Eurographics 2014 – Strasbourg – France

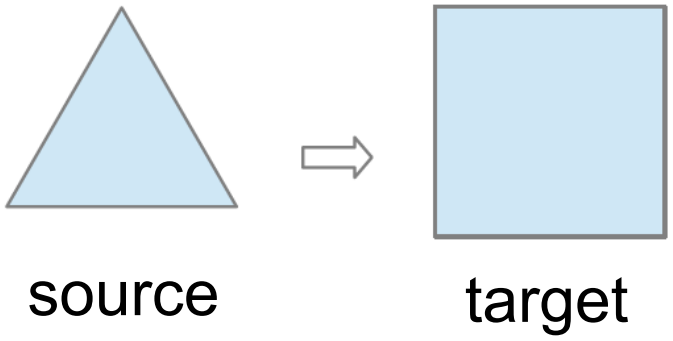
Analogy-Driven 3D Style Transfer

[Eurographics 2014]

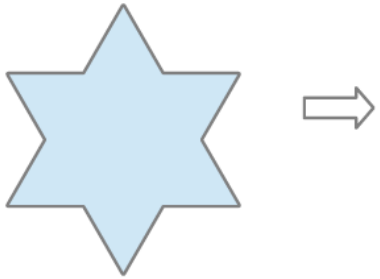
Chongyang Ma[*‡] Haibin Huang[†] Alla Sheffer[*]
Evangelos Kalogerakis[†] Rui Wang[†]

[*]University of British Columbia
[†]University of Massachusetts Amherst
[‡]University of Southern California

Shape Analogies



source target

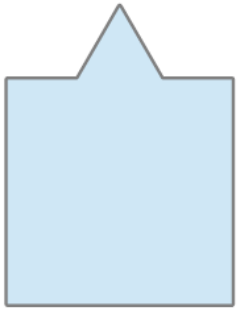


exemplar

?

output

(1)



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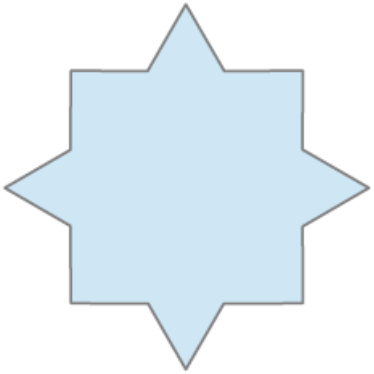

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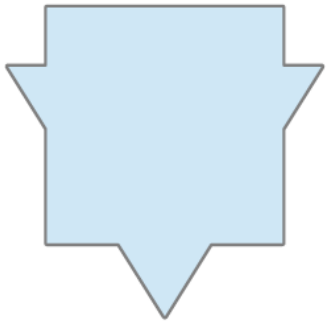

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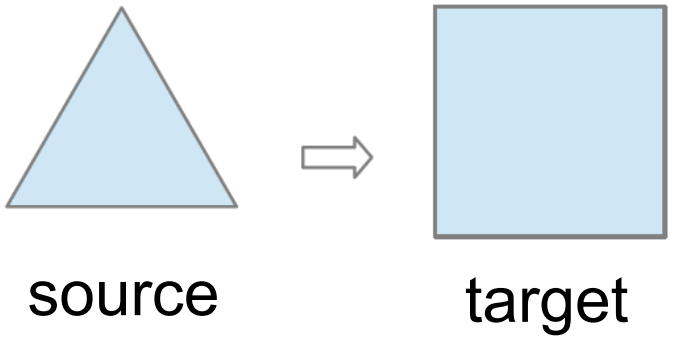

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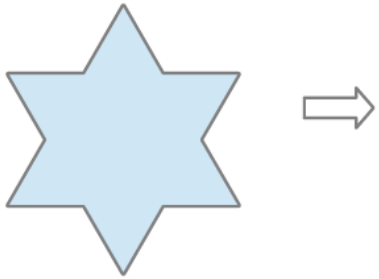


exemplar

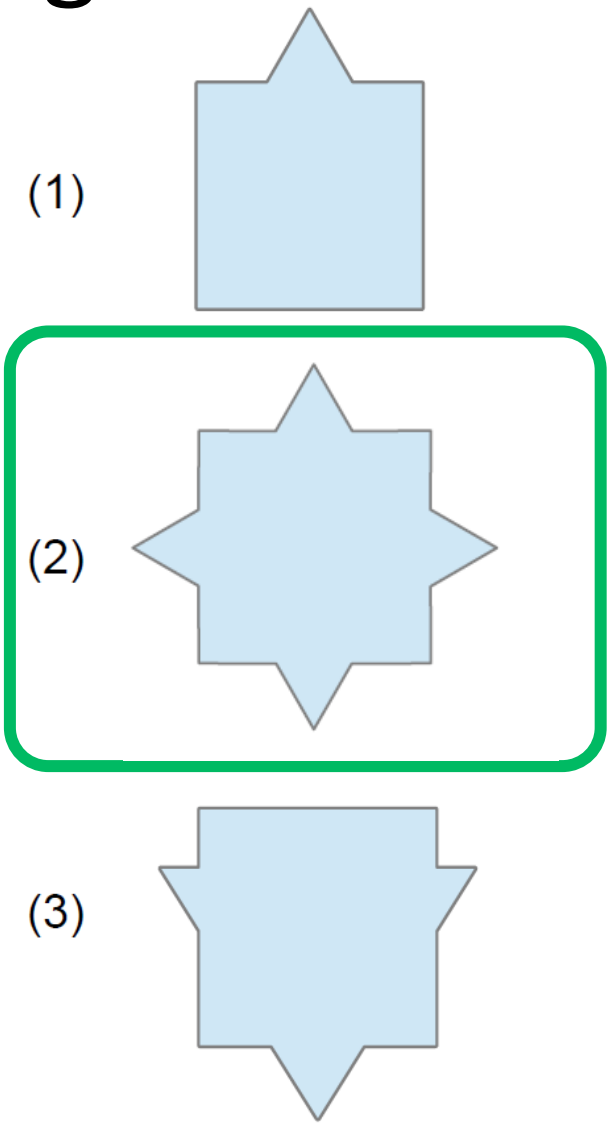
?

output

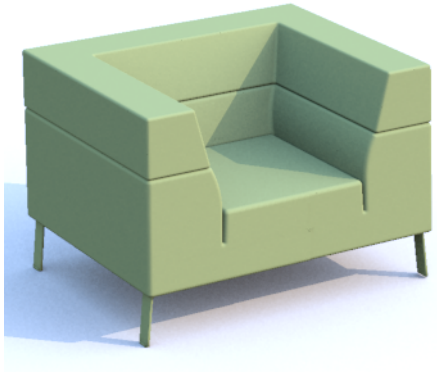
(1)

(2)

(3)



Style Transfer



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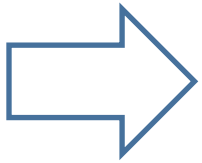
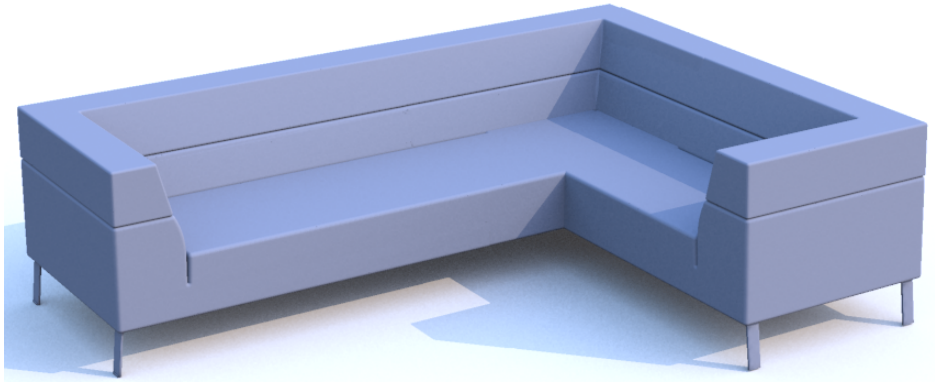
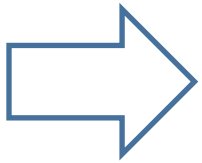




target

exemplar



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output

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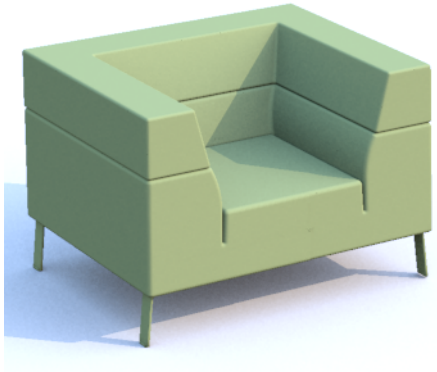

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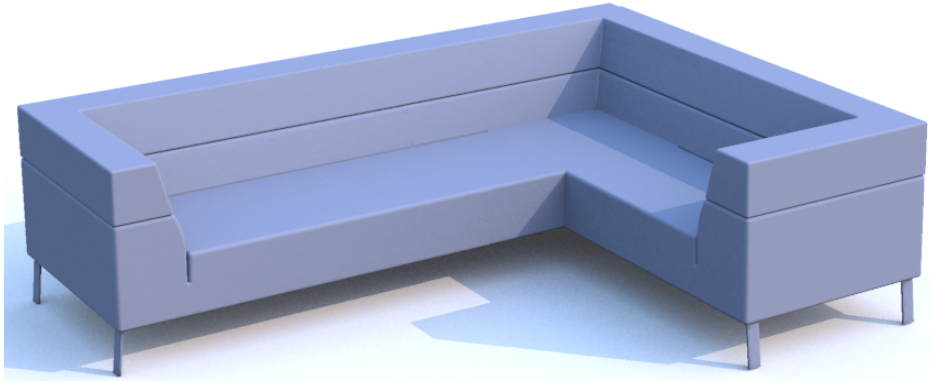

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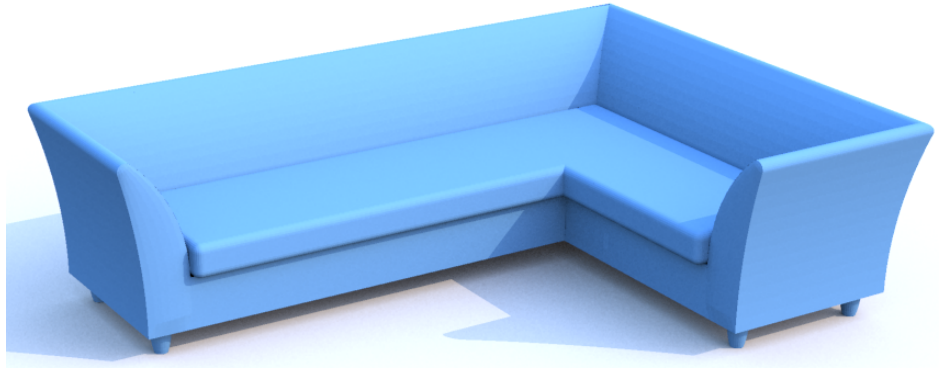


output

Shape Analysis

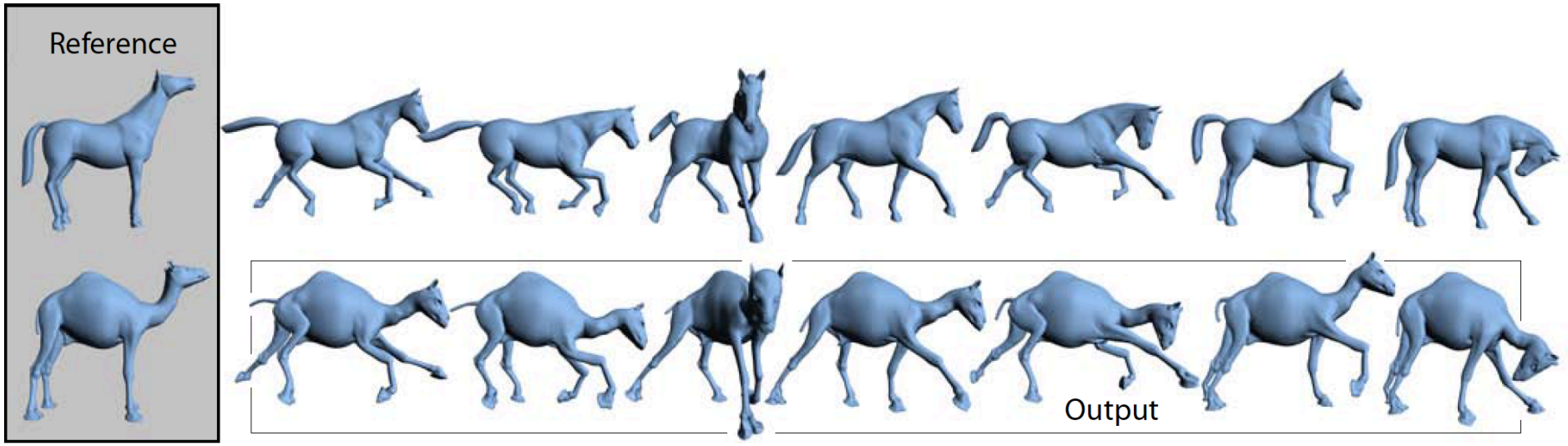
- Symmetry detection
  - [TW05, MGP06, PMW*08, MBB10]
- Full/partial mapping
  - [SAPH04, vKZHCO11, KLM*12, HZG*12, SNB*12]
- Shape analogies for retrieval
  - [ROA*13]

Part-based Shape Synthesis

- User-assisted assembly
  - [FKS*04, CKGK11]
- Randomized from shape grammars
  - [BWS10, TYK*12]
- Automatic from pre-segmented database
  - [KCKK12, XZCOC12, SFCH12]

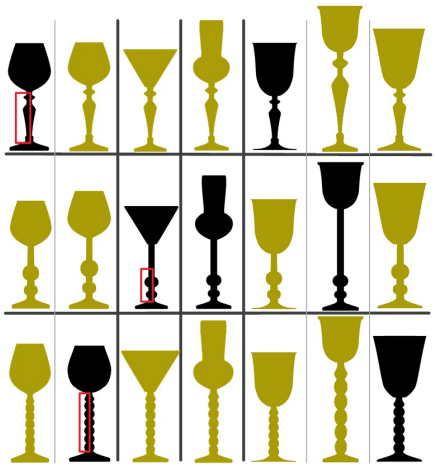
Deformation/Style Transfer

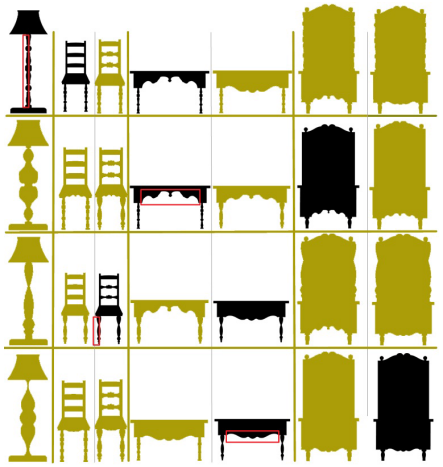
- Deformation Transfer
  - [SP04]
  - Continuous mapping, no structural difference



Deformation/Style Transfer

- Deformation Transfer
  - [SP04]
  - Continuous mapping, no structural difference
- 2D Style Transfer
  - [HJO*01, HOCS02, FTP03, LZW*13]
  - Not applicable to 3D





Deformation/Style Transfer

- Deformation Transfer
  - [SP04]
  - Continuous mapping, no structural difference
- 2D Style Transfer
  - [HJO*01, HOCS02, FTP03]
  - Not applicable to 3D
- 3D Part-Scale Transfer
  - [XLZ*10]
  - Require pre-segmentation and one-to-one mapping

Pre-Processing

- Consistently scale and align input models
  - Bounding boxes
  - Upright orientation

- Uniformly sample model surface
  - Point sample set $\{s\}$
  - Sample position $\mathbf{p}(s)$ and normal $\mathbf{n}(s)$

Algorithm Overview

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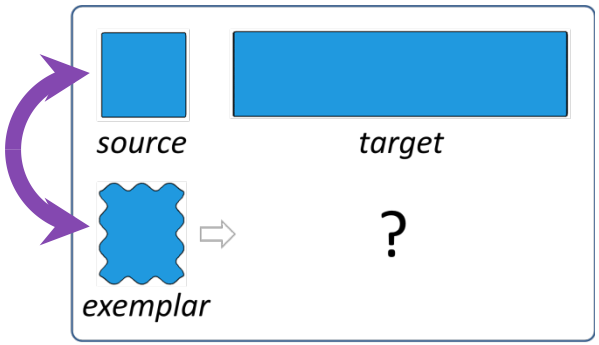
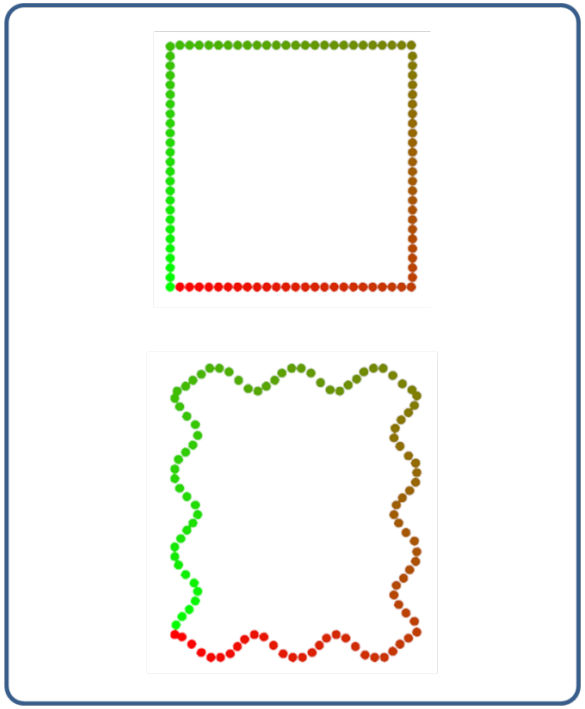
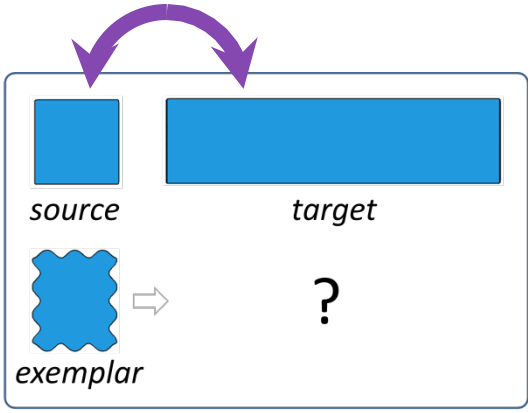


Input



Source-Exemplar Correspondence

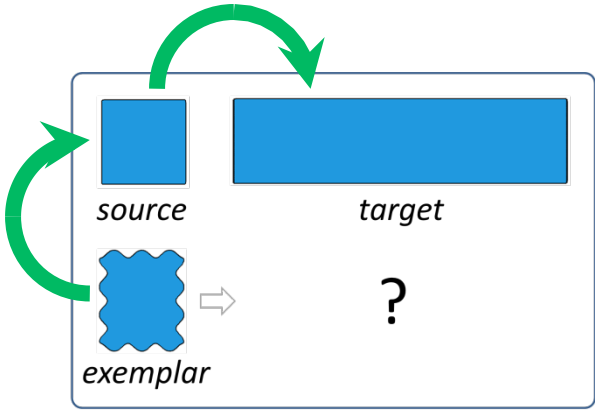
Algorithm Overview



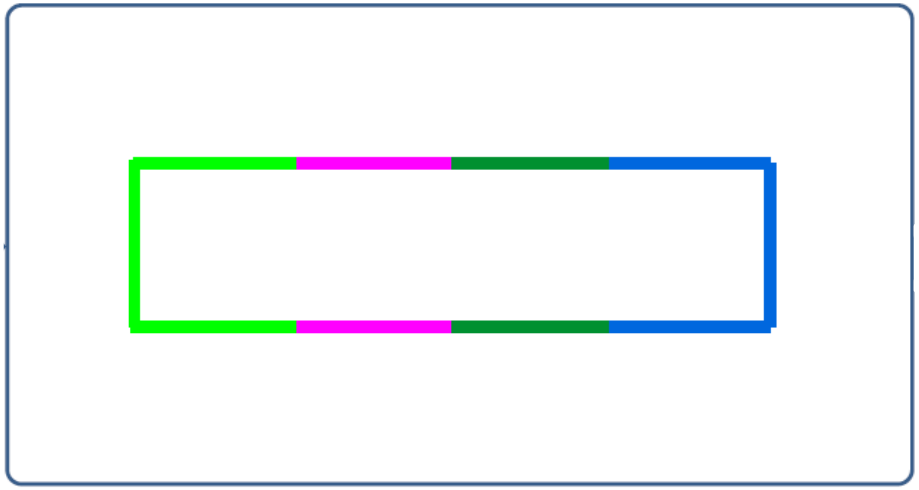
Input

Source-Target Possible Transformations

Algorithm Overview

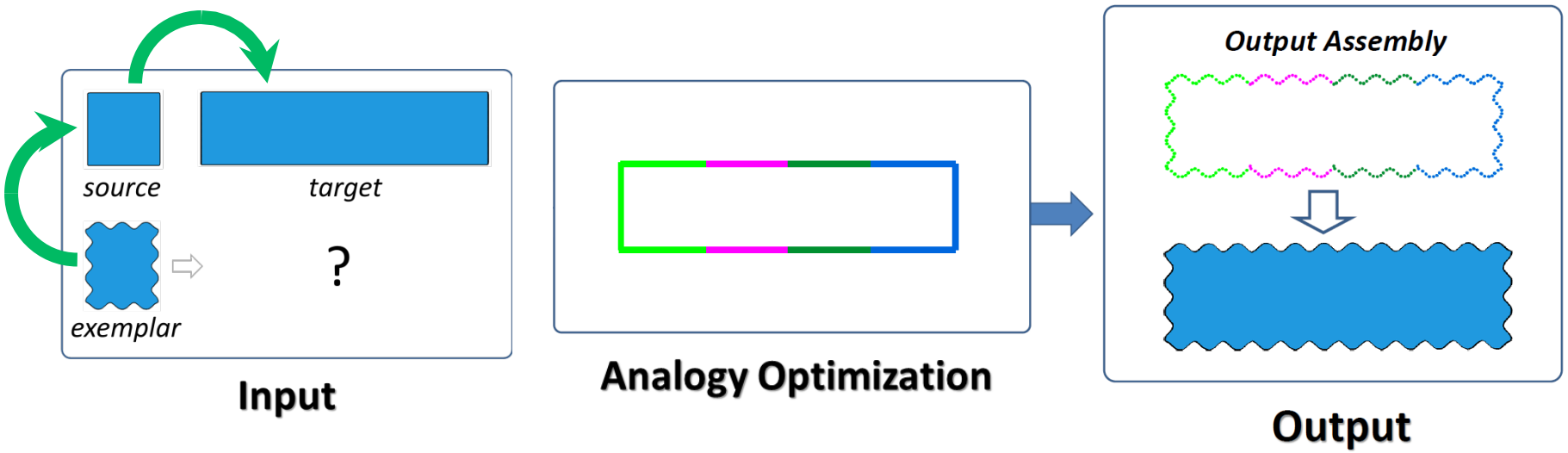


Input



Analogy Optimization

Algorithm Overview

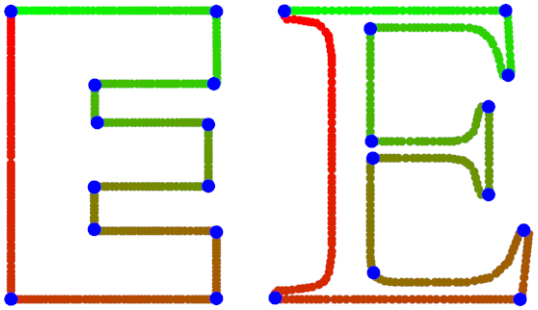


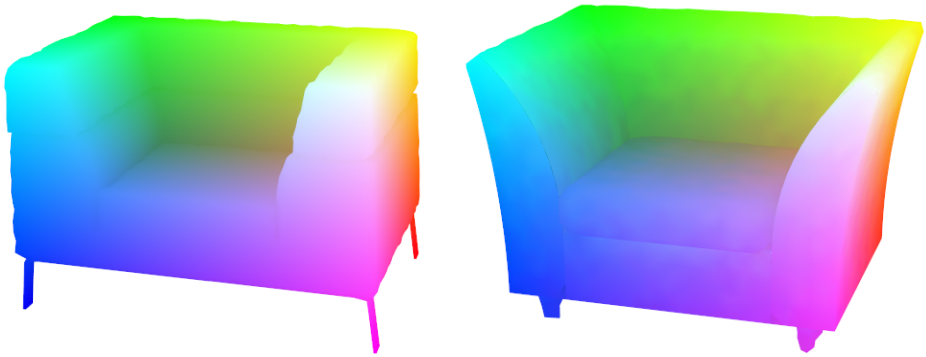
Source-Exemplar Correspondence

- Pair-wise sample distance

$$d(s_e, s_s) = \left|\hat{\mathbf{p}}(s_s) - \hat{\mathbf{p}}(s_e)\right|^2 + \lambda \cdot \cos^{-1}\left(\mathbf{n}(s_s) \cdot \mathbf{n}(s_e)\right)$$

- Minimize sum of pair-wise distance
  - Hungarian algorithm [Kuh55]





Transformation Selection

- Initial candidate set
  - Votes from all pairs of source and target samples
  - Best align local coordinate systems

- Selected transformations $\{Q\}$ [MGP06]
  - Dominant modes from mean-shift clustering
  - Associated subsets of target samples $\{s_t\}$

$$\left|Q\left(\mathbf{p}\left(s_t\right)\right)-\mathbf{p}\left(s_s\right)\right|<\delta_{\mathbf{p}},\ Q\left(\mathbf{n}\left(s_t\right)\right)\cdot\mathbf{n}\left(s_s\right)>\delta_{\mathbf{n}}$$

Analogy Optimization

- Source-to-target analogy
  - A subset of selected transformation
  - Each target sample associated to one transformation
- Multi-label energy optimization
  - Simplicity: unary term
  - Compactness: pairwise term
  - Continuity: regularization term

Analogy Optimization

- Source-to-target analogy
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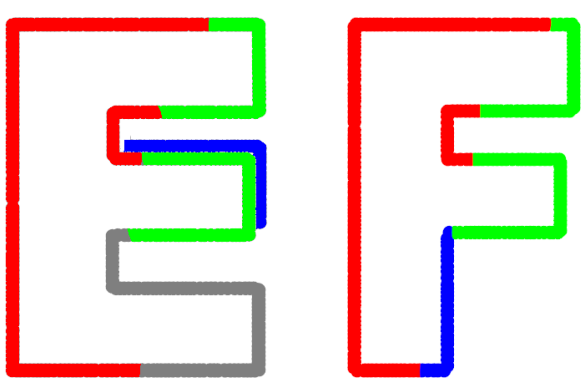
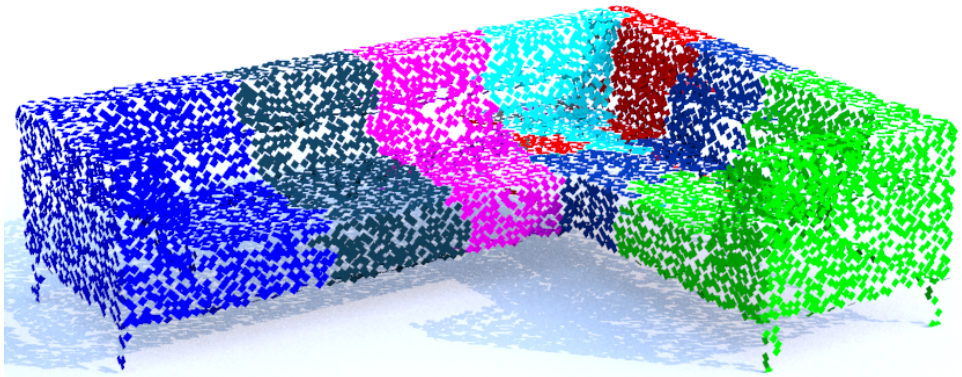
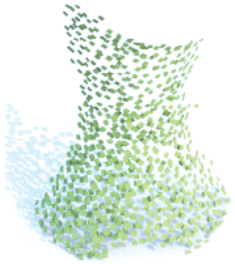


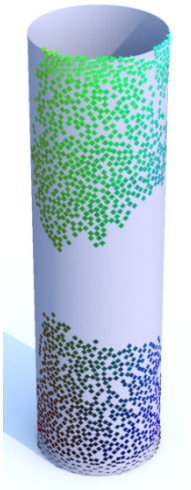


Algorithm – Scan Completion



partial scan

template



source

exemplar

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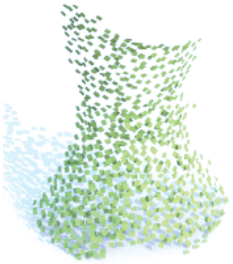

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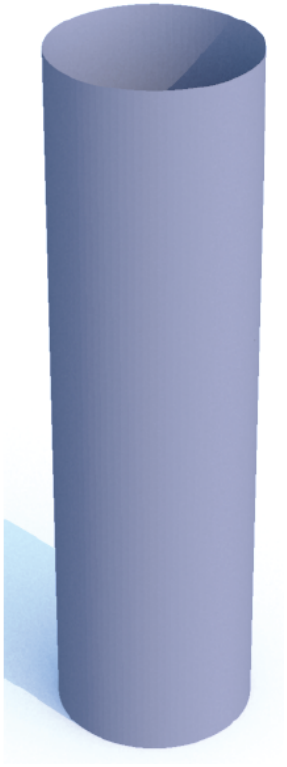

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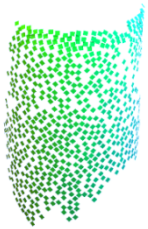

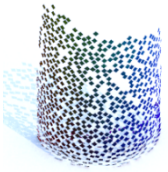

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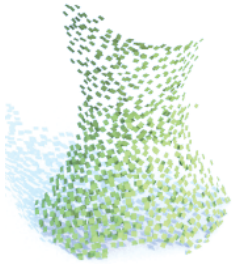

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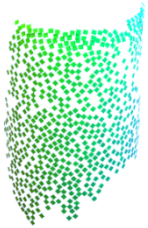

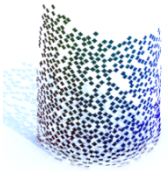

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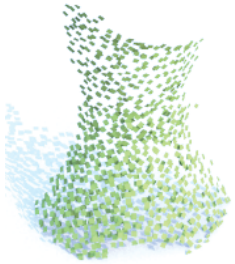

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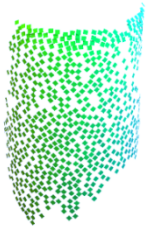

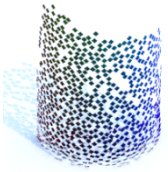

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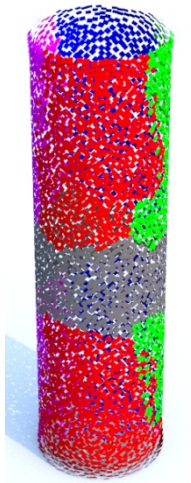

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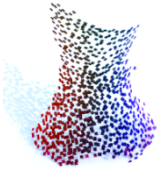

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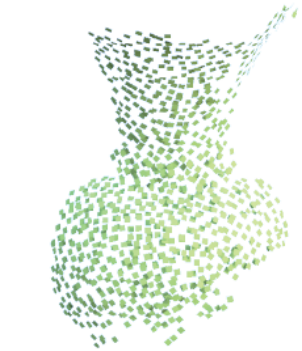

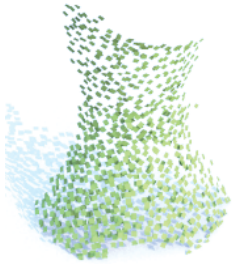

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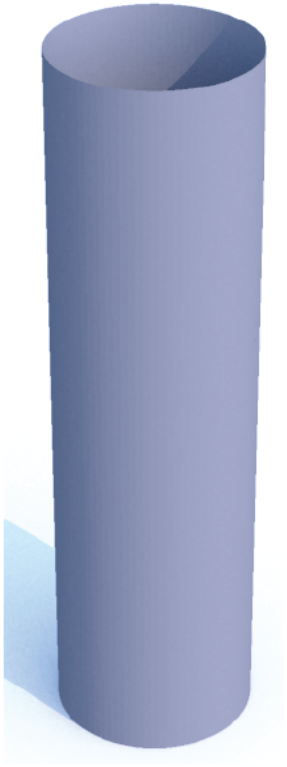

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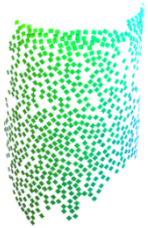

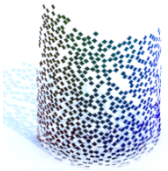

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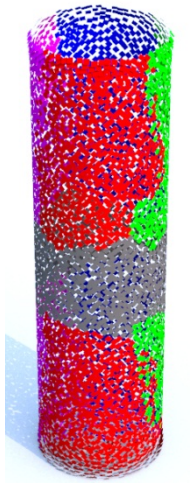
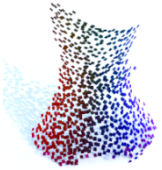


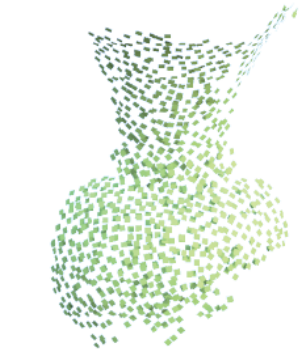
target

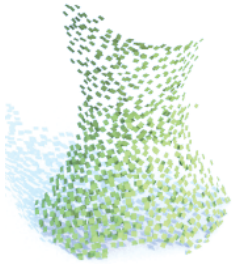


exemplar

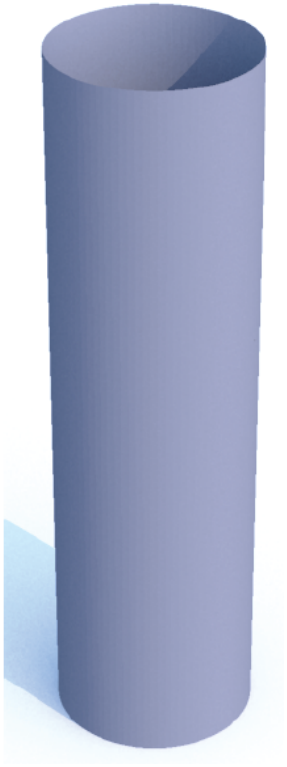
output

Algorithm – Scan Completion

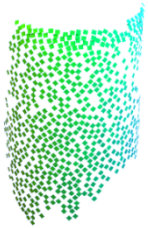


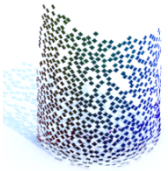


partial scan

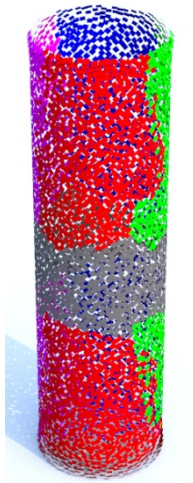


template

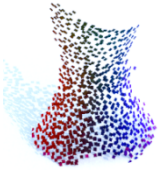




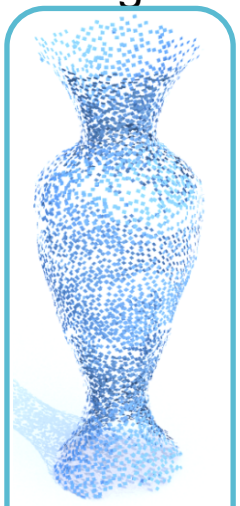
source



target



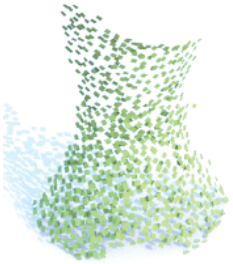
exemplar

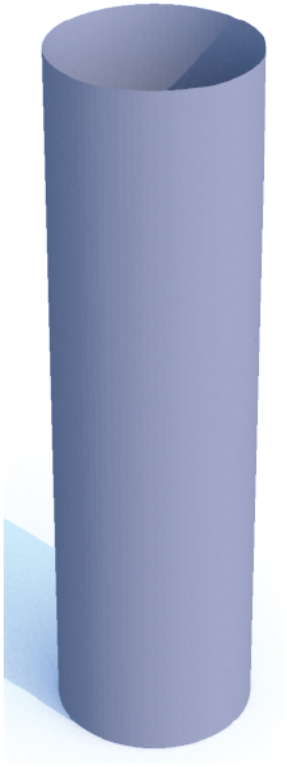


output

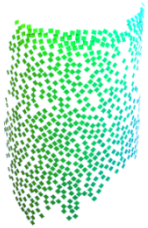
Algorithm – Scan Completion

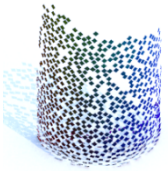
partial scan





template





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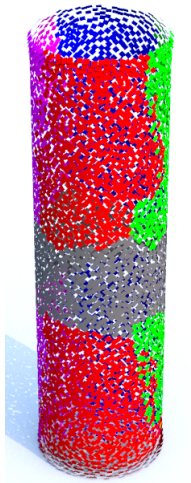
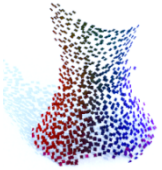


target

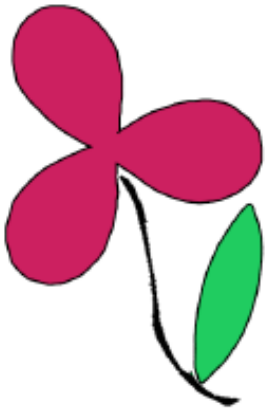


exemplar

output

reconstructed result

Results – 2D Style Transfer



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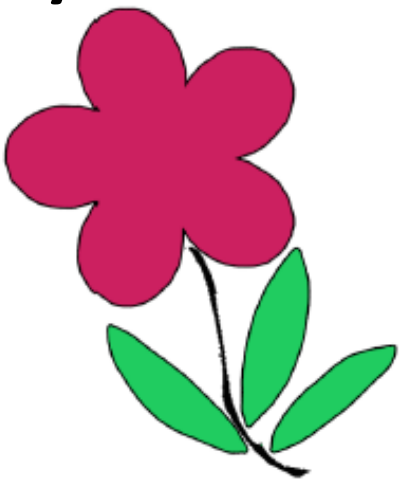
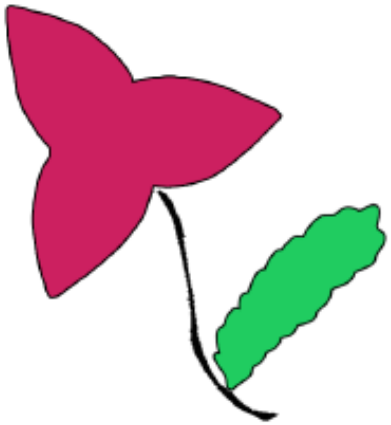


target

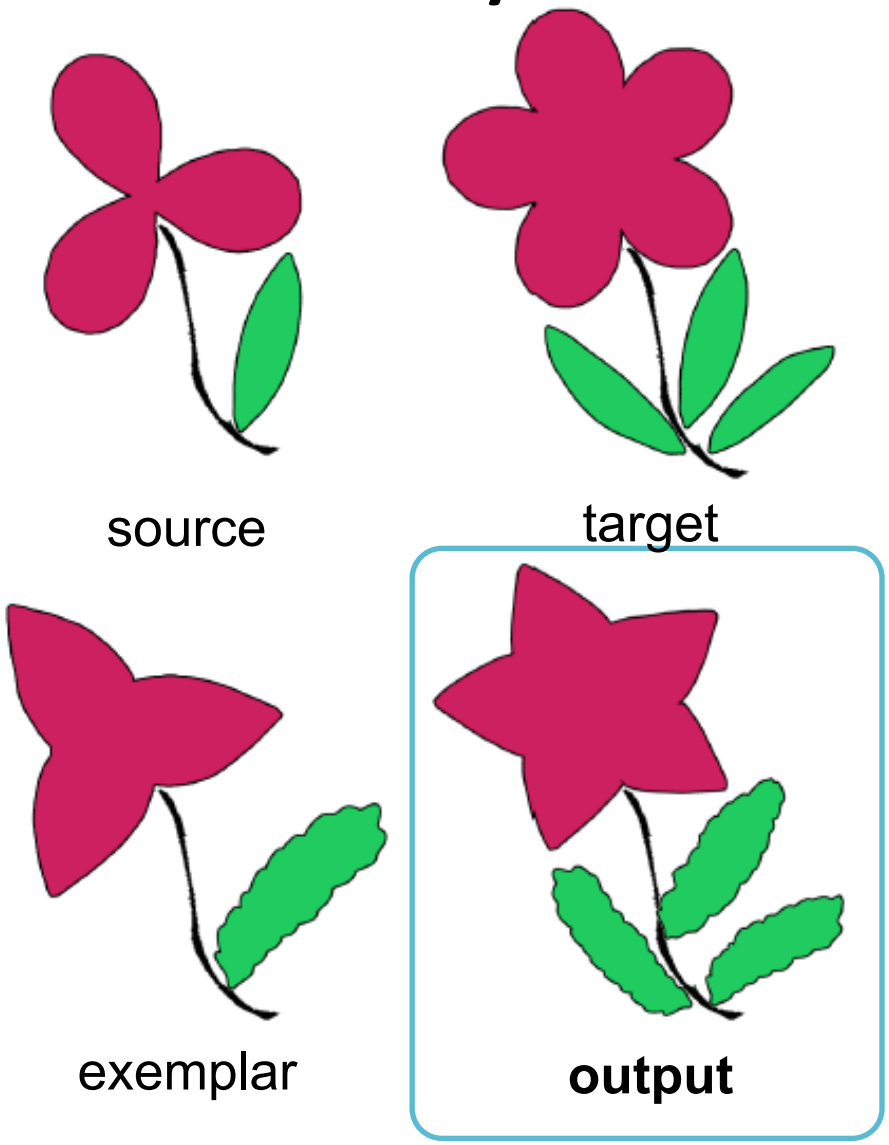


exemplar

?

output

Results – 2D Style Transfer



Results – 2D Style Transfer

source

exemplar

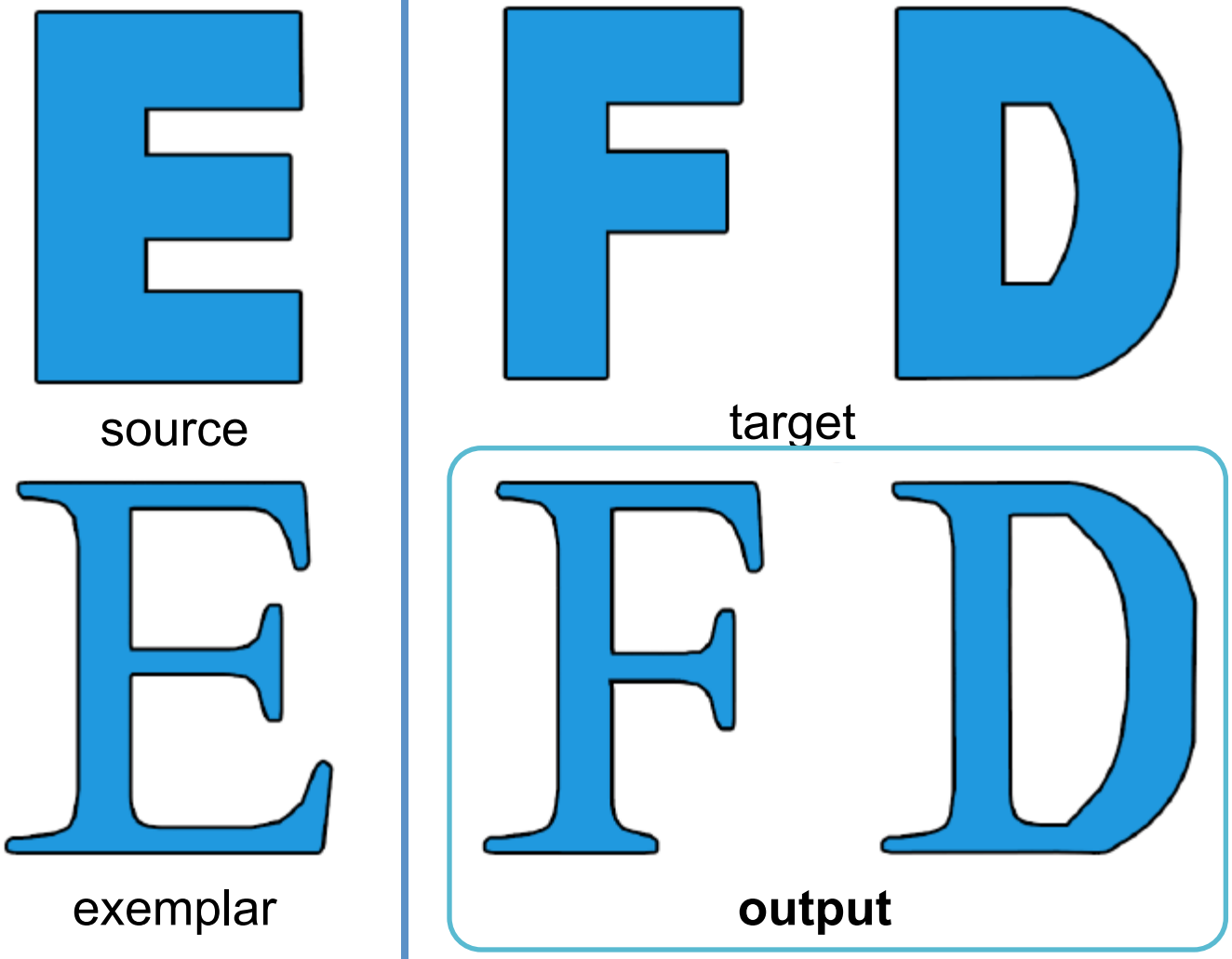
target

?

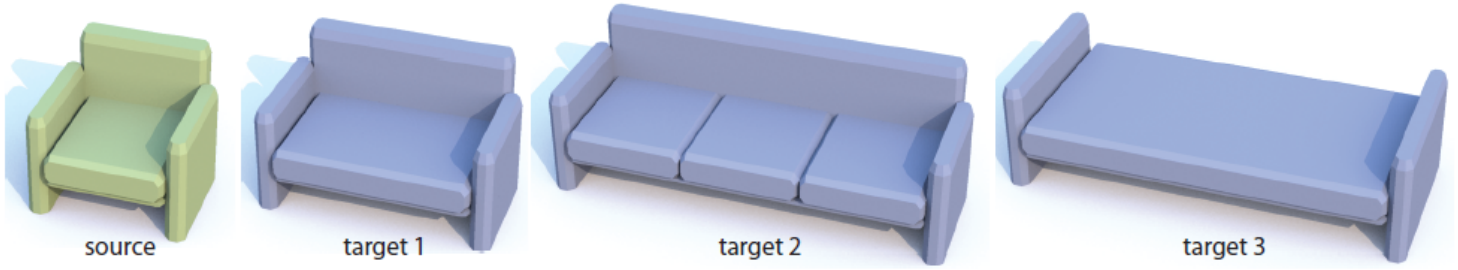
?

output

Results – 2D Style Transfer



Results – 3D Style Transfer



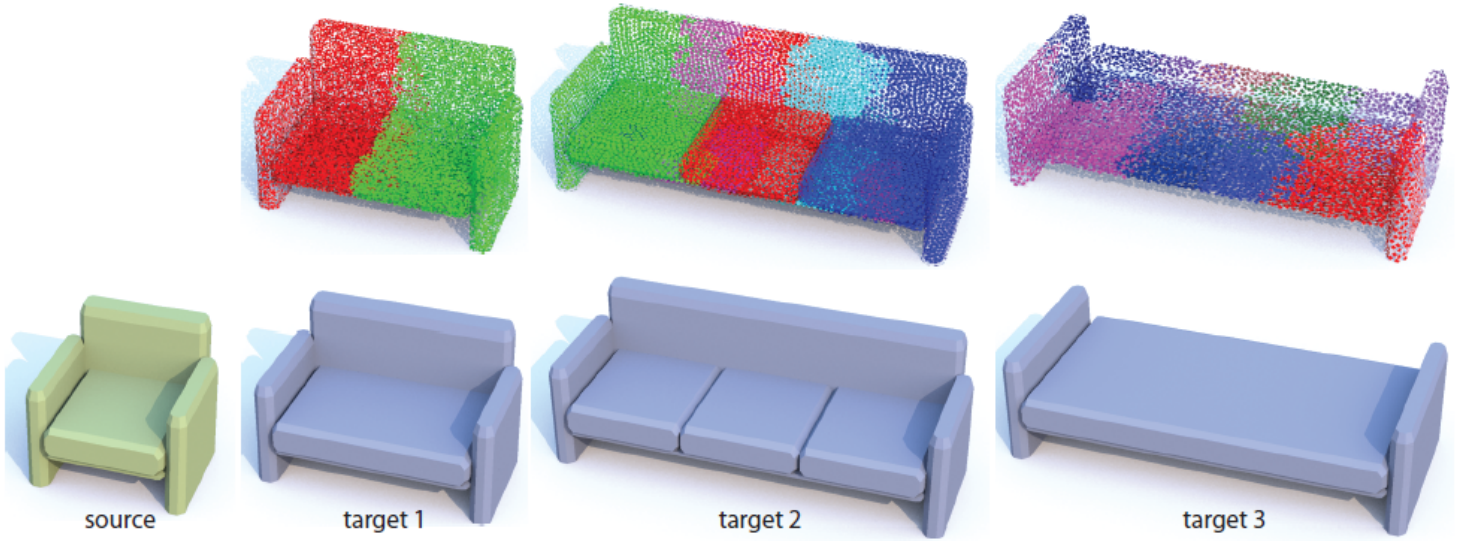
exemplar A

? ? ?

exemplar B

? ? ?

Results – 3D Style Transfer



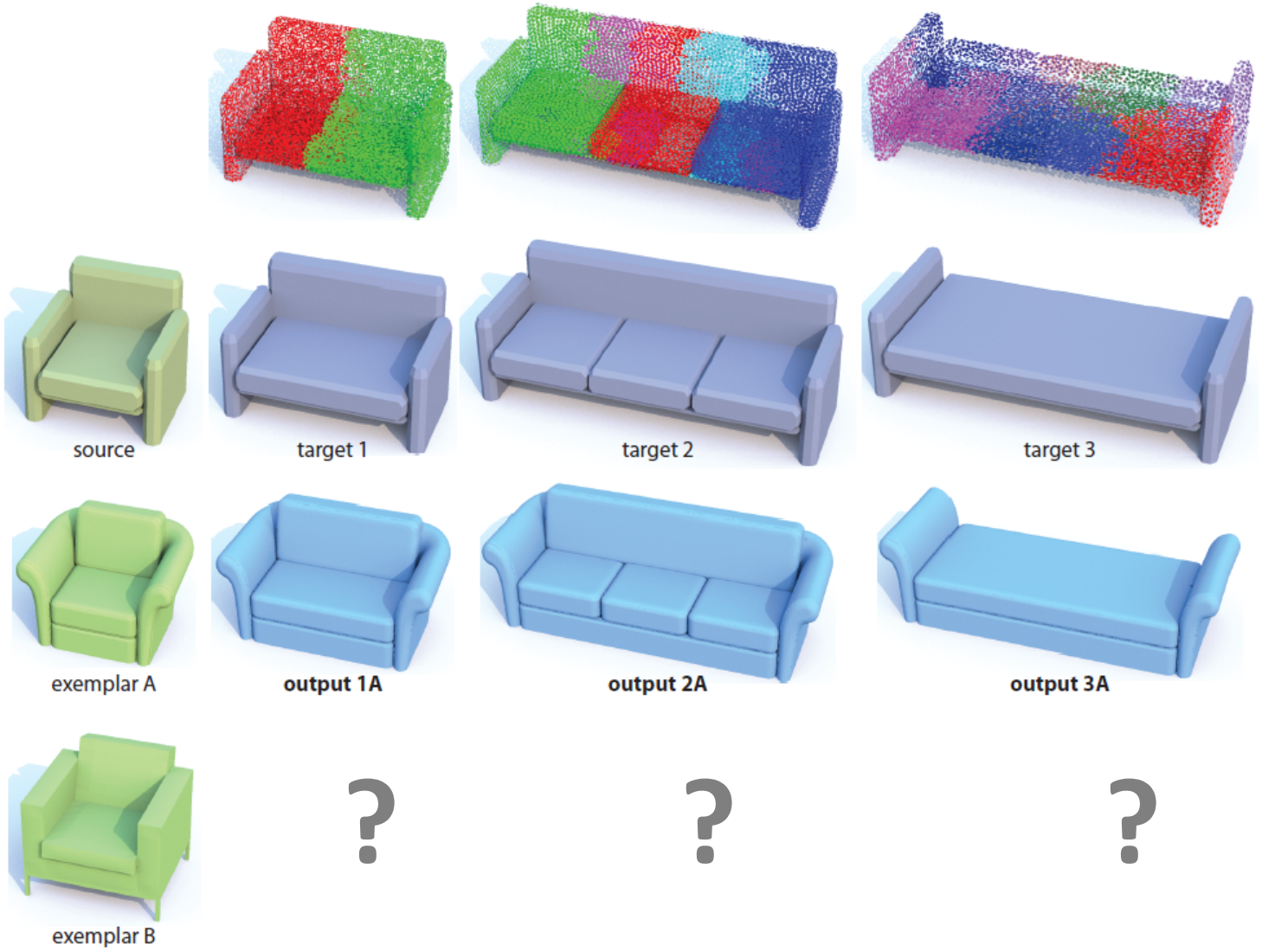
exemplar A

? ? ?

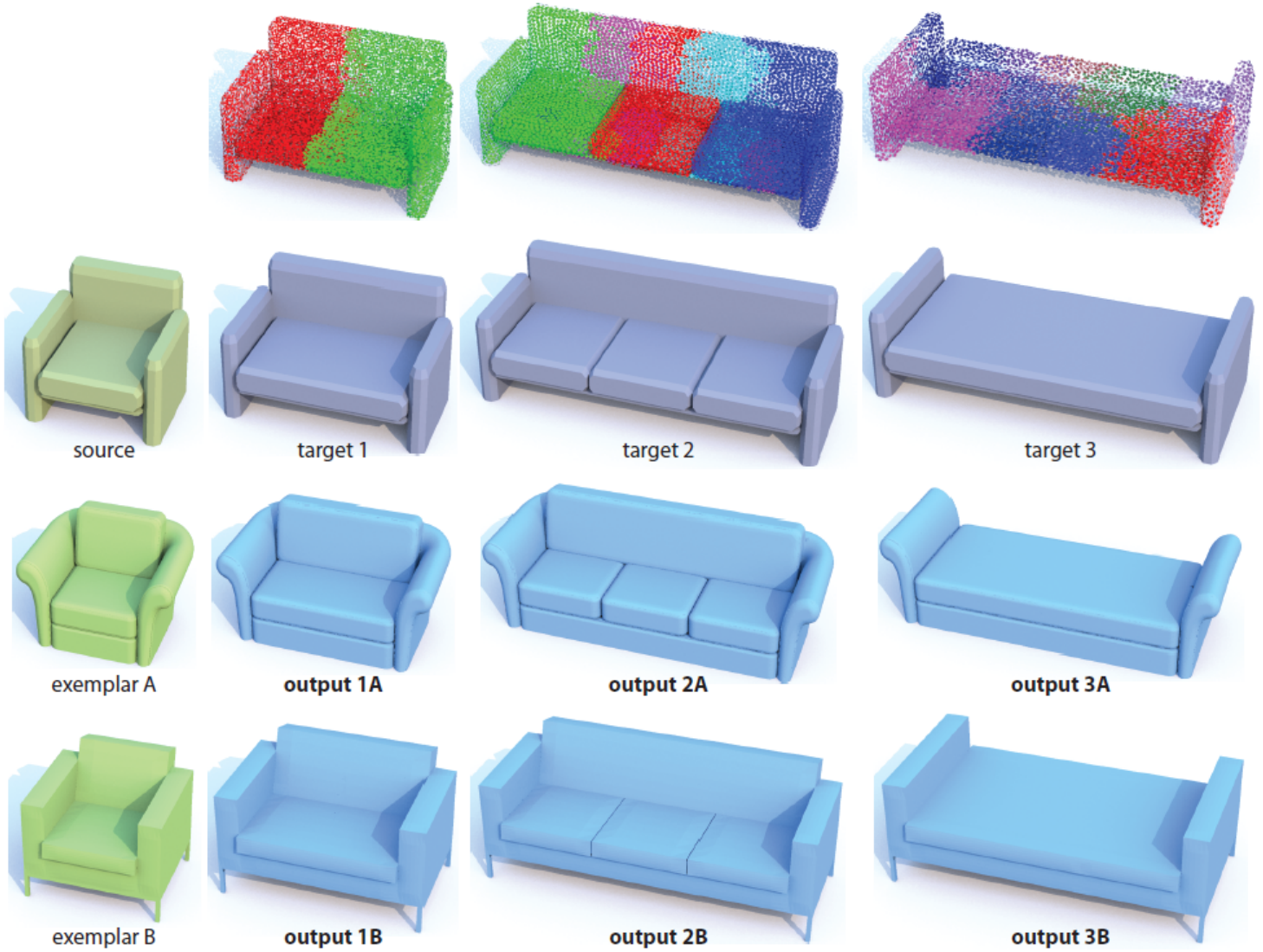
exemplar B

? ? ?

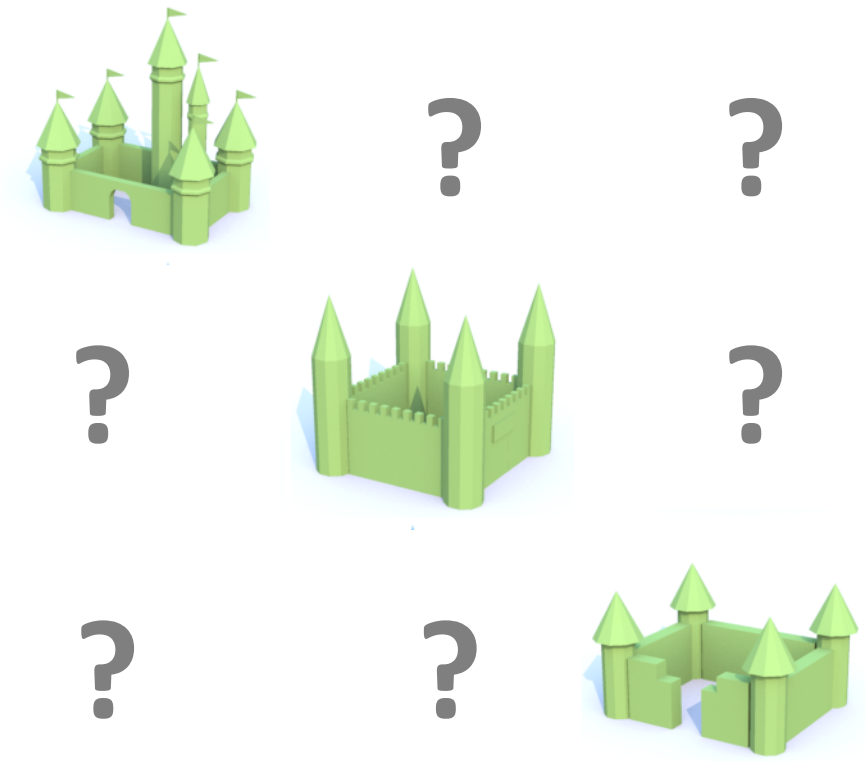
Results – 3D Style Transfer



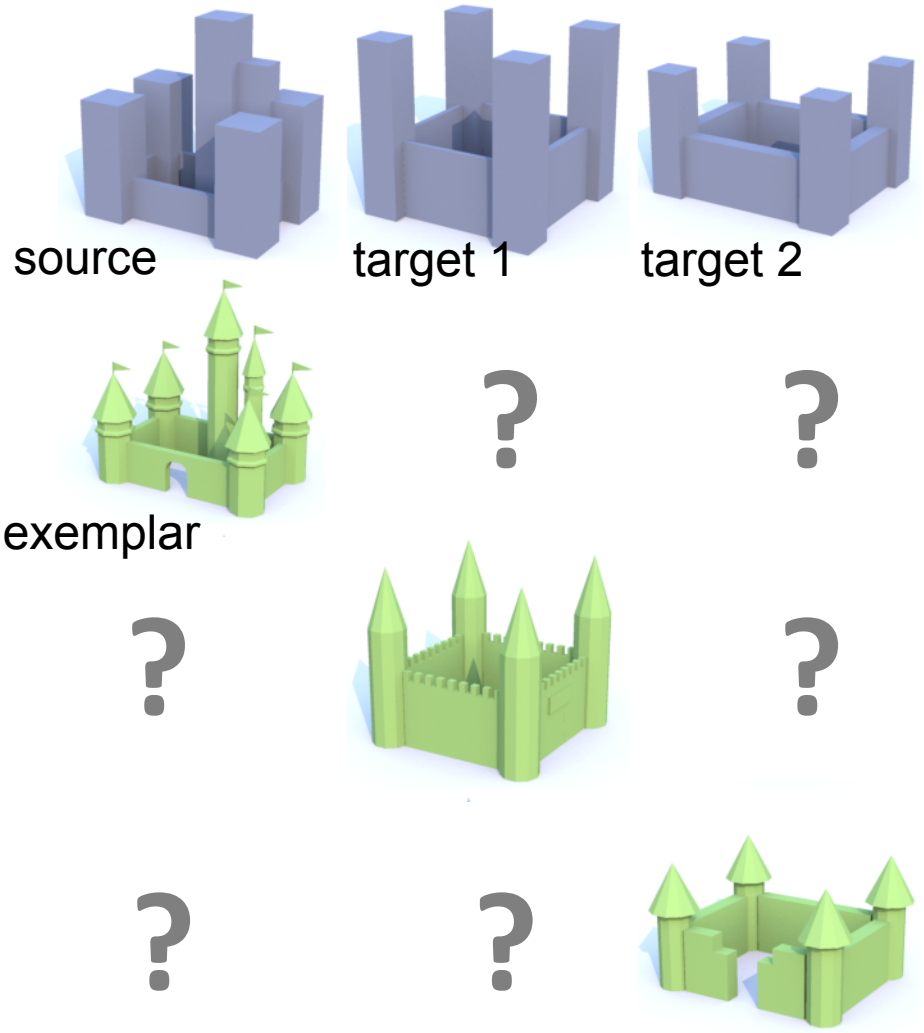
Results – 3D Style Transfer



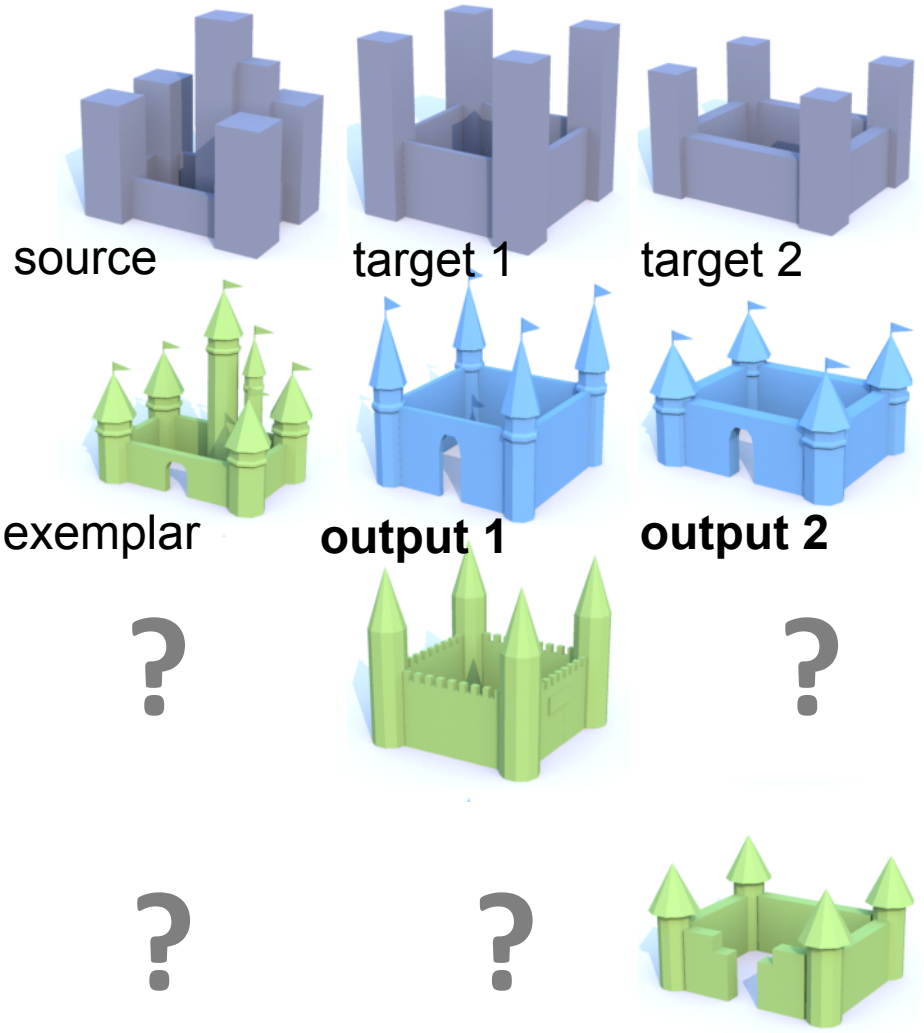
Results – 3D Style Exchange



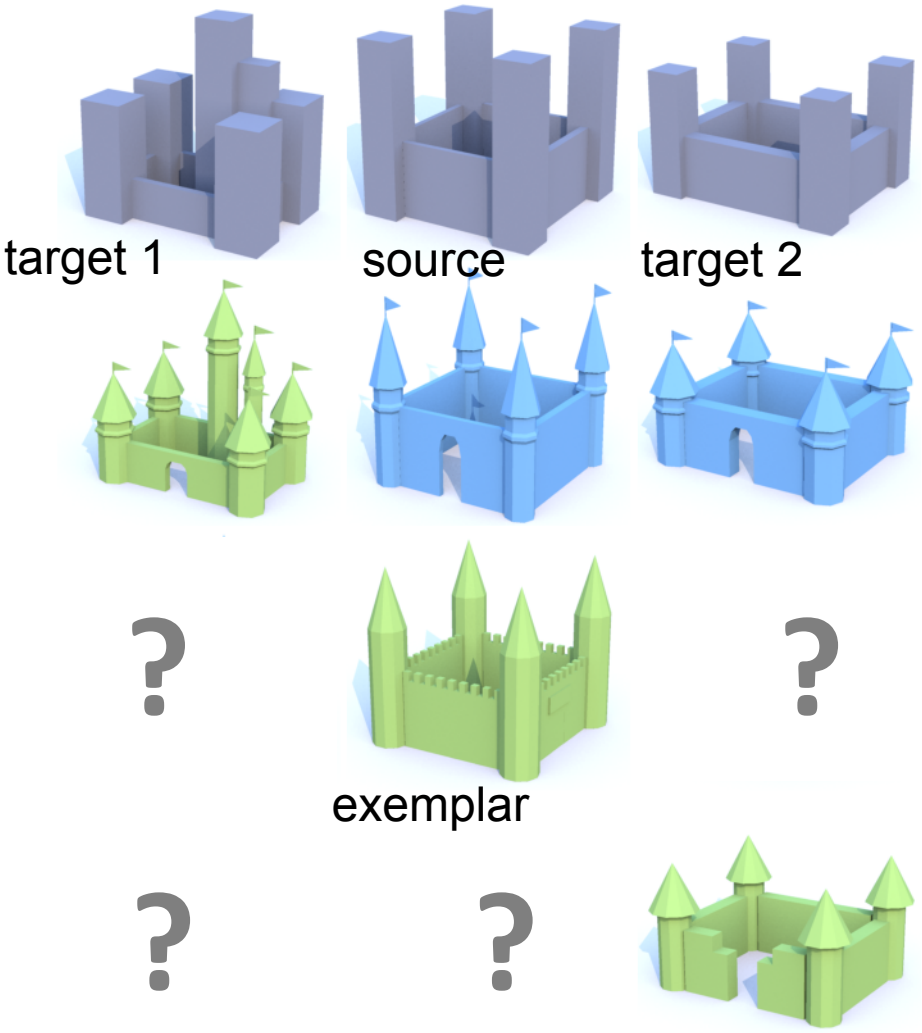
Results – 3D Style Exchange



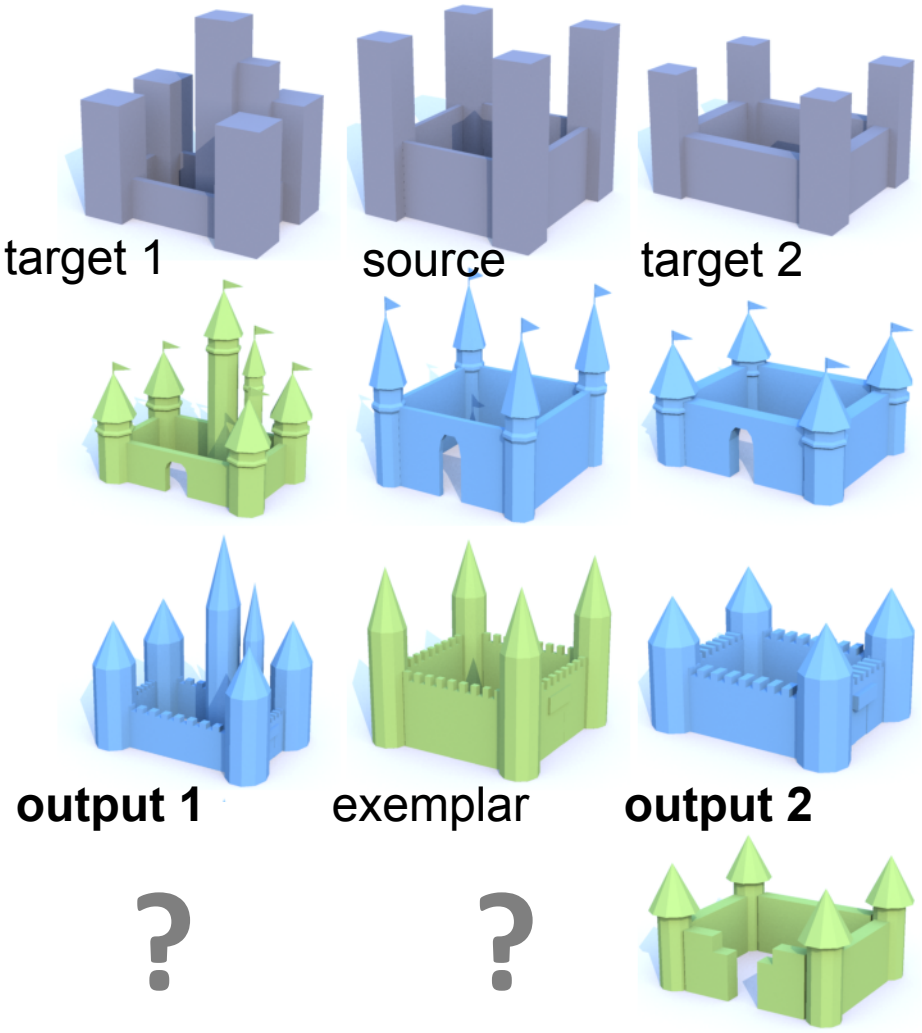
Results – 3D Style Exchange



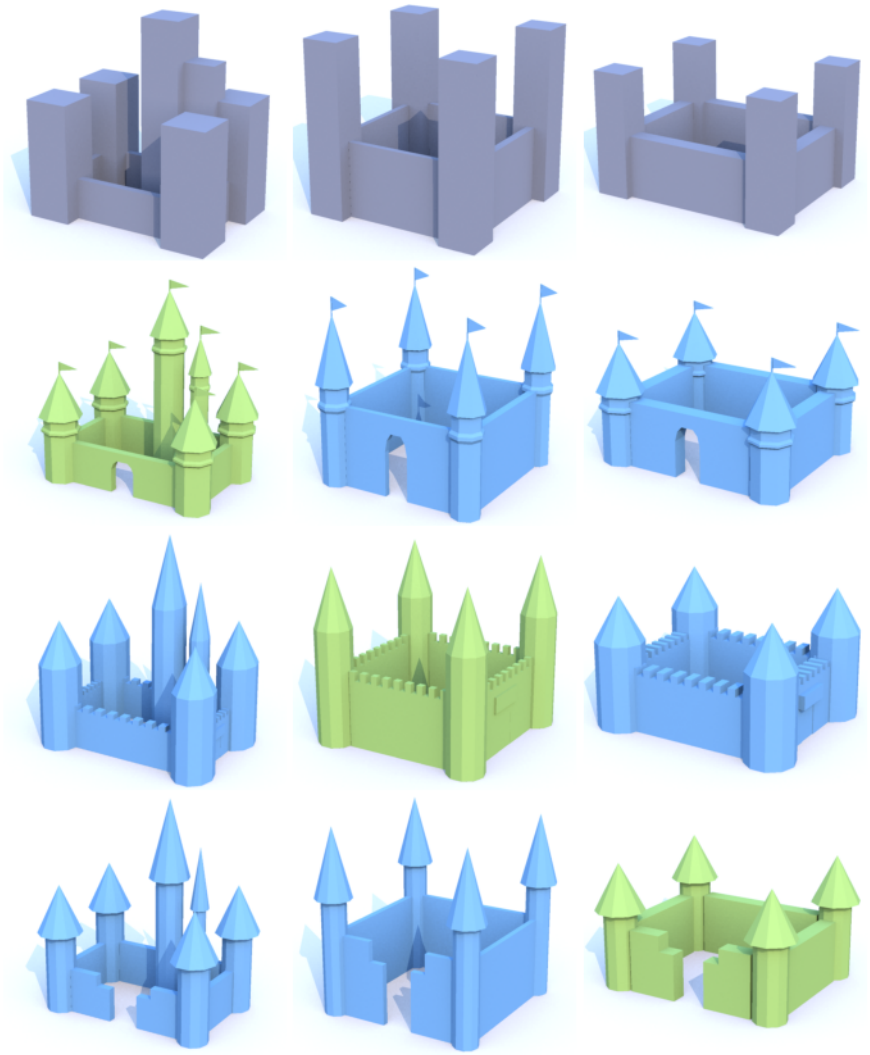
Results – 3D Style Exchange



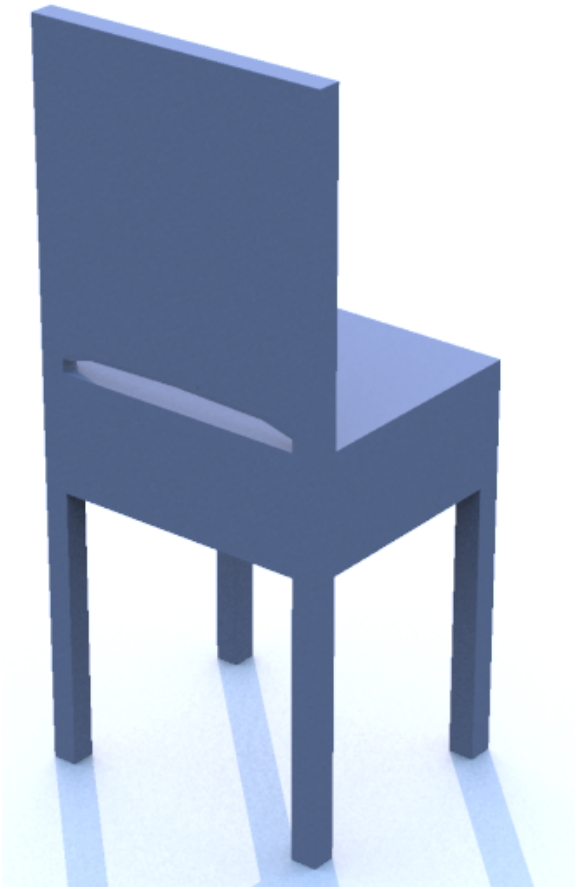
Results – 3D Style Exchange



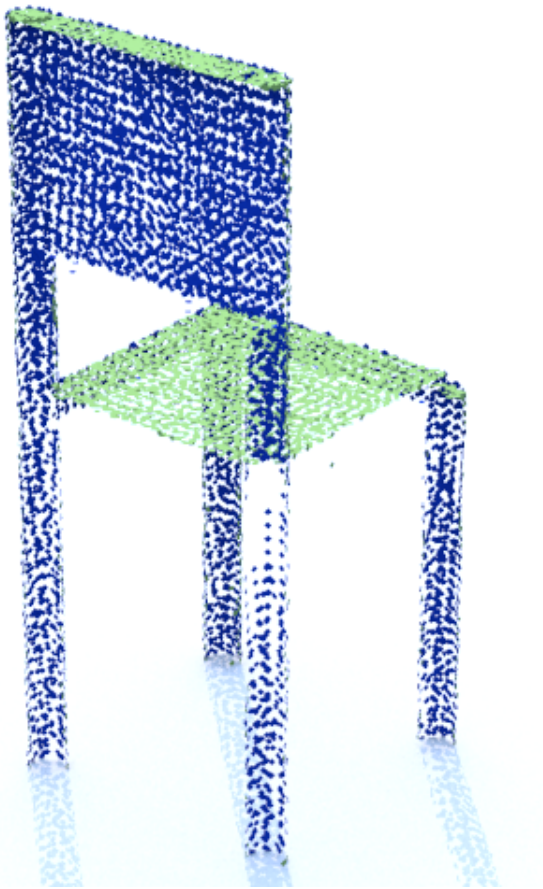
Results – 3D Style Exchange



Results – Scan Completion



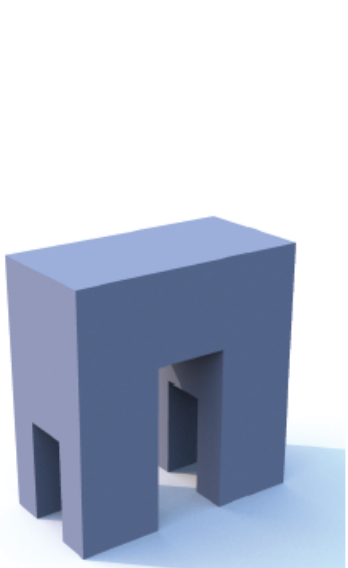
template



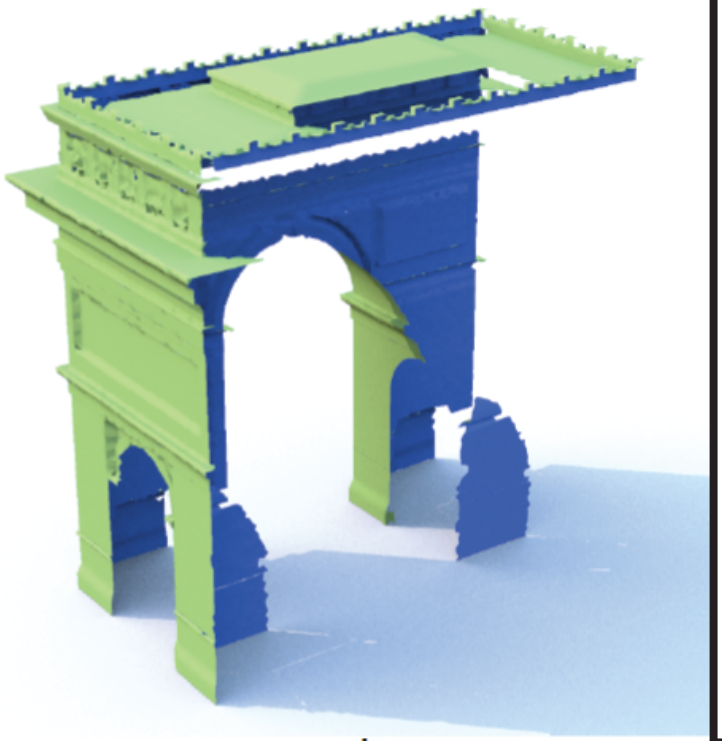
partial scan

output

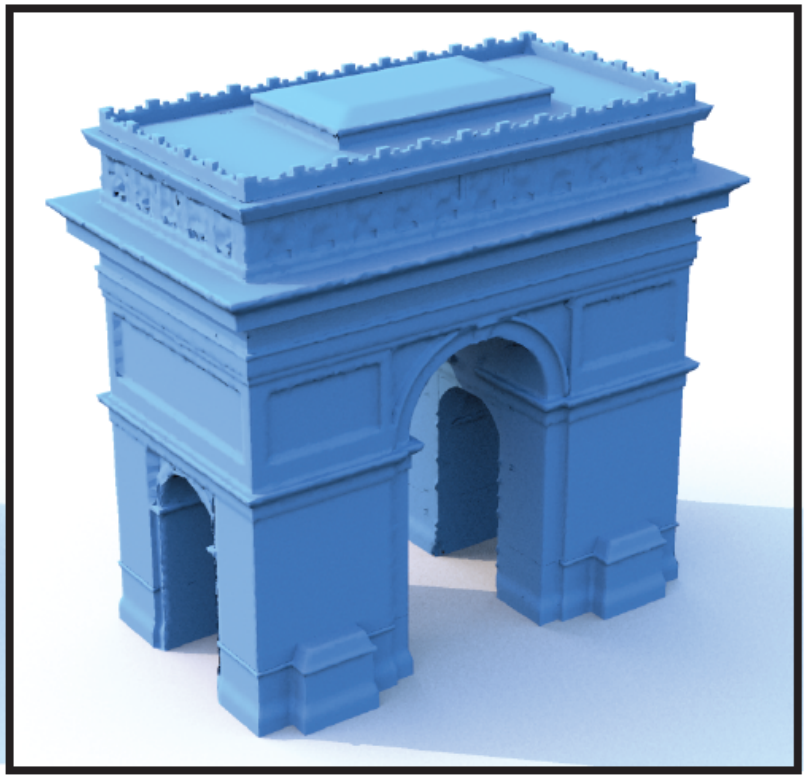
Results – Scan Completion



template



exemplar



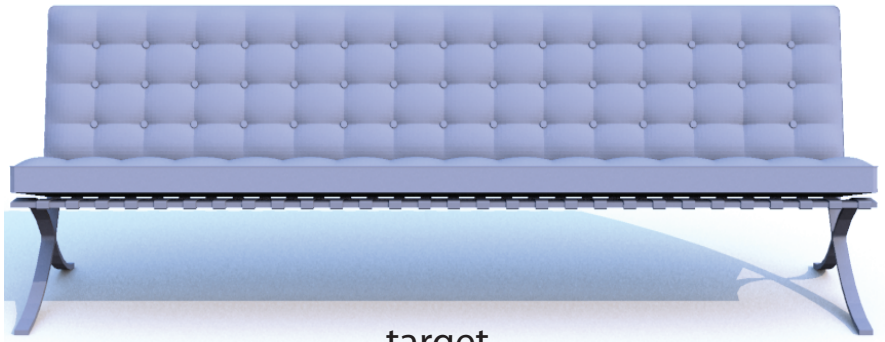
output

Comparison

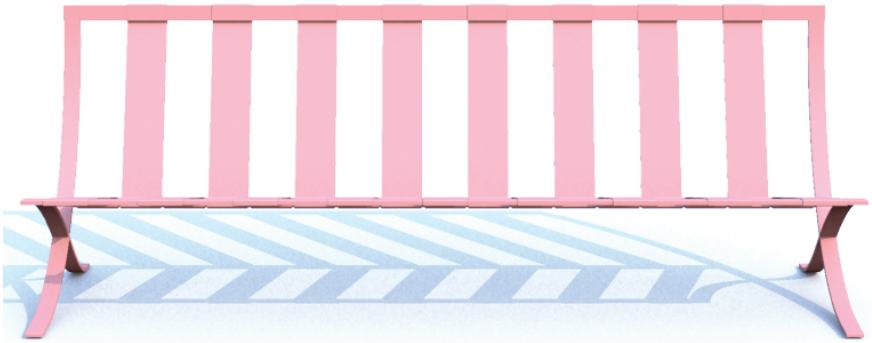
Style transfer based on anisotropic part scaling

source

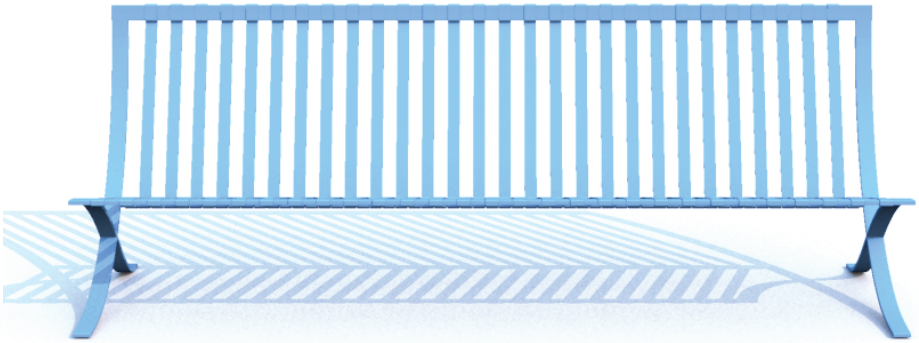
exemplar



target



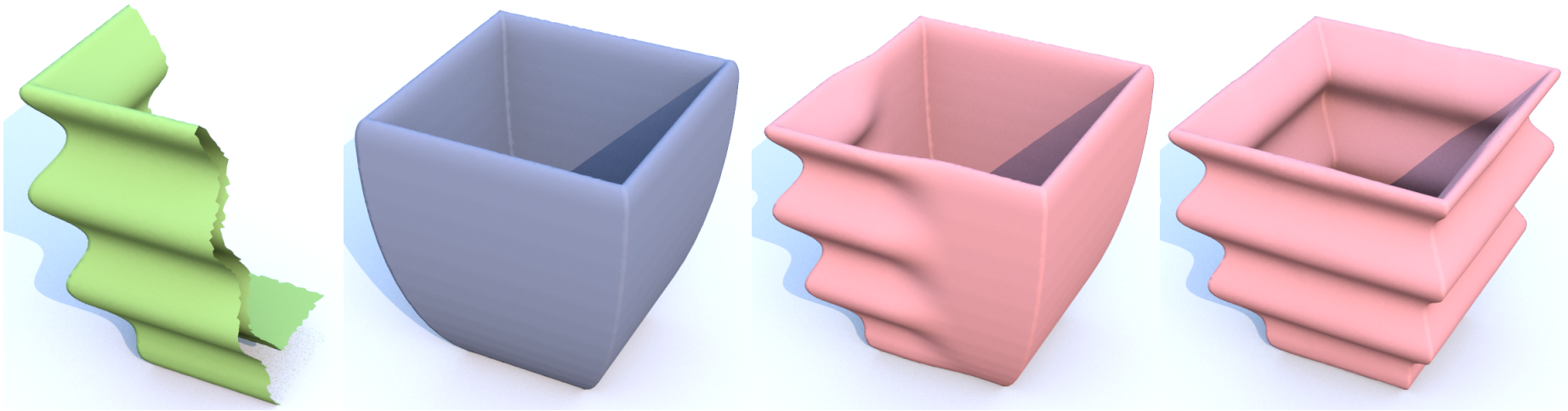
[XLZ* 2010]



our result

Comparison

Template based scan completion



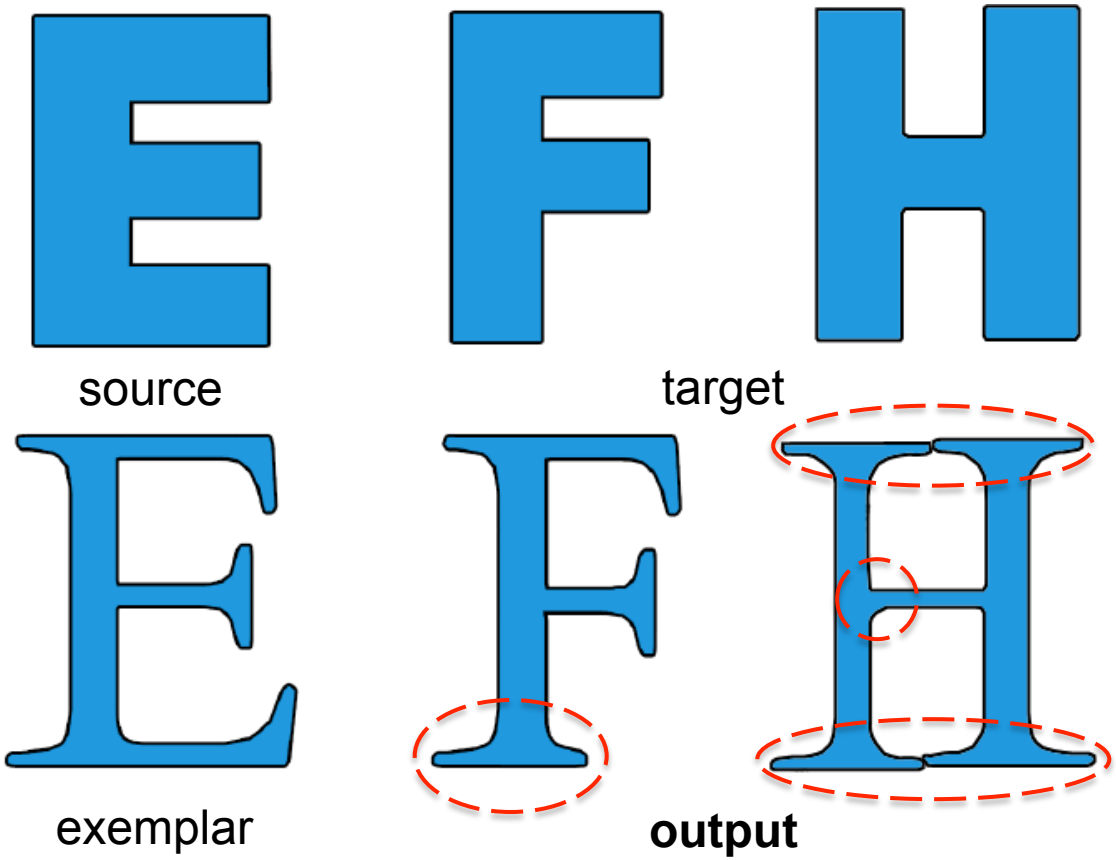
exemplar template [KS05] our result

Conclusion

- A analogy-driven shape synthesis framework
  - Automatically transfer diverse style characteristics between 3D shapes
- A multi-label optimization algorithm
  - Assemble simple, compact and continuous shape analogies

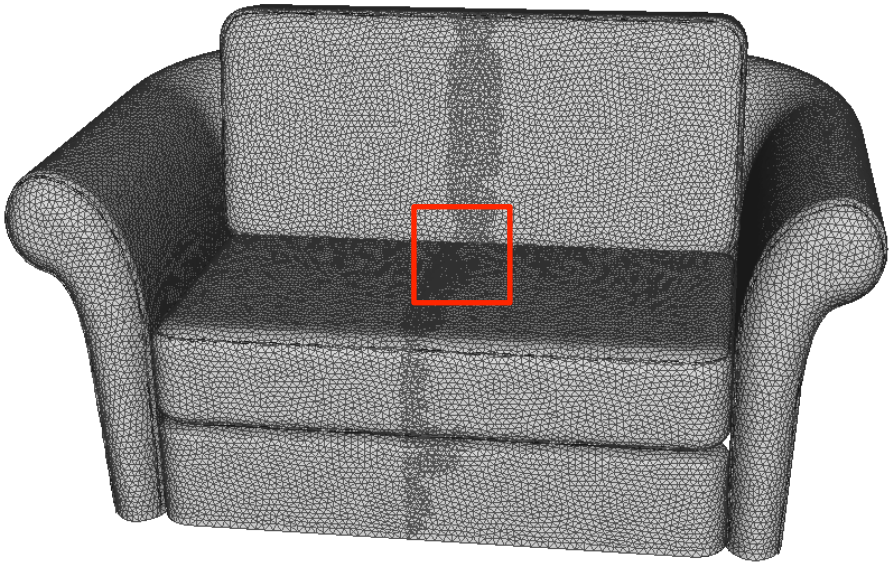
Limitations

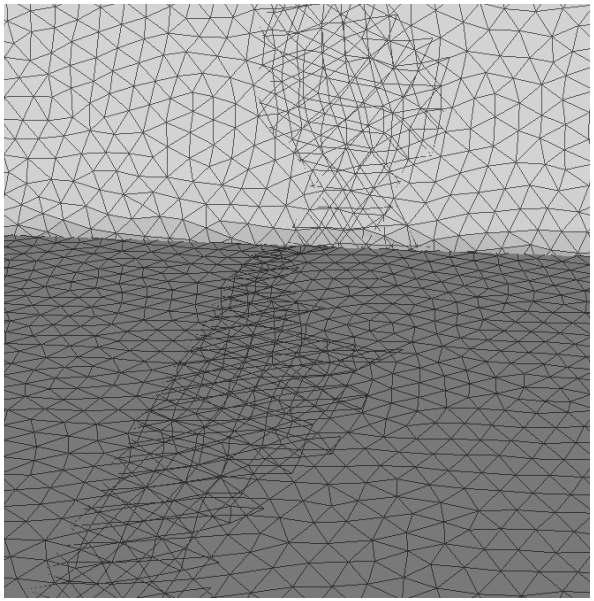
- Symmetry between source and target only
  - No constraints for self-symmetric target



Limitations

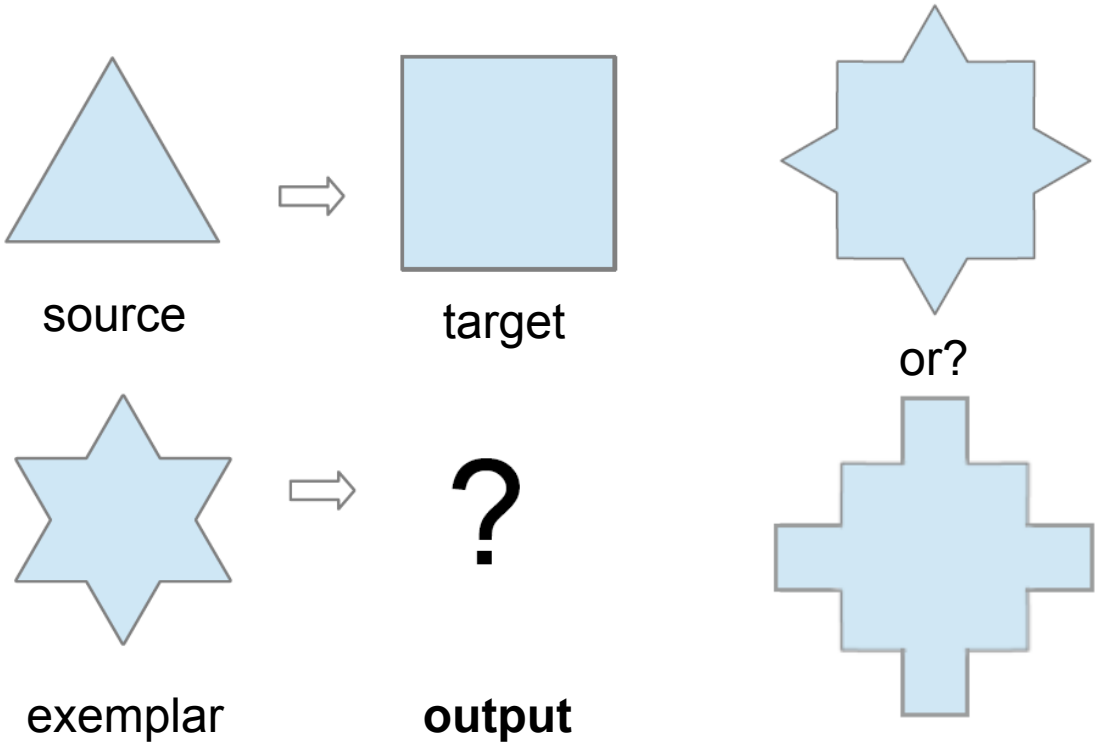
- Overlapping mesh patches
  - No stitching





Limitations

- One reasonable solution only
  - Ambiguity



Future work

- Free-form deformation
  - Organic shapes
- Automatic input alignment
  - Shape matching and analysis tools
- Infer a source shape
  - Given only the target and exemplar

Acknowledgements

- Niloy Mitra and Richard Zhang
  - Source code
- Daniel Cohen-Or
  - Comments on paper
- Liangliang Nan
  - Scanned vase data
- Mikhail Bessmeltsev and Andrew McGregor
  - Images and videos
- NSERC and GRAND NCE
  - Funding

Thank you!