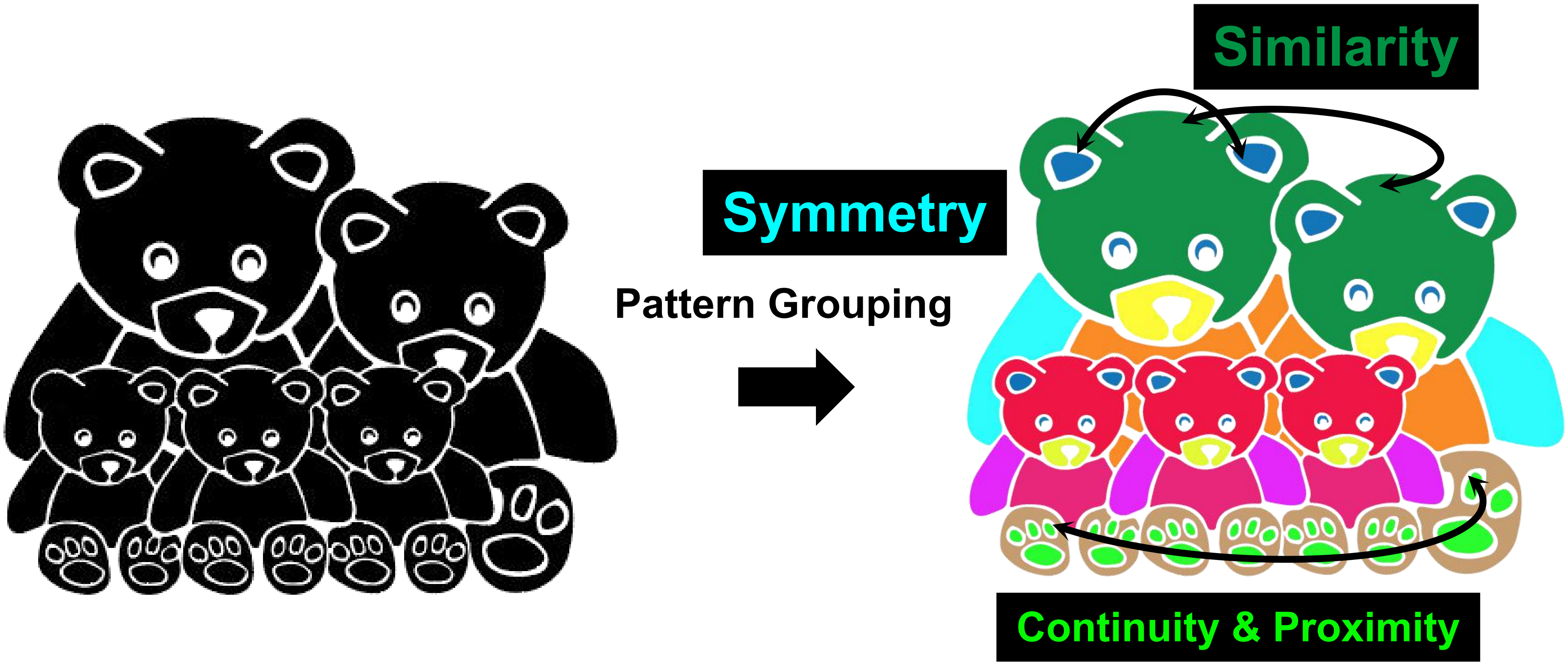
[a] UMASS Amherst [b] Simon Fraser University [c] Ecole Polytechnique

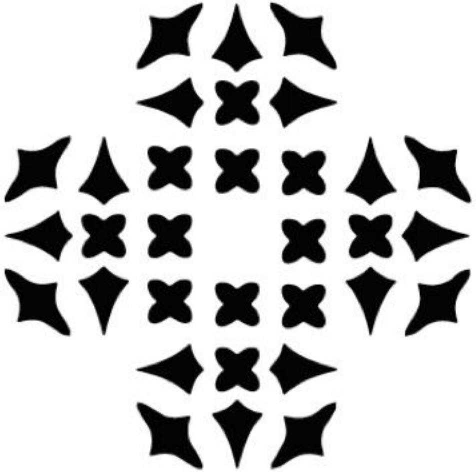
Pattern Grouping Problem: **motivation**

Pattern Grouping

Pattern Grouping Problem: **motivation**



Challenges (1)： conflicting grouping principles



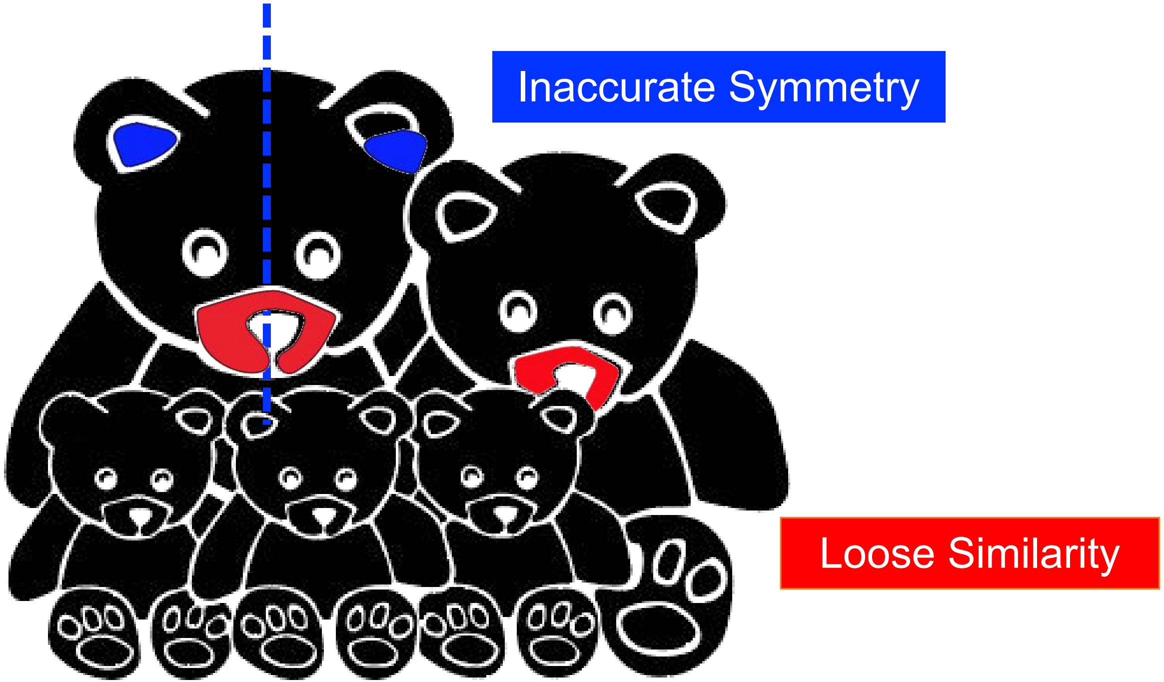
Input Pattern

Symmetry rule wins

Similarity rule wins

Challenges (2): various noises

Challenges (2): various noises



Challenges (3): Rich **Variations** and **Complexity**

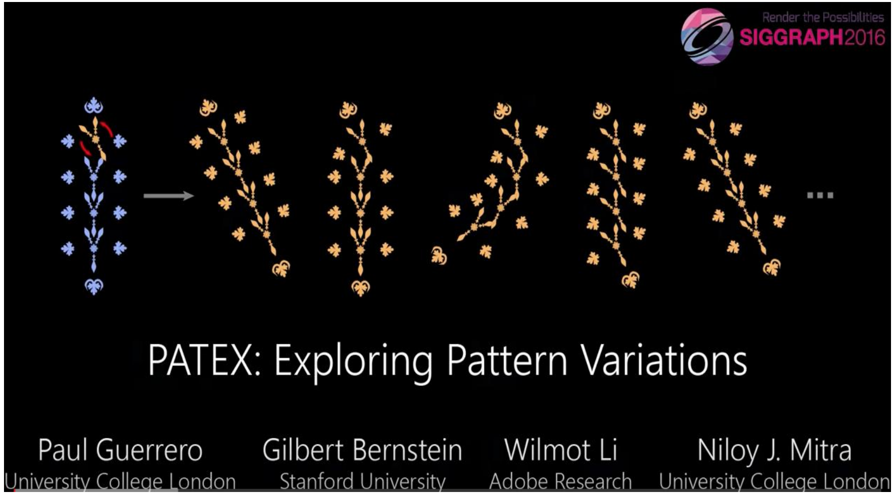
Applications of Pattern Grouping

- **Pattern Editing**

Inverse Procedural Modeling by Automatic Generation of L-systems. O. Stava, et al. 2010

Applications of Pattern Grouping

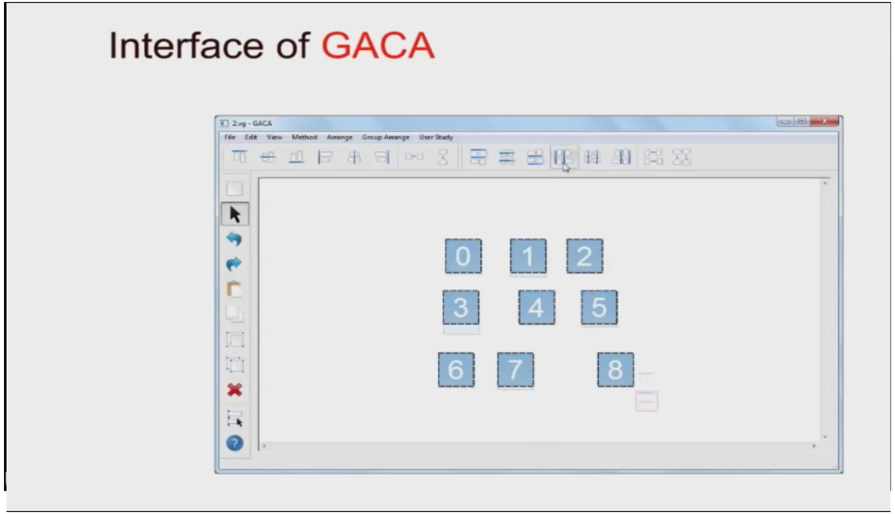
- **Pattern Editing**
- **Pattern Exploration**



PATEX: Exploring Pattern Variations. P. Guerrero, et al. 2016

Applications of Pattern Grouping

- ❑ **Pattern Editing**
- ❑ **Pattern Exploration**
- ❑ **Layout Optimization**



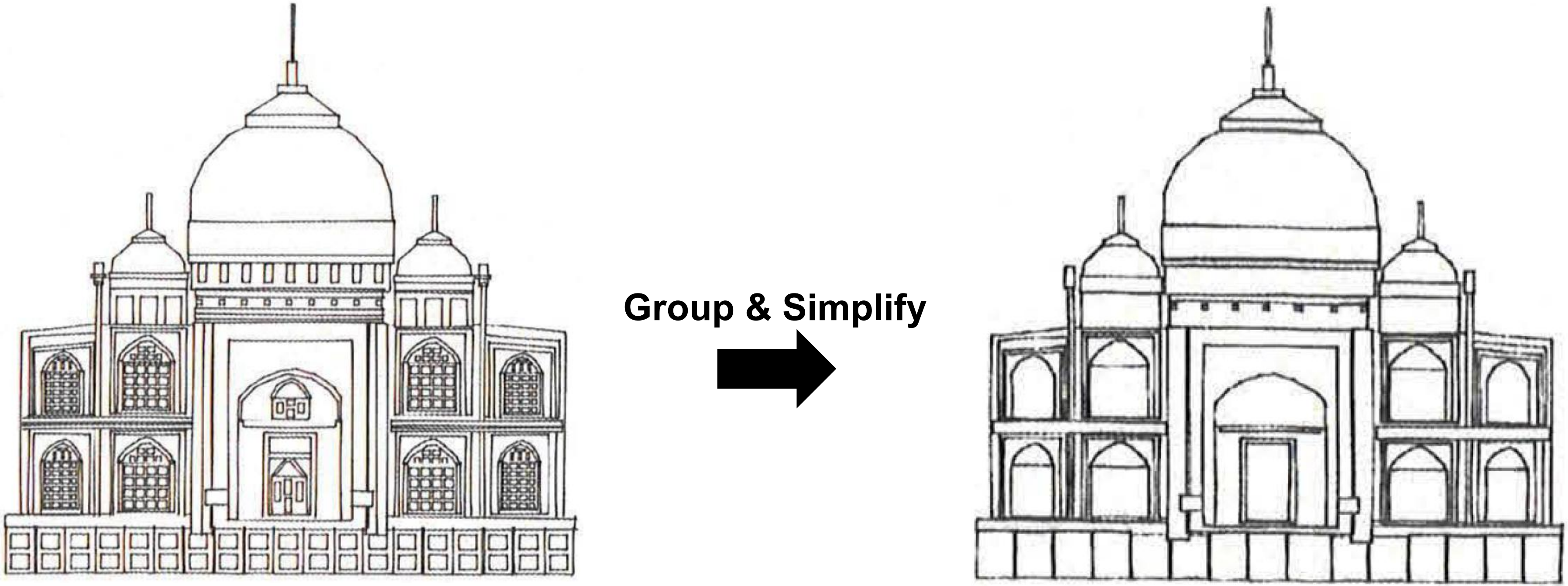
GACA: Group-Aware Command-based Arrangement of Graphic Elements. P. Xu, et al. 2015

Related Work: **Model** & **Rule** Driven

- **Gestalt-based pattern grouping**
  - Conjoining Gestalt Rules for Abstraction of Architectural Drawings. Nan et al. TOG, 2011.
  - Perceptual grouping by selection of a logically minimal model, Feldman, ICCV, 2003.
  - The whole is equal to the sum of its parts: A probabilistic model of grouping by proximity and similarity in regular patterns, Kubovy & Berg. Psychological Review, 2008.

- **Symmetry-based pattern grouping**
  - Folding meshes: hierarchical mesh segmentation based on planar symmetry. Simari et al. SGP, 2006.
  - Co-Hierarchical Analysis of Shape Structures. O. Kaick et al. TOG, 2013.
  - Symmetry Hierarchy of Man-Made Objects. Wang et al. Computer Graphics Forum, CGF, 2011.
  - Layered Analysis of Irregular Facades via Symmetry Maximization. Zhang et al. TOG, 2013.

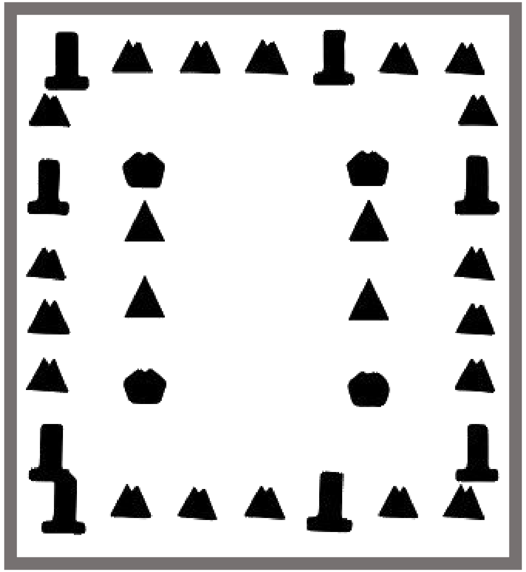
Related Work: Gestalt-Based Pattern Grouping



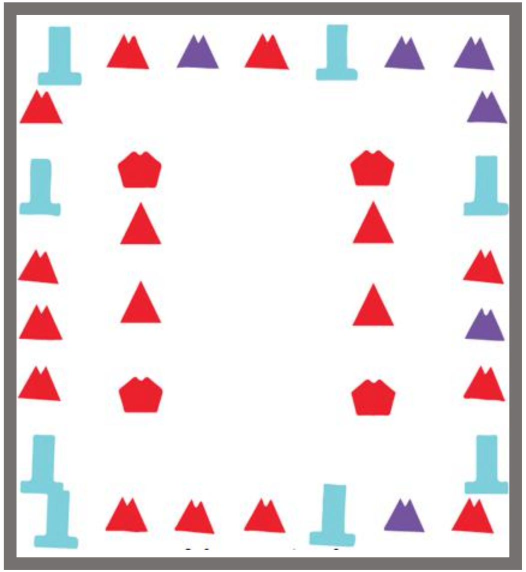
Conjoining gestalt rules for abstraction of architectural drawings,
Nan et al. TOG, 2011.

Nan’s Strategy: model-driven

- ❑ **Hand-engineering** rules to quantify grouping models
- ❑ **Hand-tuning** relative importance of rules

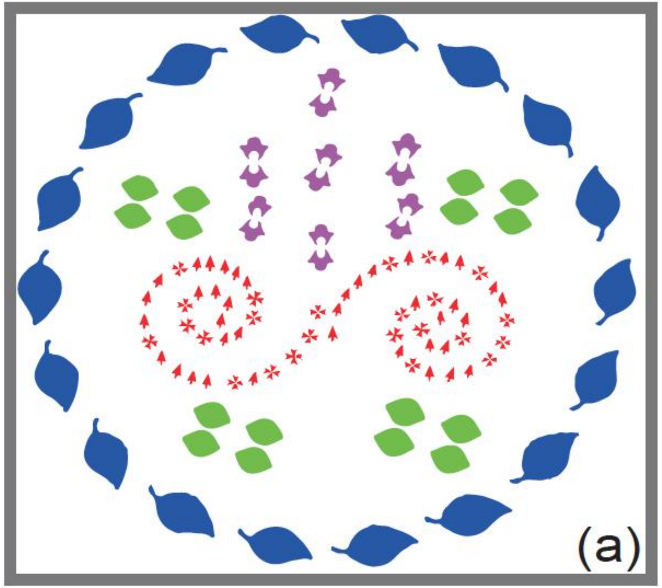


Nan et al ’s strategy

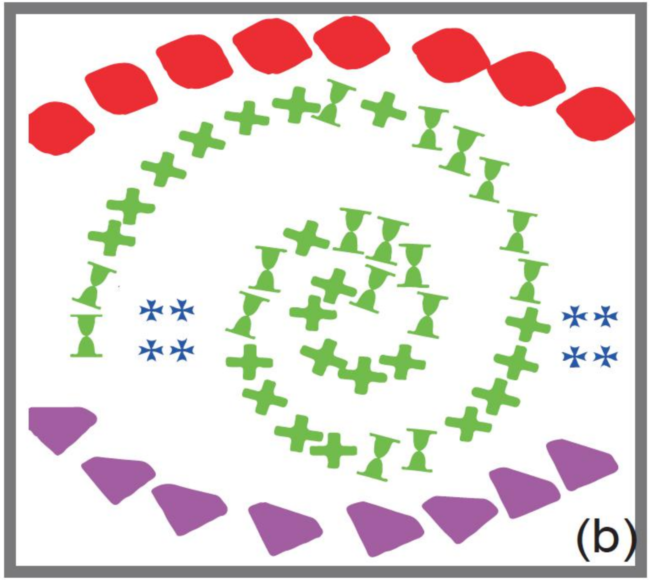


Our Work: First data-driven approach

- Learning to group discrete graphical patterns from human annotations
- Loosely consider Gestalt principles
- Learn relative importance of features, without hand-engineer rules
- Robust noise handling thanks to learning approach



Convey



Our Strategy

- ❑ Learning to group discrete graphical patterns from human annotations
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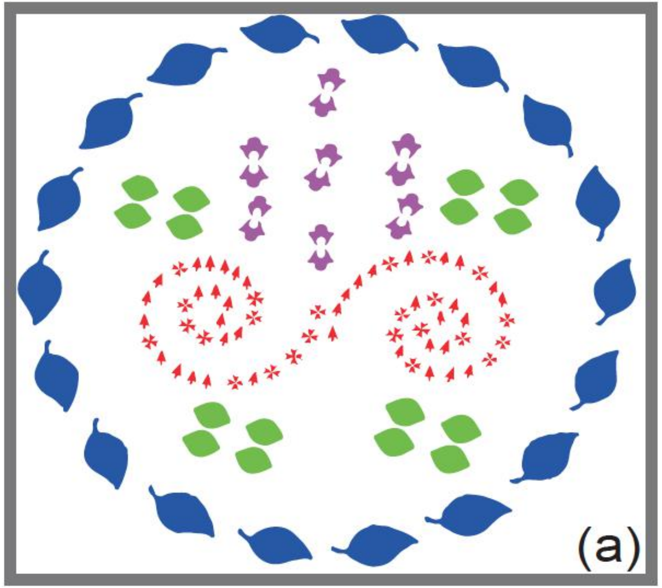
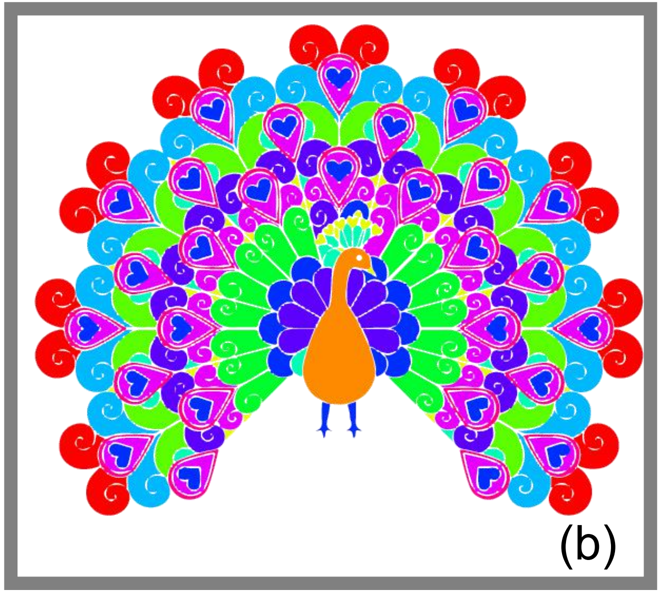


Generalize

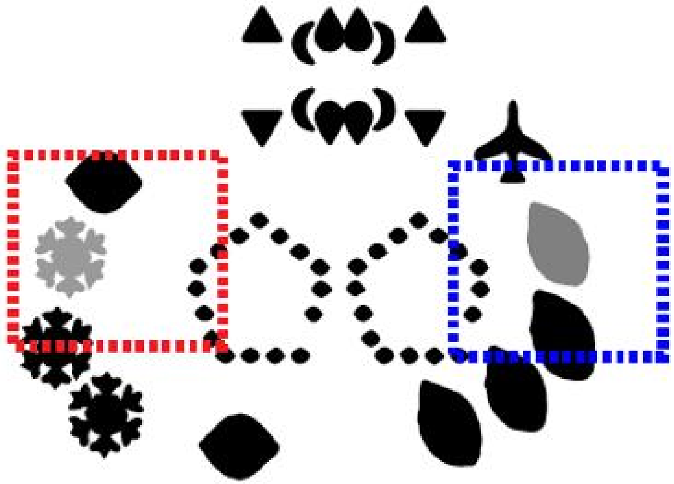


Our Solution: **learn features for clustering**

- **Learned feature descriptor for each elements**
- **Clustering in learned feature space**

Our Solution: **bottom-up strategy**

- ❑ **Learned feature descriptor for each elements**
- ❑ **Clustering in learned feature space**

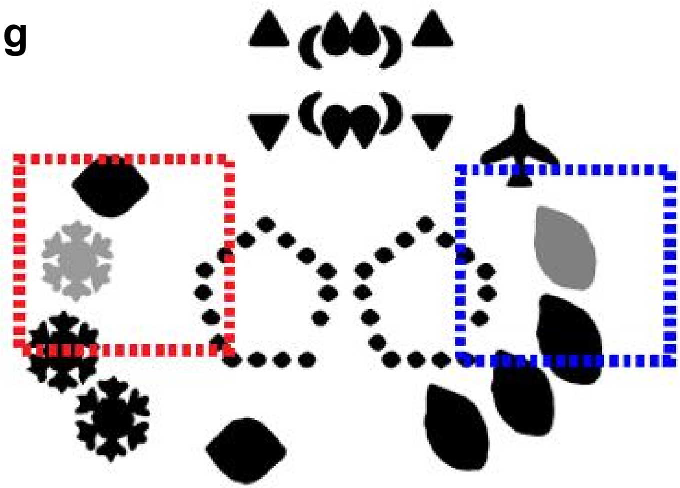


Our Solution: **learn features for clustering**

- **Learned feature descriptor for each elements**
- **Clustering in learned feature space**
- **Not optimize the clustering algorithm itself**
- **Learn a feature space suitable for clustering**

Our Solution

- Element -> learned feature descriptor
- Clustering in learned feature space
- Not optimize the clustering algorithm itself
- Learn a feature space suitable for clustering



Feature Learning: **how do human group**

Feature Learning: **how do human group**

Similar & close-by

Feature Learning: **how do human group**

Horizontal Alignment

Feature Learning: **how do human group**

How can we **migrate** human experience into machine learning?

Feature Learning: **local Information**

- ❑ Similarity **----- Shape-Aware**
- ❑ Continuity
- ❑ Proximity

Context-Aware

Local Information

Feature Learning: **global Information**

- ❑ Similarity **----- Shape-Aware**
- ❑ Continuity
- ❑ Proximity

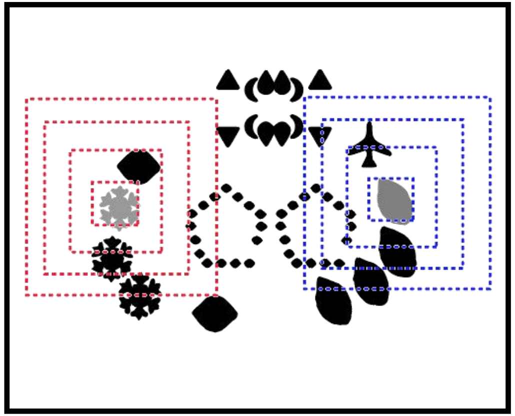
Context-Aware

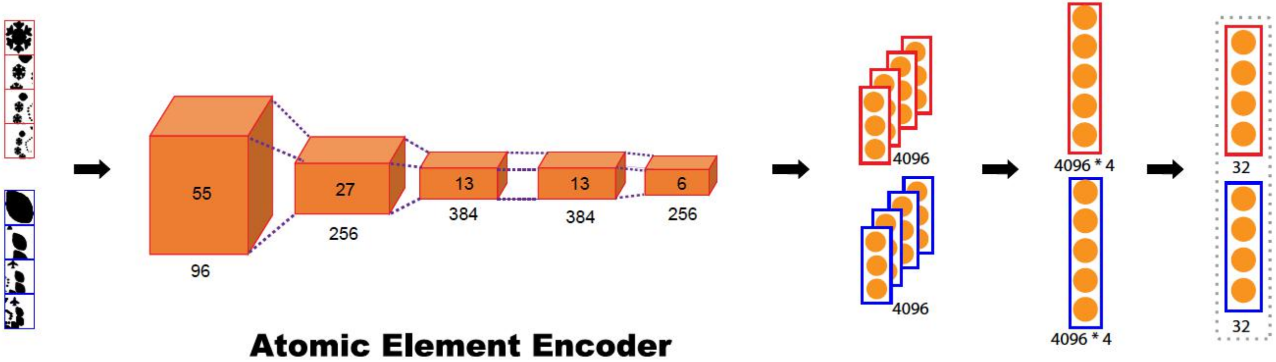
Local Information

- ❑ Symmetry **----- Structure-Aware**

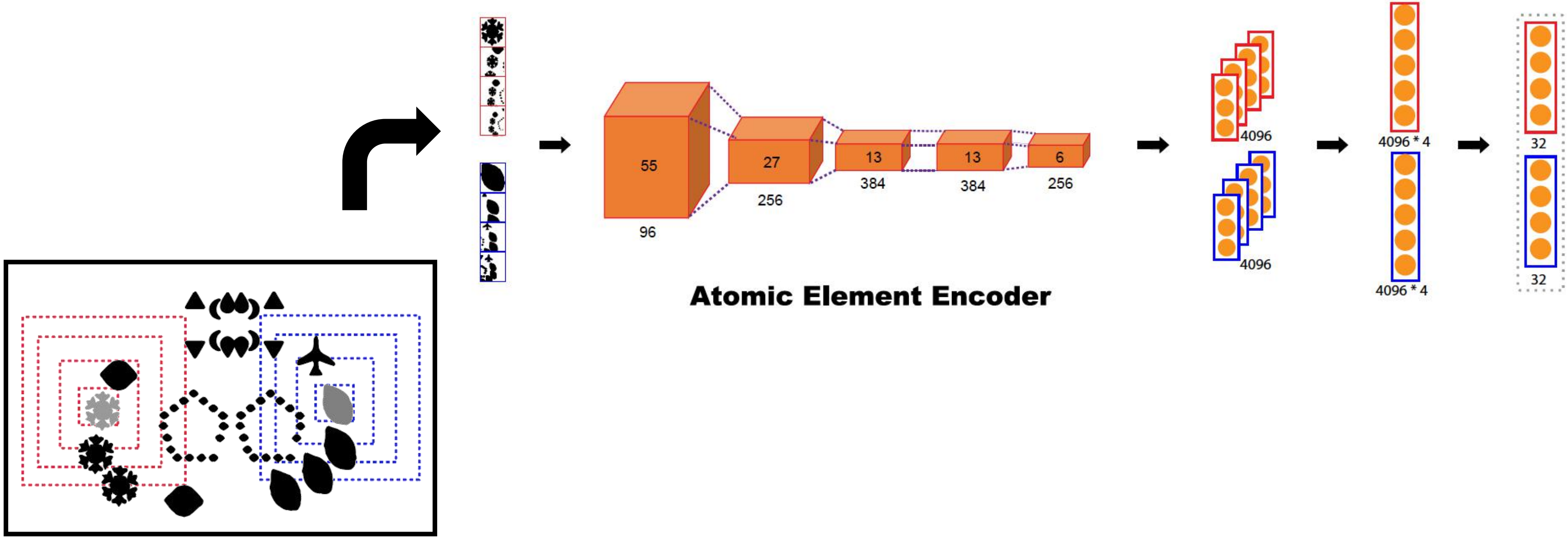
Global Information

Local feature: **Atomic Element Encoder**

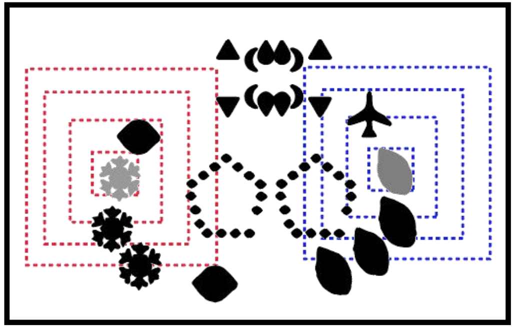


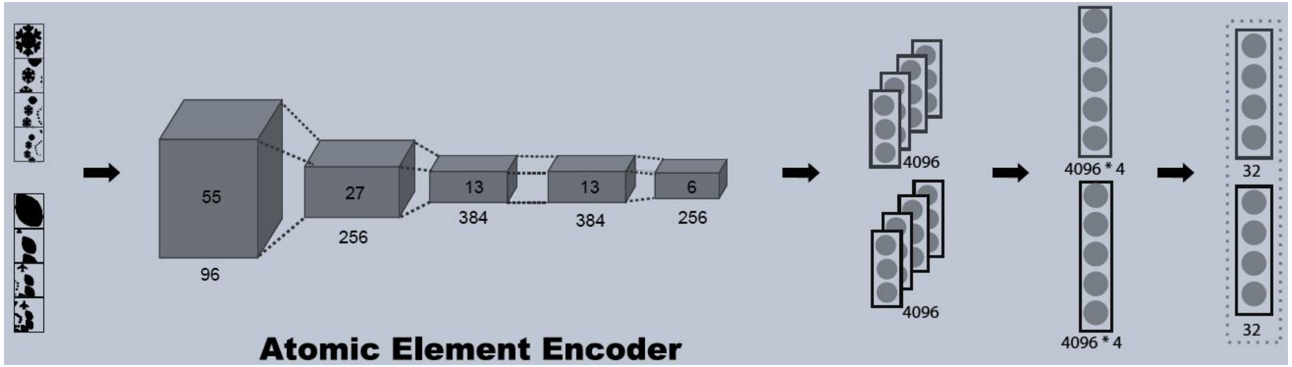


Local feature: **Atomic Element Encoder**

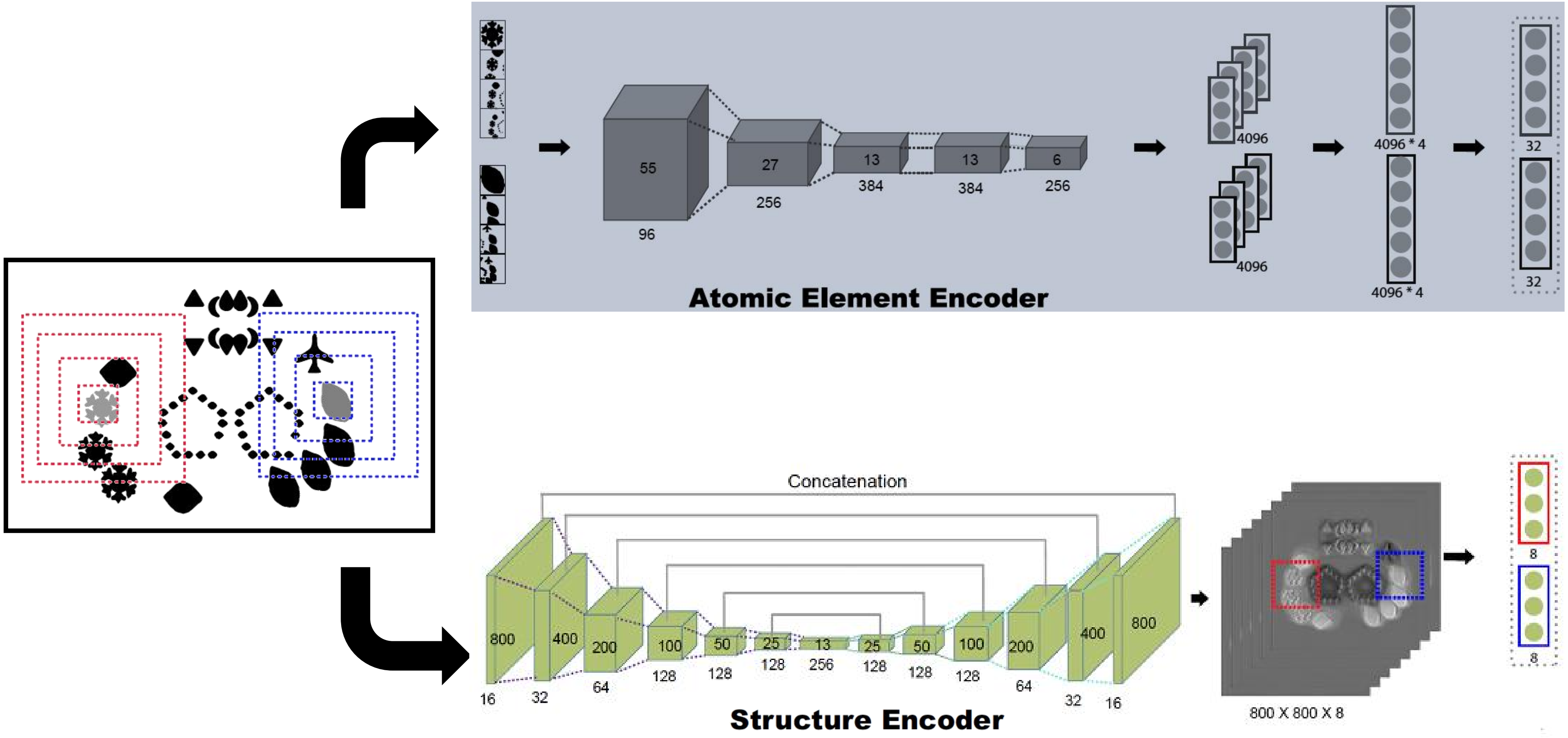


Local feature: **Atomic Element Encoder**

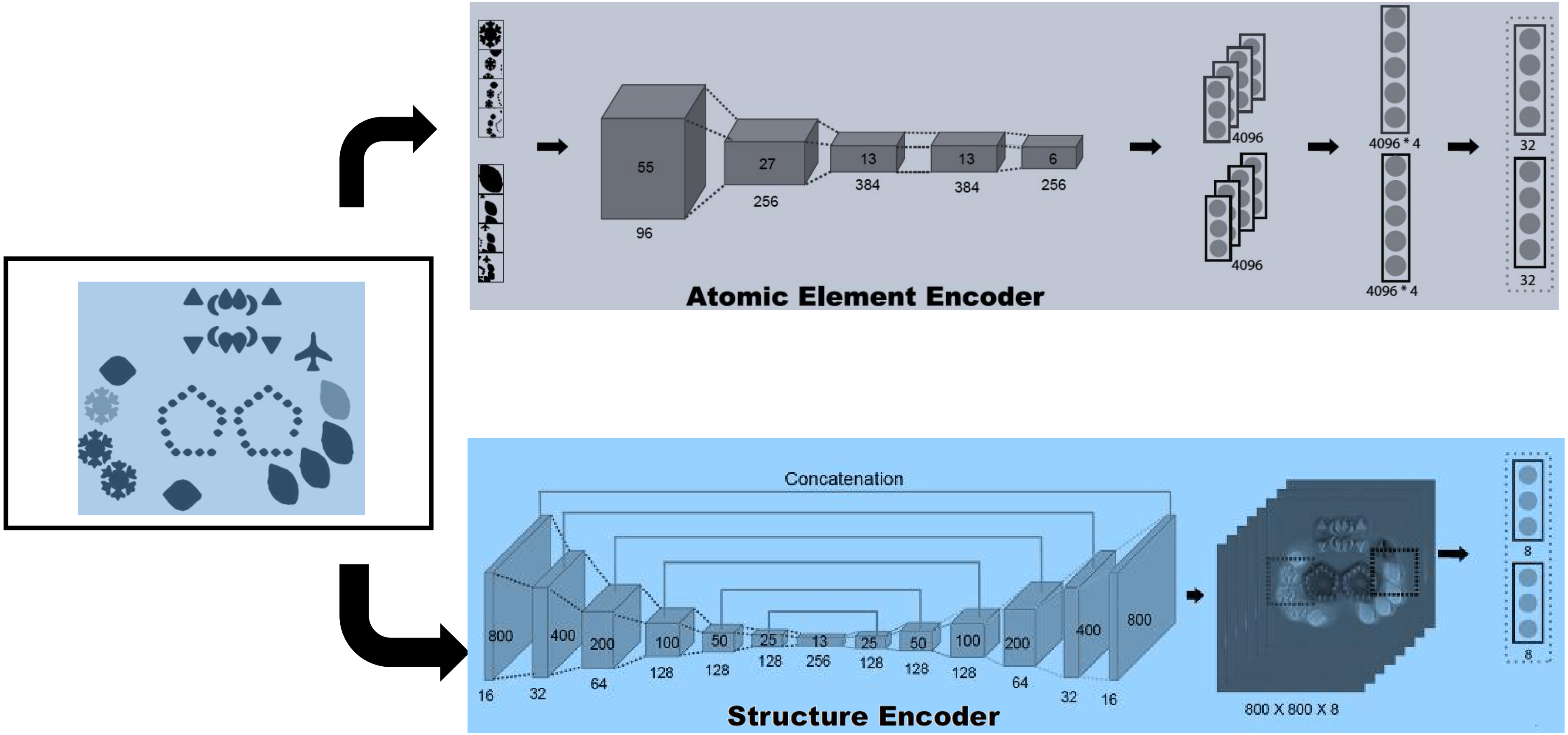




Local feature: **Structure Encoder**

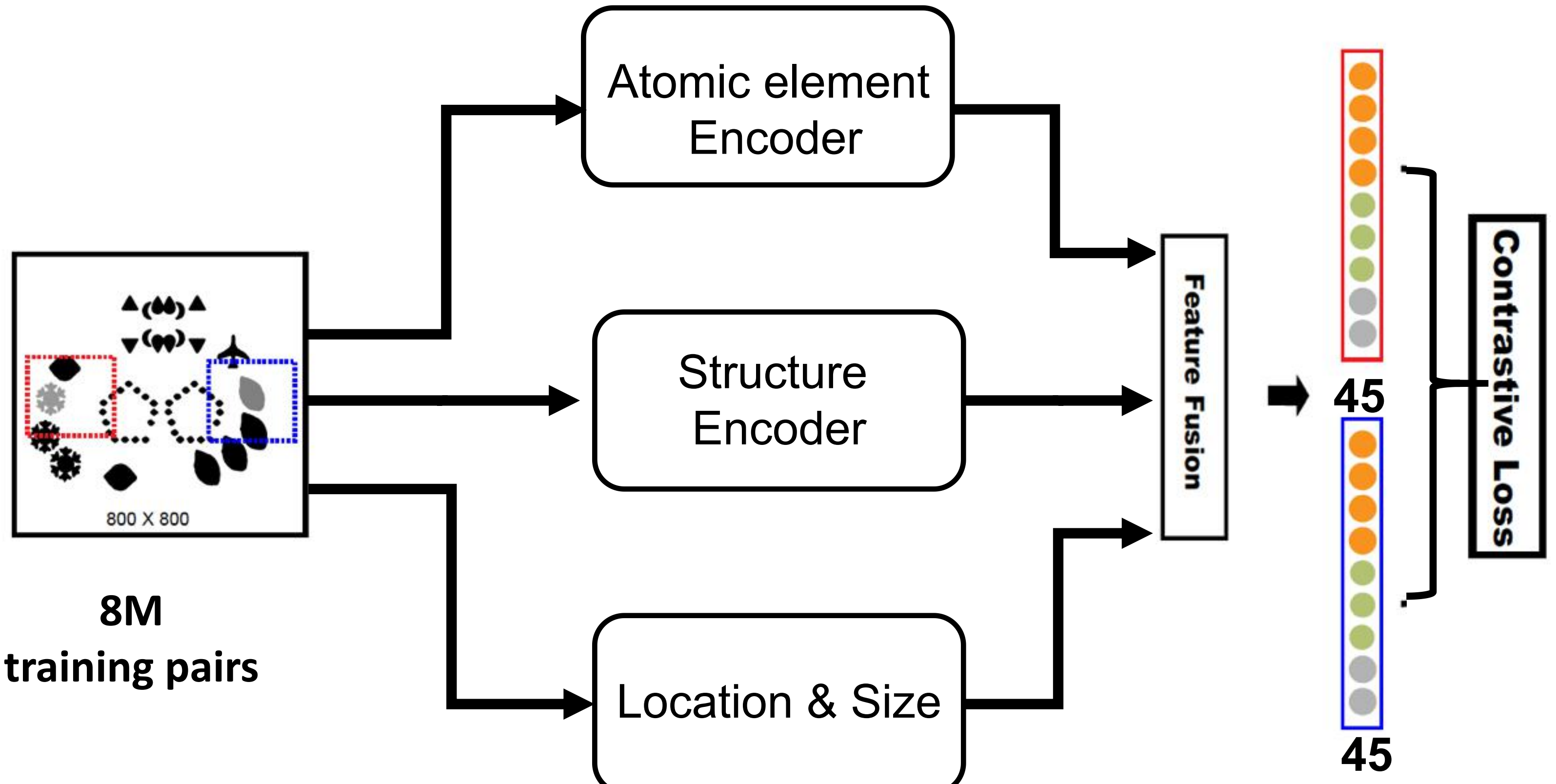


Global feature: **Structure Encoder**

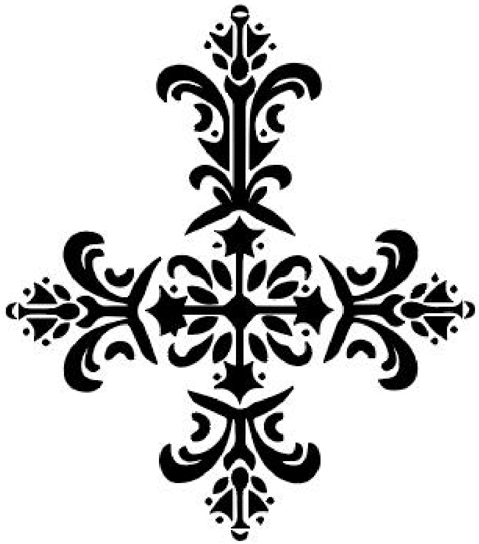


Network Architecture

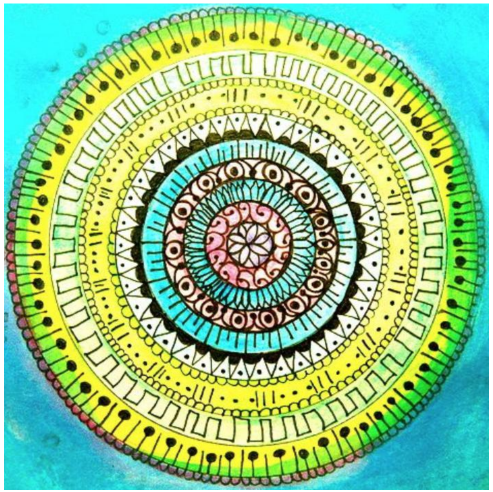
Network Architecture



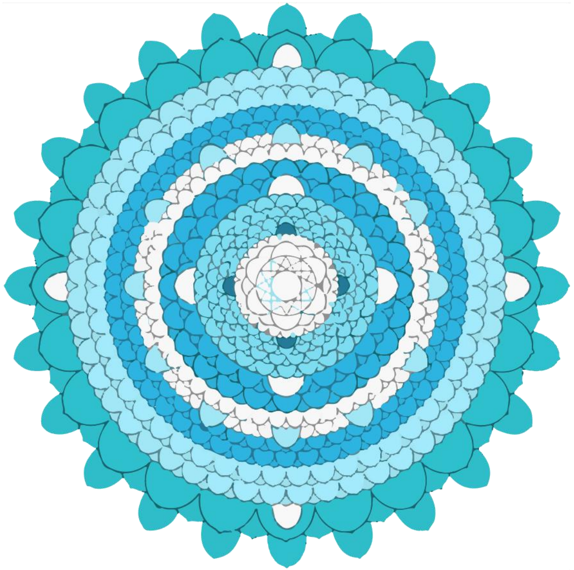
Data Collection: Lack of suitable patterns on the web



Black & White

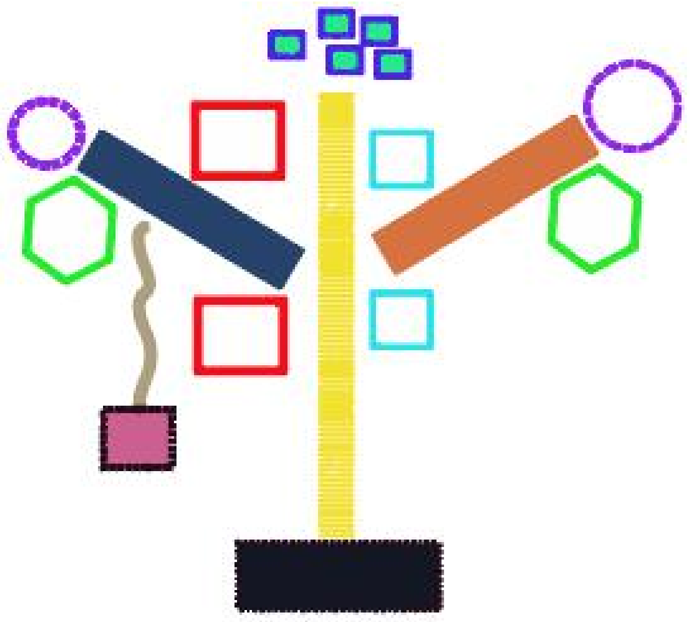


Color Gradient



Lack Structural Variety

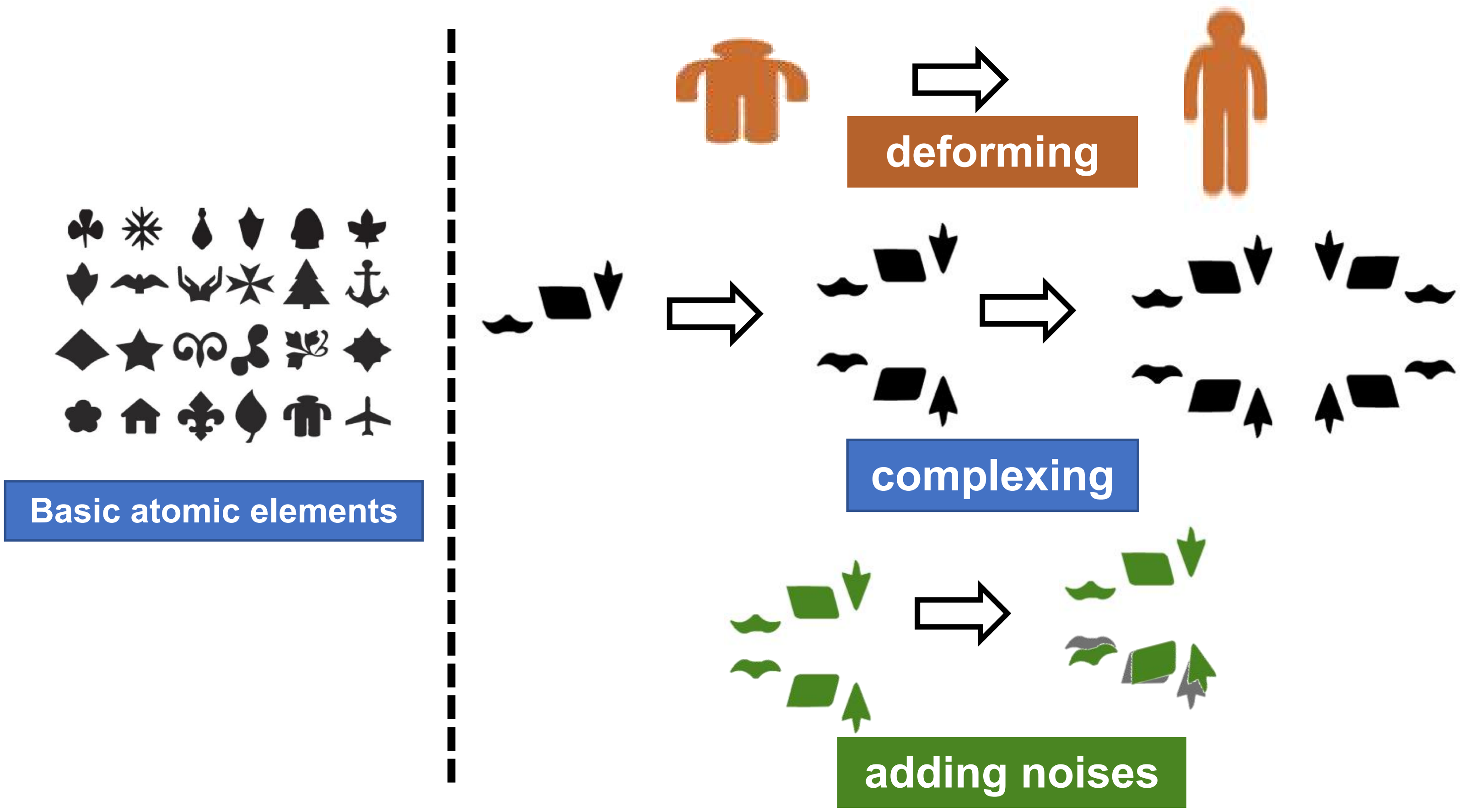
Layout Templates Based Training Data Collection



Layout Template

Pattern Examples

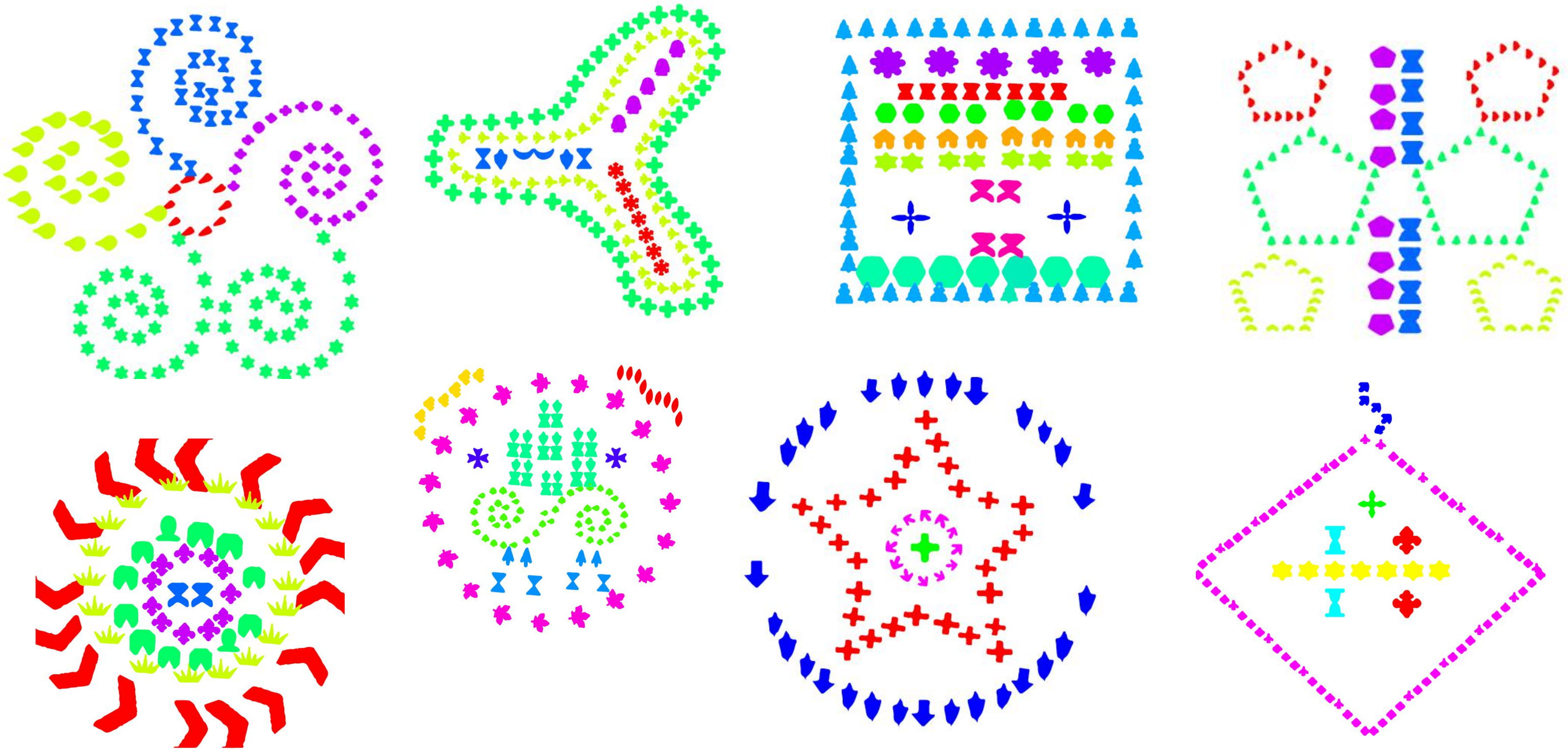
Training Data: **element collection**



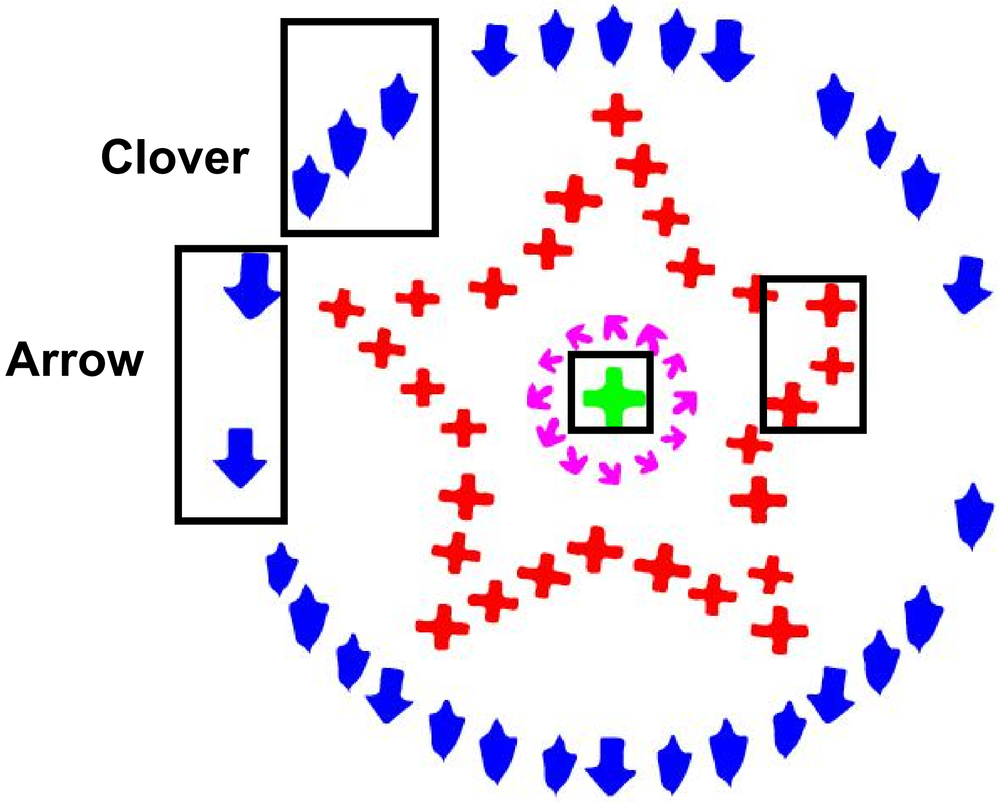
Training Data Collection

- ~800 pattern layout templates
- ~8K pattern images
- 500 positive and 500 negative pairs of elements
- ~ **8M** training pairs

Results on **synthesized patterns**



Grouping Results on **synthesized patterns**



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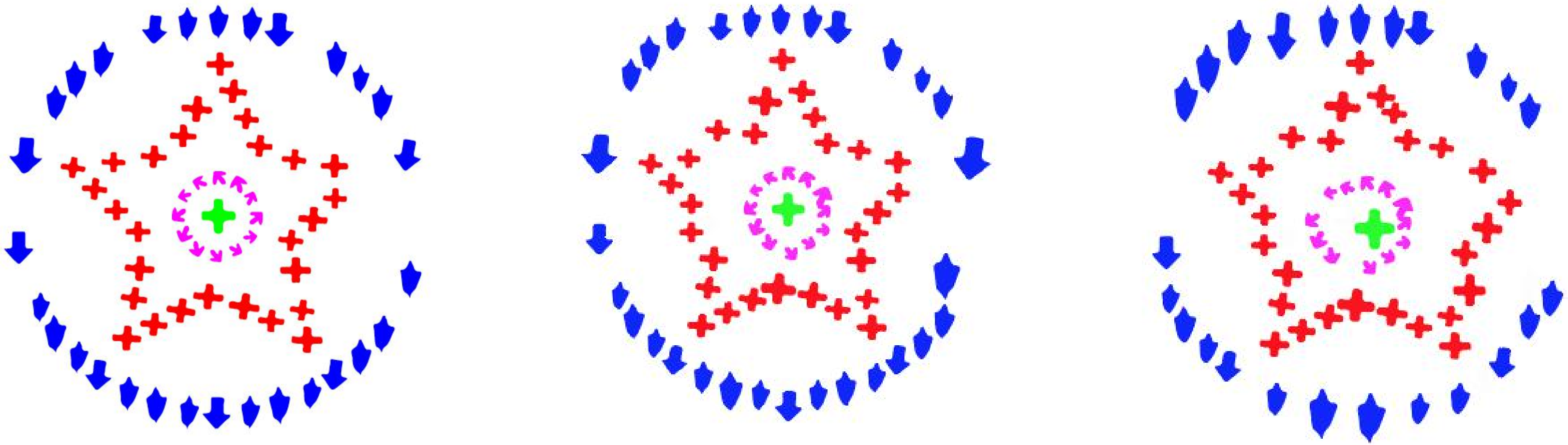
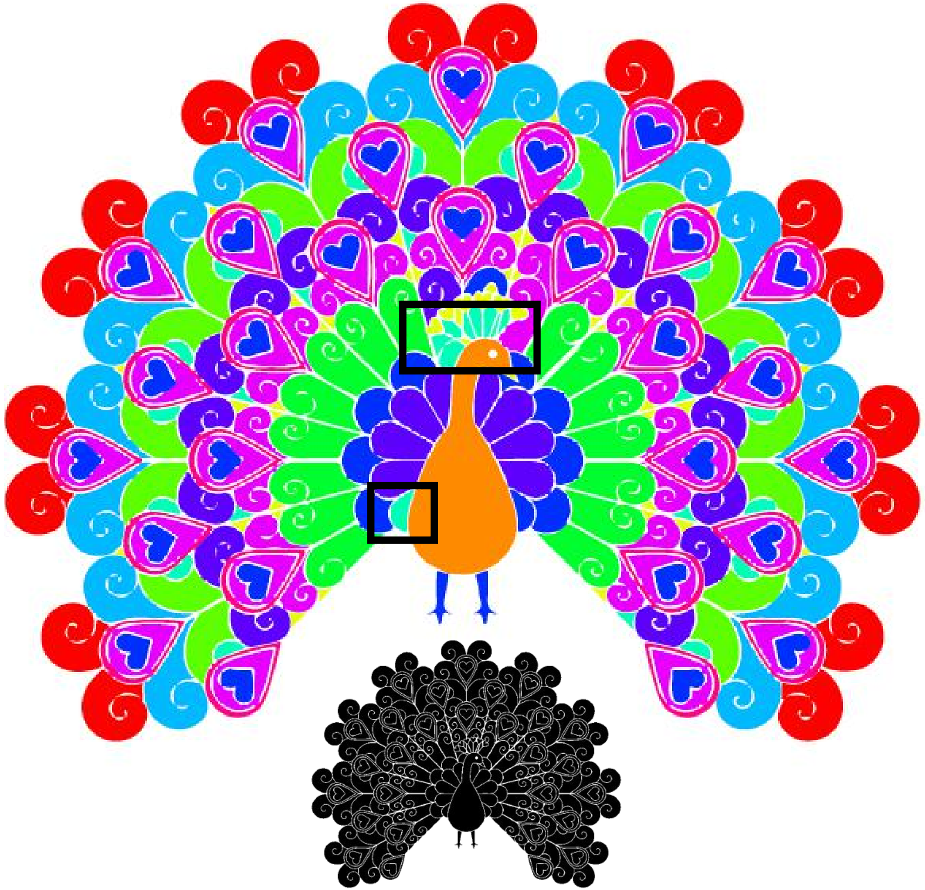
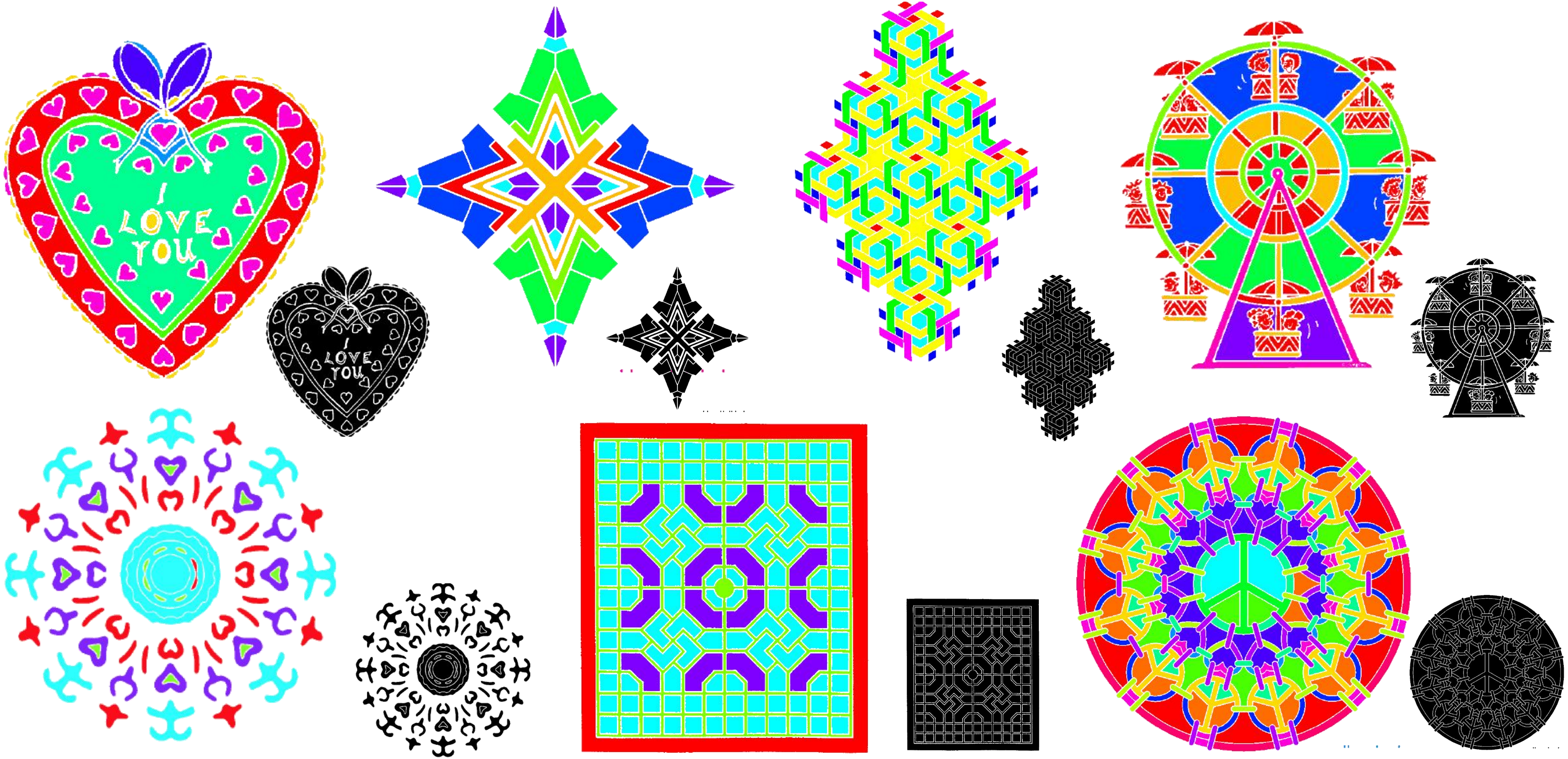


Noise level increase

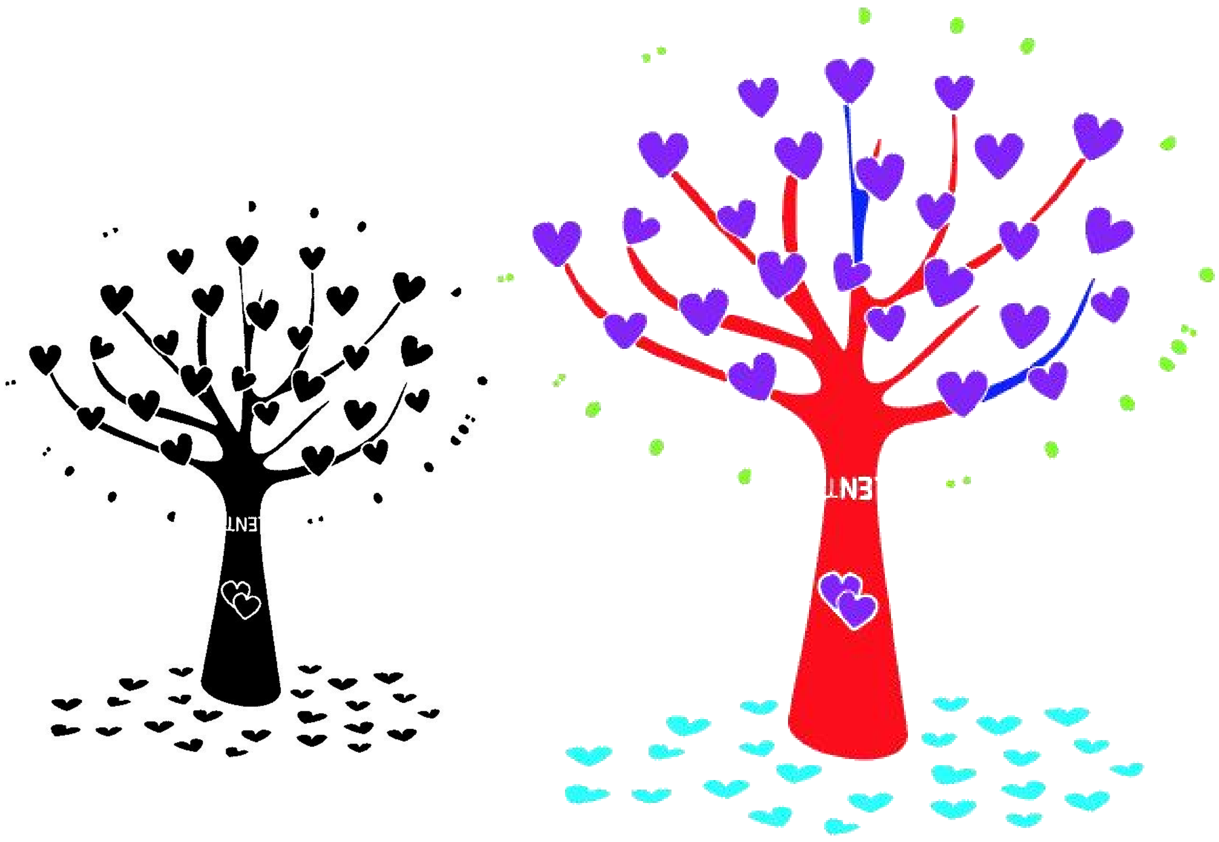
Results on **downloaded patterns**



Results on **downloaded patterns**



Results on downloaded **Challenging** patterns



Results on downloaded **Challenging** patterns

Quantitative Results with various **measures and alternatives**

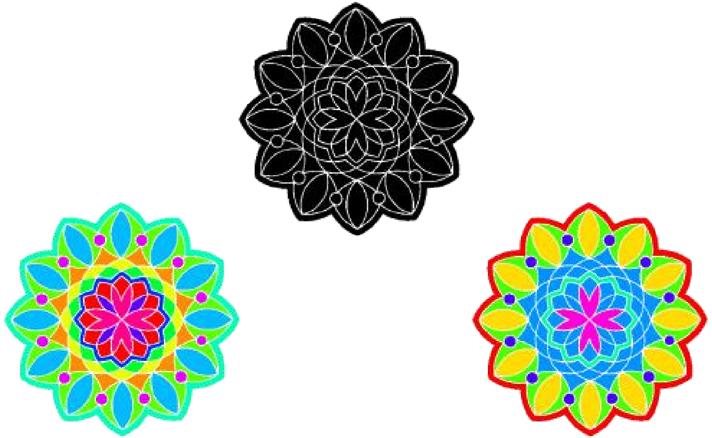
	preset #group		auto #group	
	Rand index	purity	Rand index	purity
geometry distance	77.62%	73.13%	76.47%	76.64%
AlexNet	76.60%	70.96%	74.41%	71.16%
fine-tuned AlexNet	77.72%	73.12%	77.59%	80.21%
element encoder	78.34%	74.59%	77.72%	78.82%
structure encoder	78.79%	73.24%	77.35%	74.68%
element+structure enc.	80.28%	75.75%	80.03%	81.84%
our full measure	**83.05%**	**80.24%**	**83.58%**	**85.76%**

Greater score mean better grouping results

Quantitative Results with various **Clustering** Strategies

	Rand index	purity
affinity propagation	**83.05%**	**80.24%**
agglomerative (average linkage)	75.93%	71.13%
agglomerative (single linkage)	71.11%	68.38%
agglomerative (complete linkage)	76.76%	71.79%
k-means	80.85%	75.58%
Gaussian Mixture Models	80.92%	74.91%
normalized cuts	77.48%	71.72%
Tagger [Greff et al. 2016]	66.54%	55.21%

Results of **User Study**



A

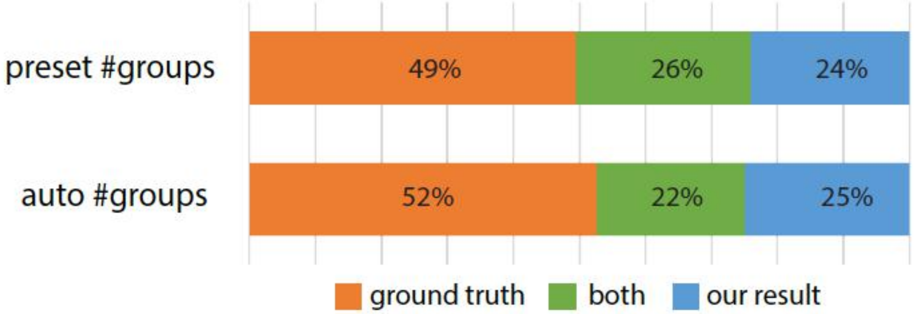
B

(i) A - 40%

(ii) B - 0%

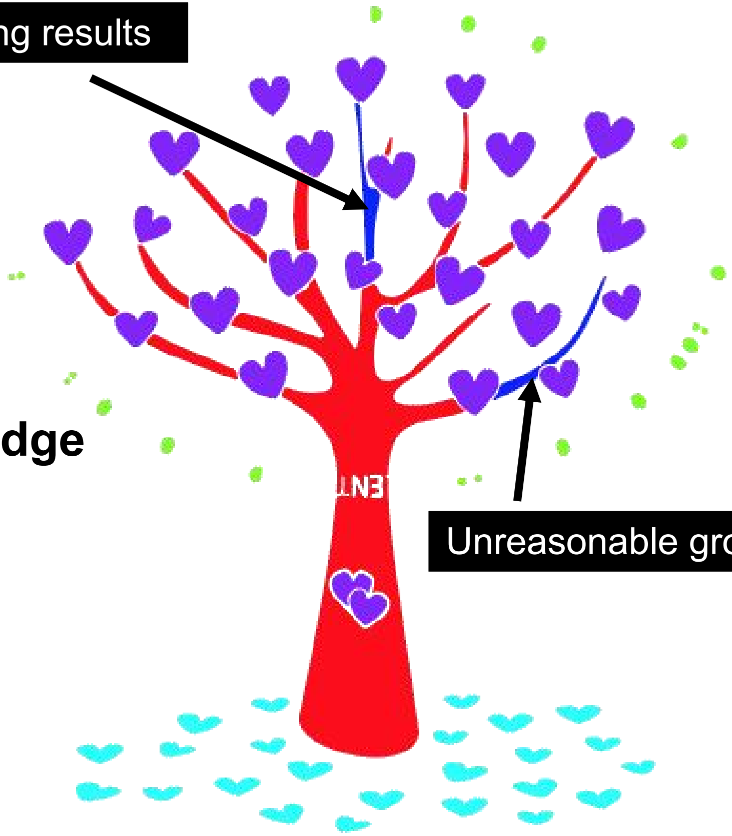
(iii) Both - 60%

(iv) Neither - 0%



Limitation on model

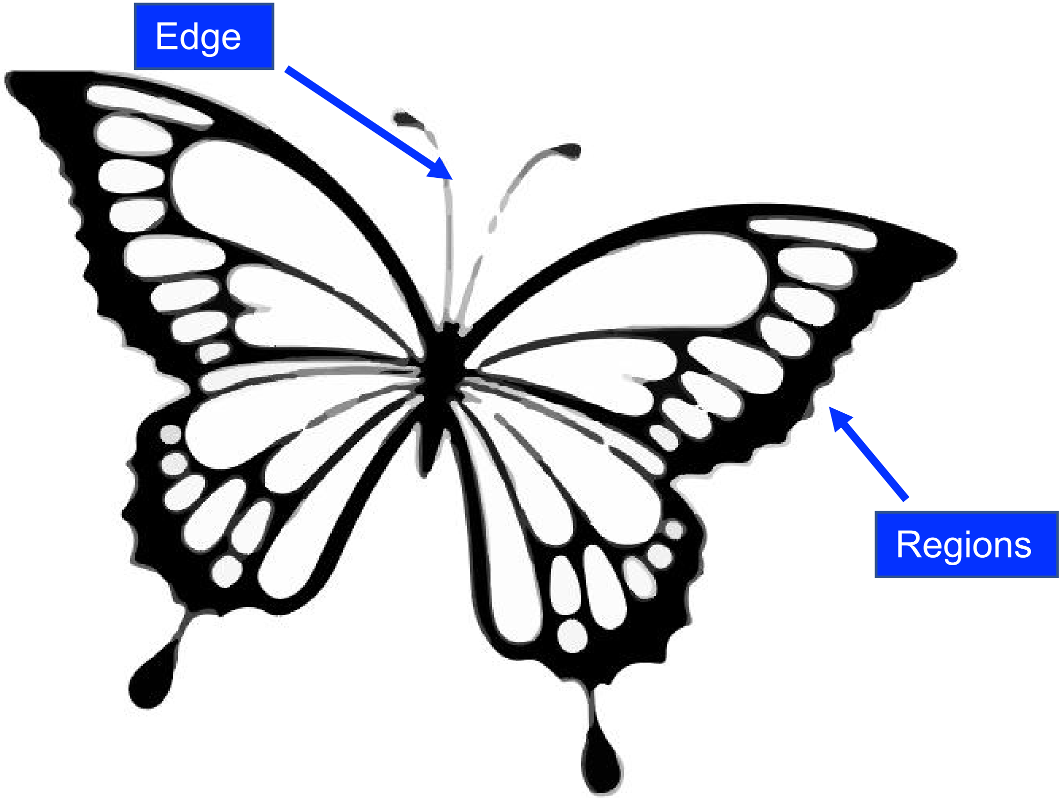
Unreasonable grouping results



No Semantic knowledge

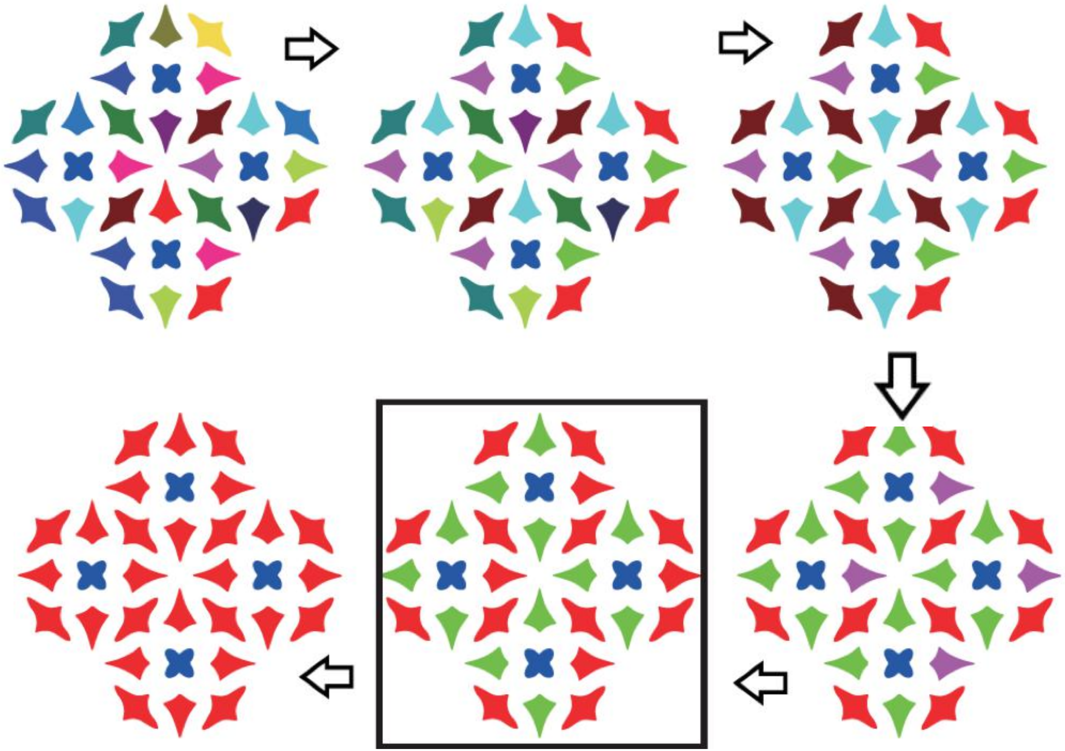
Unreasonable grouping results

Limitation on input data



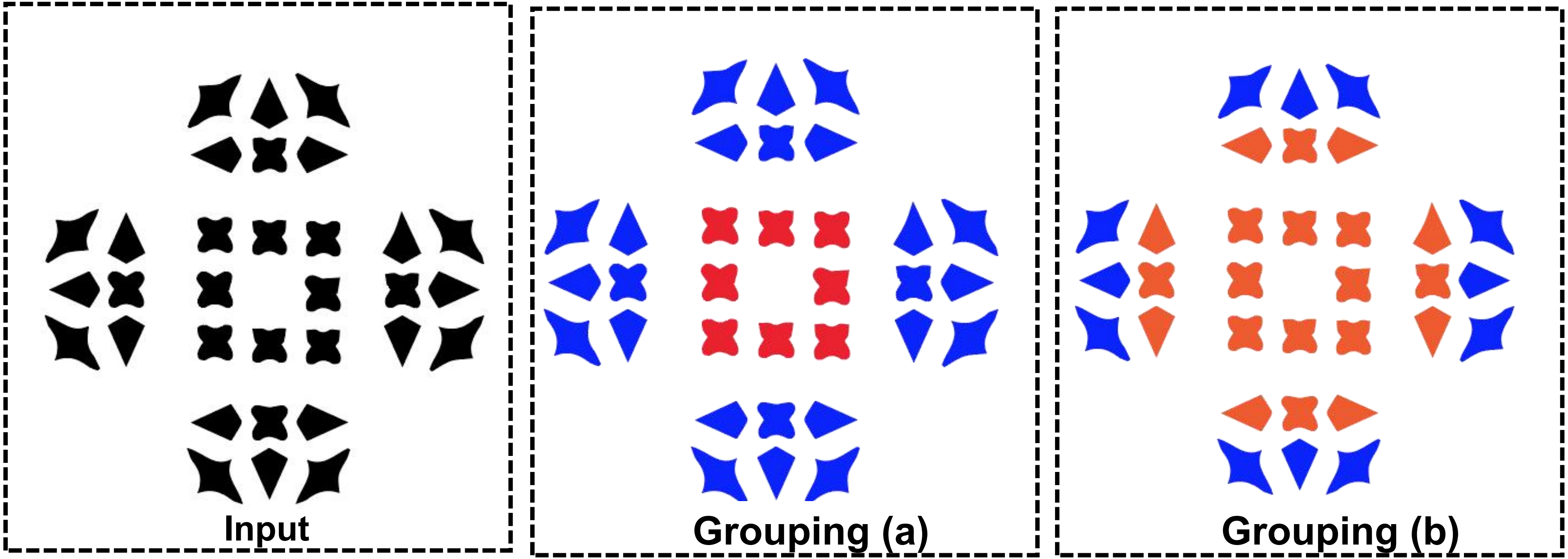
Future work: Unified Framework for Various types of Input Data

Other Future Directions: **Hierarchical Grouping**



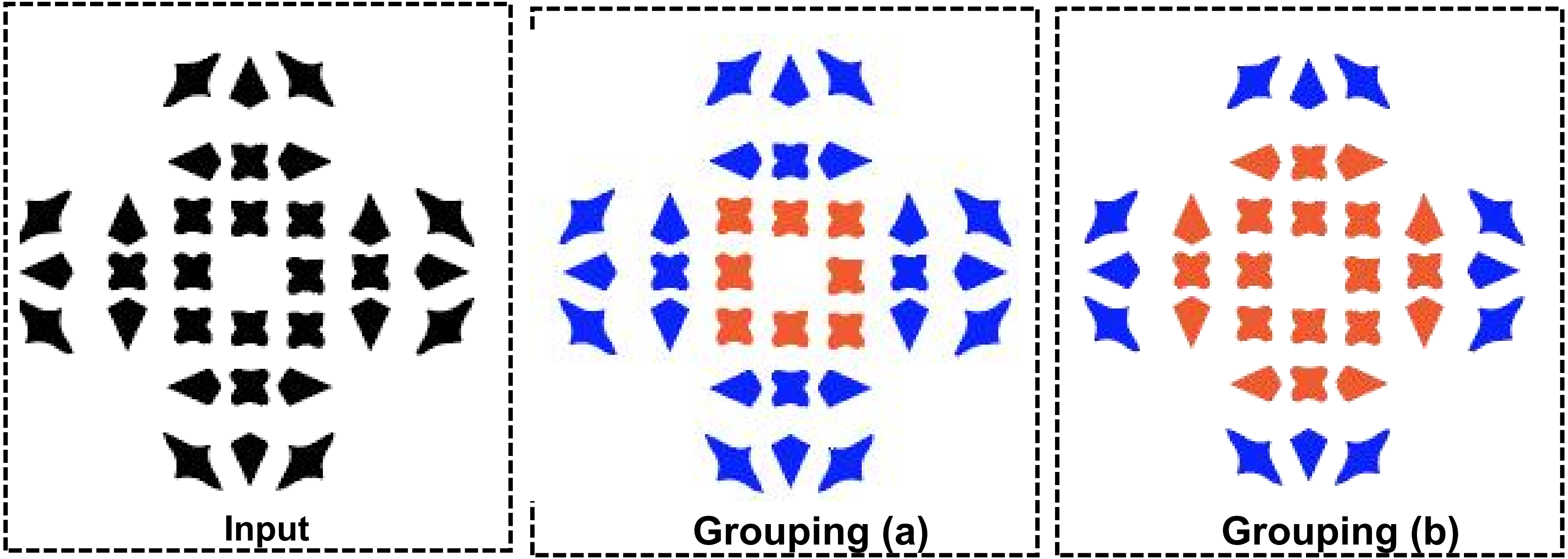
The optimal result

Other Future Directions: **learn to rank grouping results**



Which Grouping Results is better?

Other Future Directions: **learn to rank grouping results**



Ranking order Changed

Conclusion

- **First (data-driven + deep CNN)** for **discrete** 2D patterns**.**
- **Learned** shape-, context-, and structure-aware descriptors for graphical elements.
- A large, annotated dataset is provided **online.**
  http://people.cs.umass.edu/~zlun/papers/PatternGrouping/ **(source code + dataset)**

Conclusion

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Acknowledgements

- **Dr. Ke Li** for the help on **experimental data preparation.**
- The Science and Technology Plan Project of Hunan Province**.**
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- NSERC Canada.
- Gift funds from Adobe Research.

Thanks!

Q&A

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