



GENERATIONS / VANCOUVER  
12-16 AUGUST  
**SIGGRAPH2018**

# StrokeAggregator:

## Consolidating Raw Sketches into Artist-Intended Curve Drawings

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Alla Sheffer <sup>1</sup>

1



THE UNIVERSITY  
OF BRITISH COLUMBIA

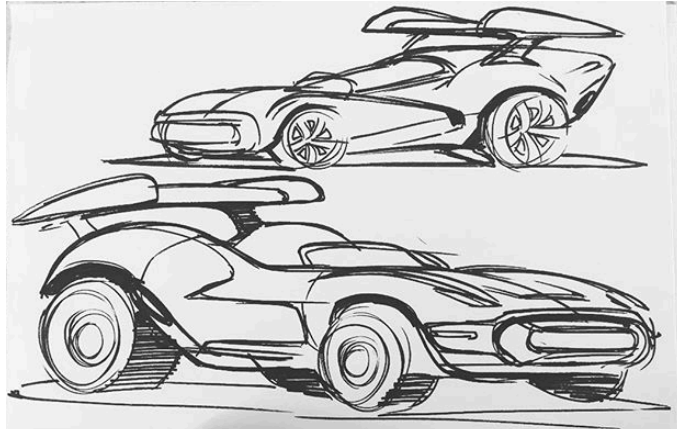
2



UNIVERSIDAD  
PANAMERICANA

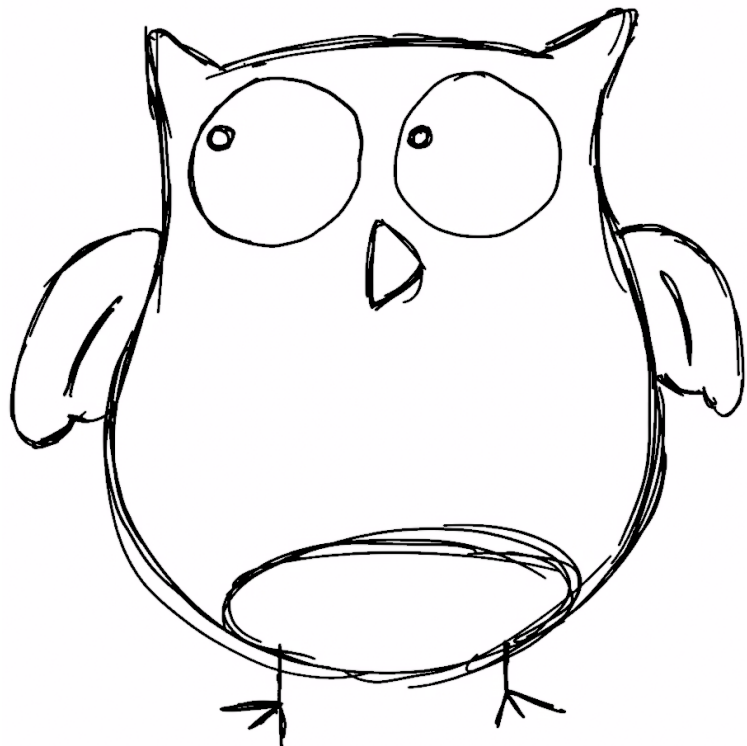
# Sketching is Ubiquitous

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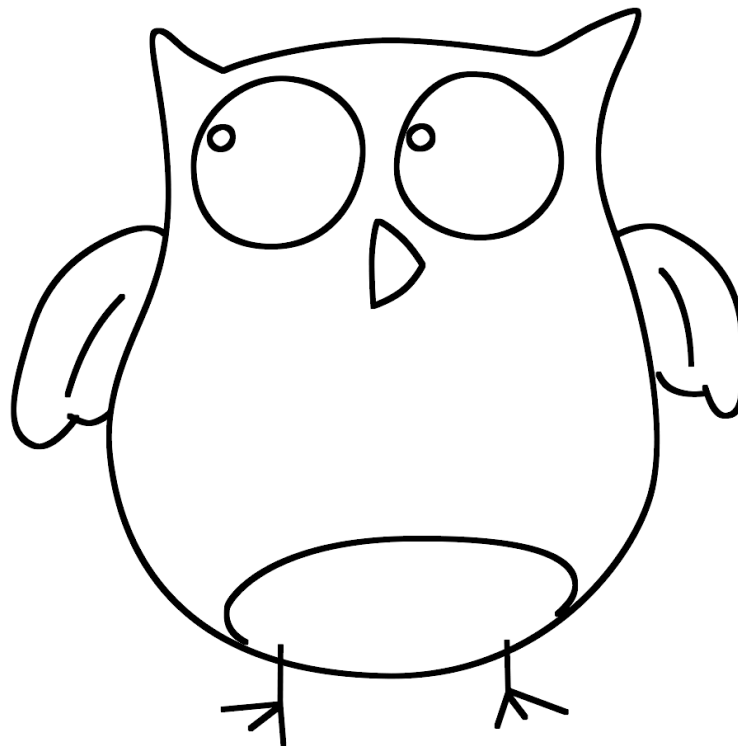
# Sketch Interpretation

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What artists

**draw**

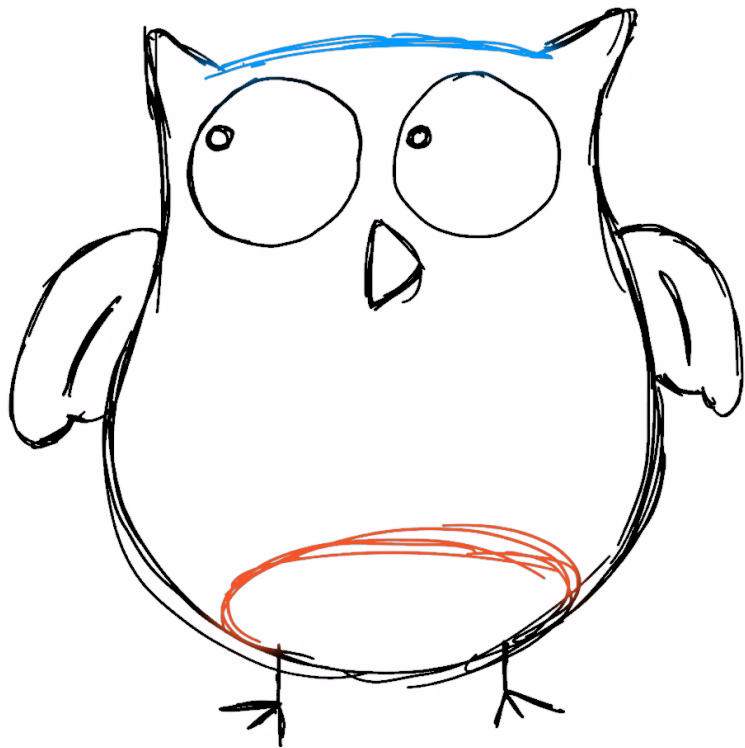


What viewers

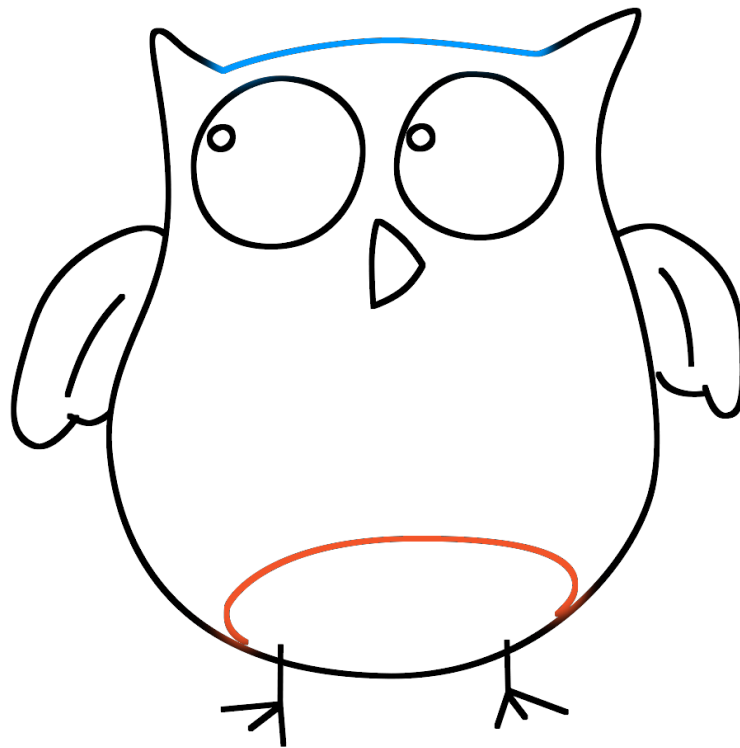
**see**

# Sketch Interpretation

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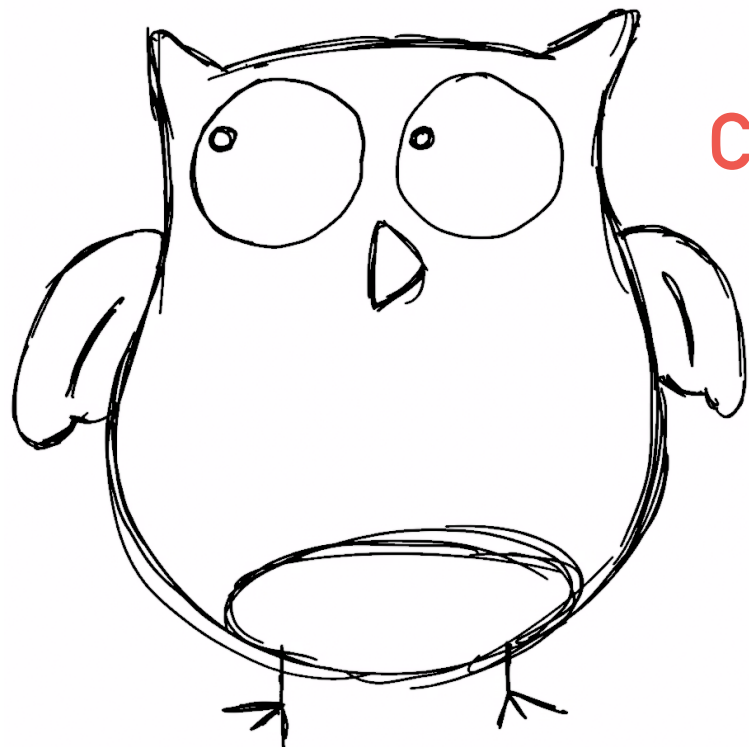


Multiple raw strokes



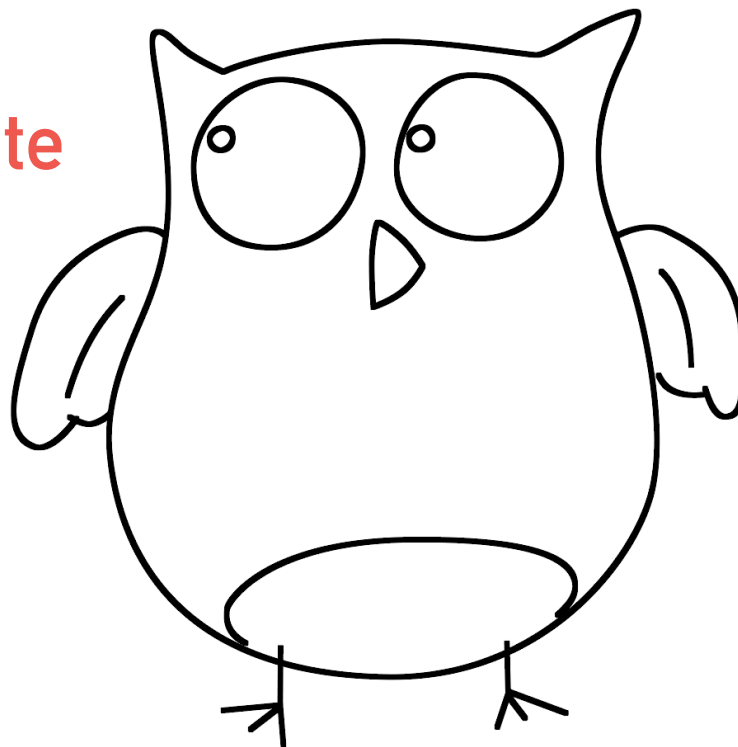
Individual aggregate curves



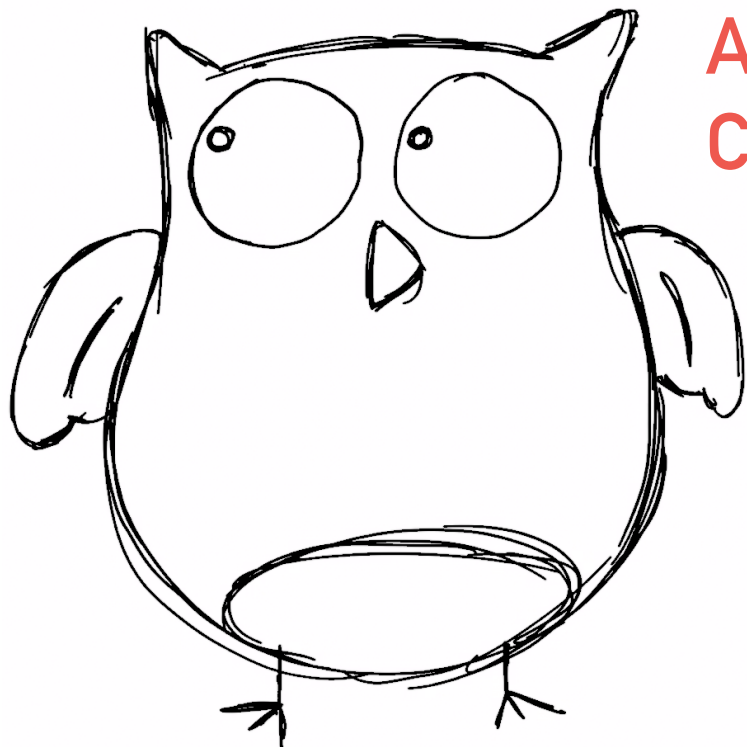


What artists  
**draw**

Consolidate

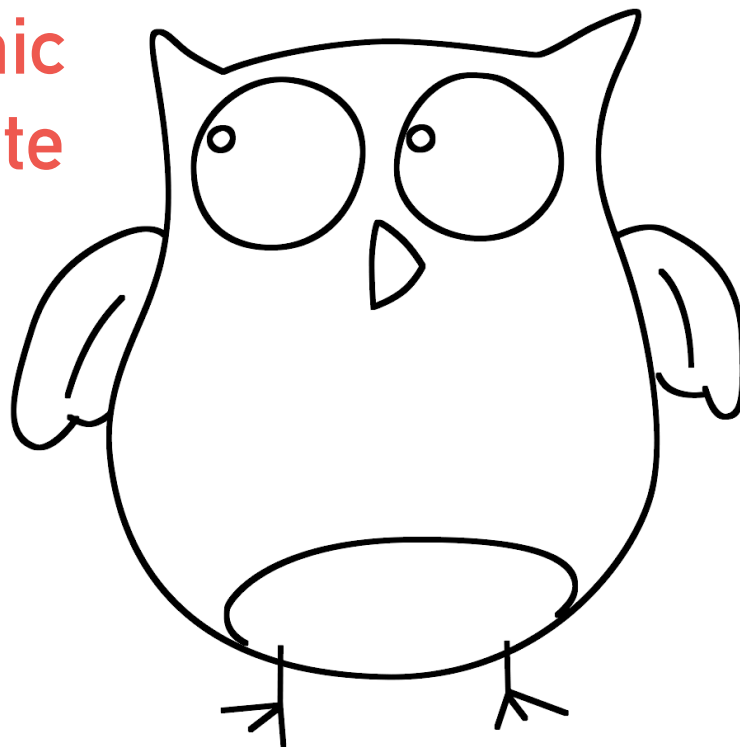


What viewers  
**see**



What artists  
**draw**

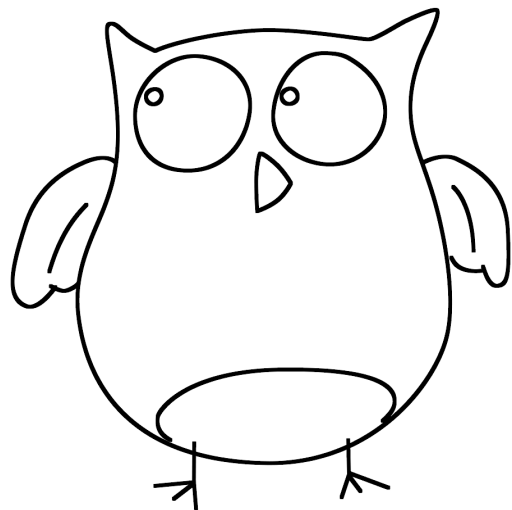
Algorithmic  
Consolidate



What viewers  
**see**

# Automatic Consolidation: Applications

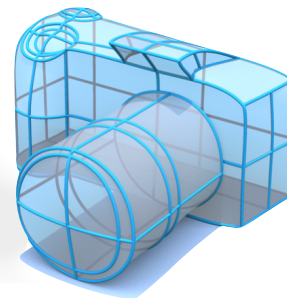
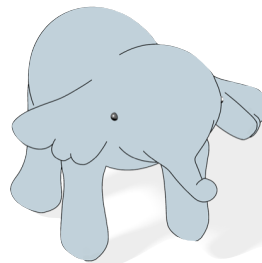
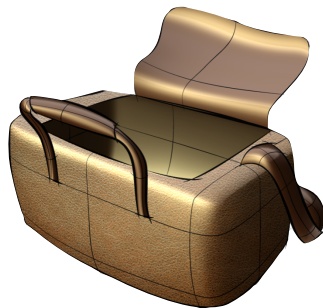
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Traditional usages  
(coloring, icon design etc.)



Sketch-based modeling/image  
manipulation



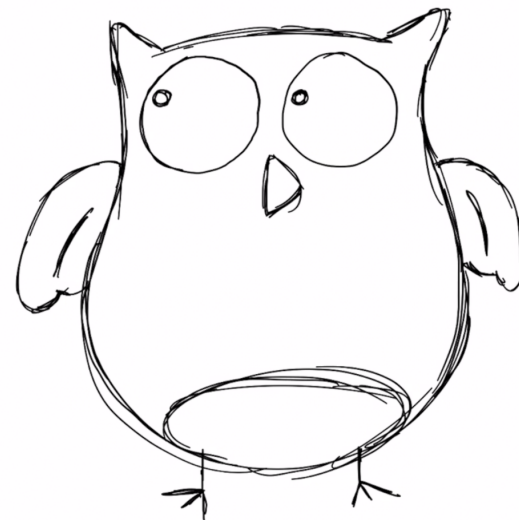
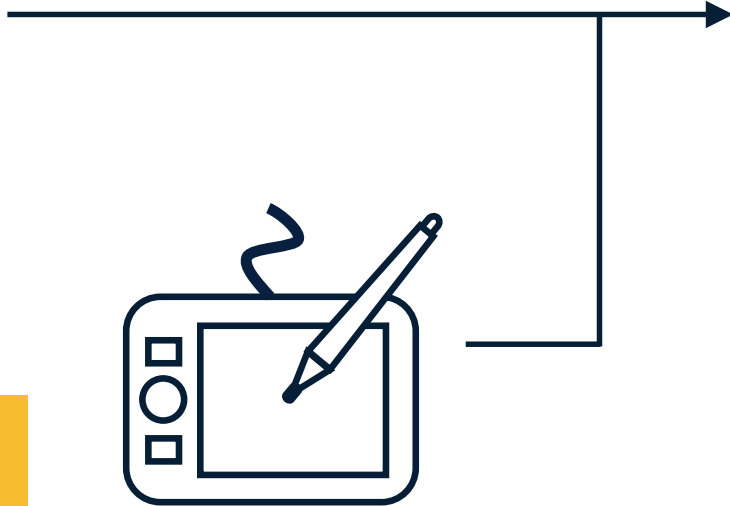
# Method Input

Raster input  
(traditional)

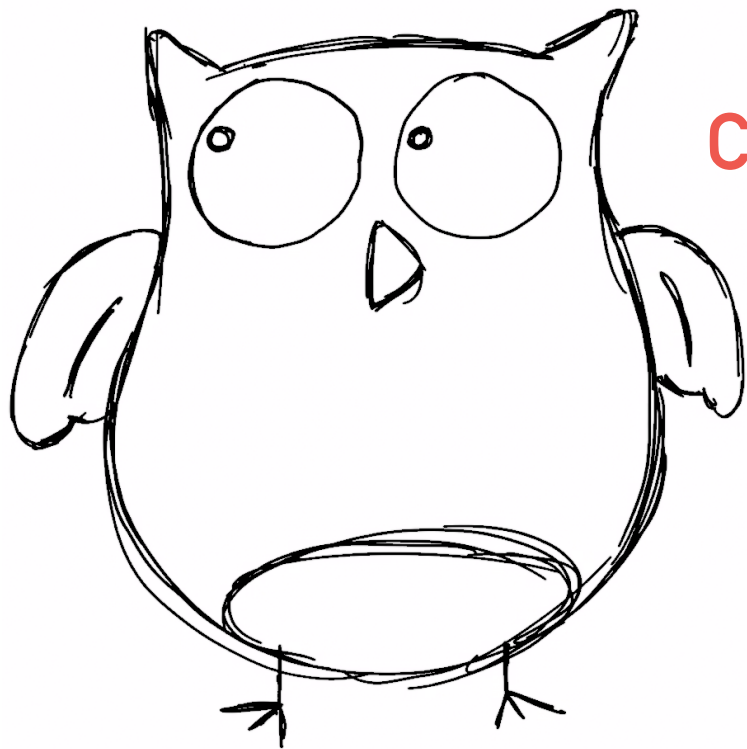
Vector input

Ubiquitous:  
tablet, etc.

More informative:  
stores tangents

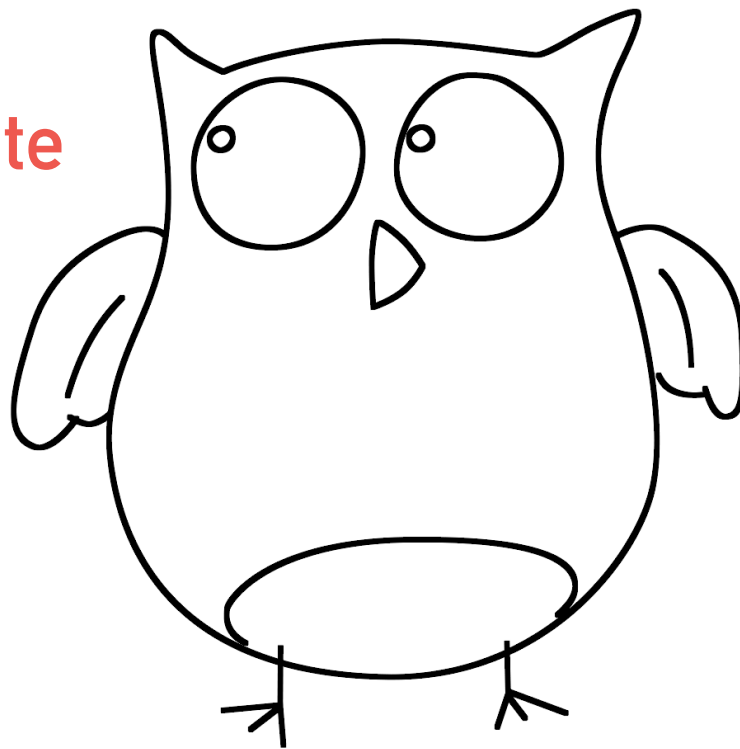


# Goal: Automatic Consolidation



Raw sketches:  
**Vector** format

Consolidate



Consolidated curves:  
**Vector** format

- **Vectorization**

Bao and Fu [2012]

Noris et al. [2013]

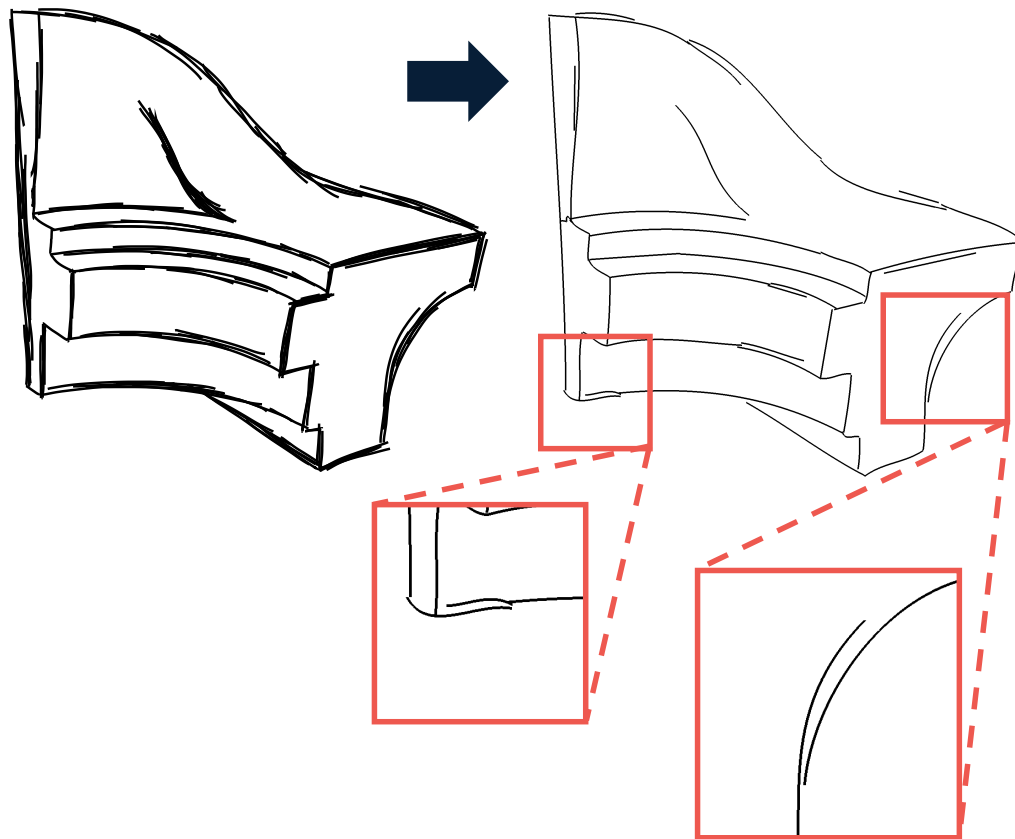
Bo et al. [2016]

Favreau et al. [2016]

Designed for “Clean” sketch or  
mild overdrawing

Fails on more challenging inputs

[Favreau et al. 2016]



- **Vectorization**

Bao and Fu [2012]  
Noris et al. [2013]  
Bo et al. [2016]  
Favreau et al. [2016]

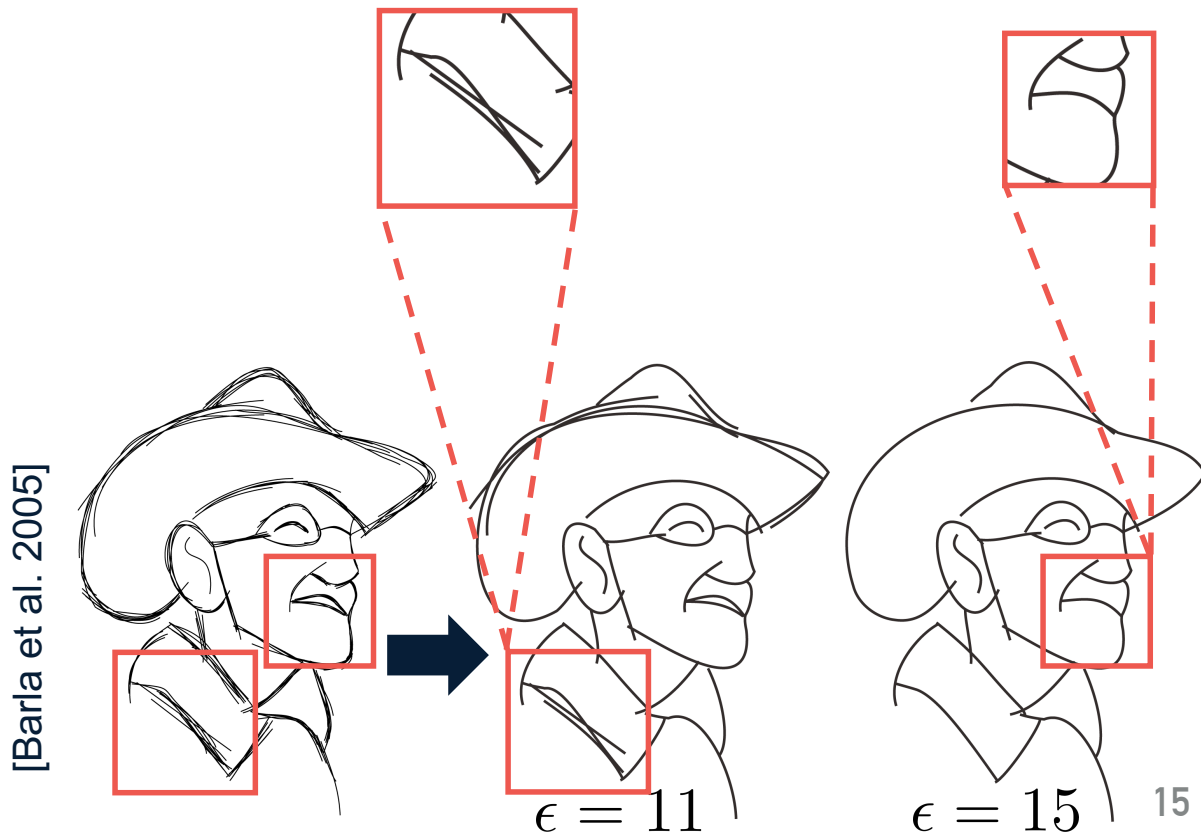
Designed for “Clean” sketch or  
mild overdrawing

Fails on more challenging inputs

- **Simplification**

Barla et al. [2005]  
Shesh and Chen [2008]  
Bao and Fu [2012]

Fails when density changes

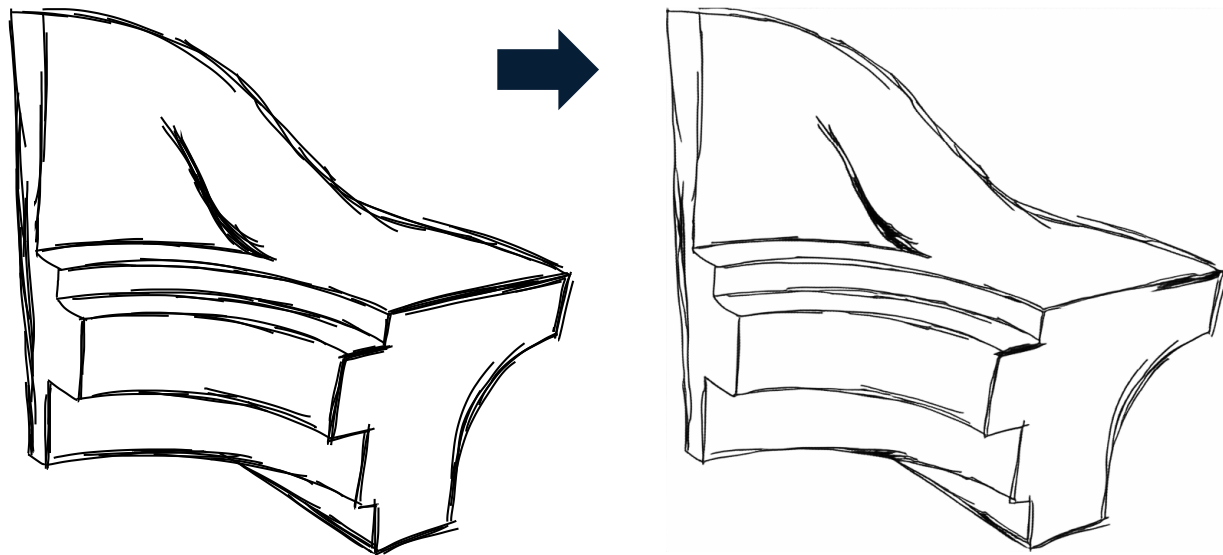




- **Raster -> Raster**

DL-Based: Simo-Serra et al. [2016, 2017]

Data dependent  
(sensitive to scale)

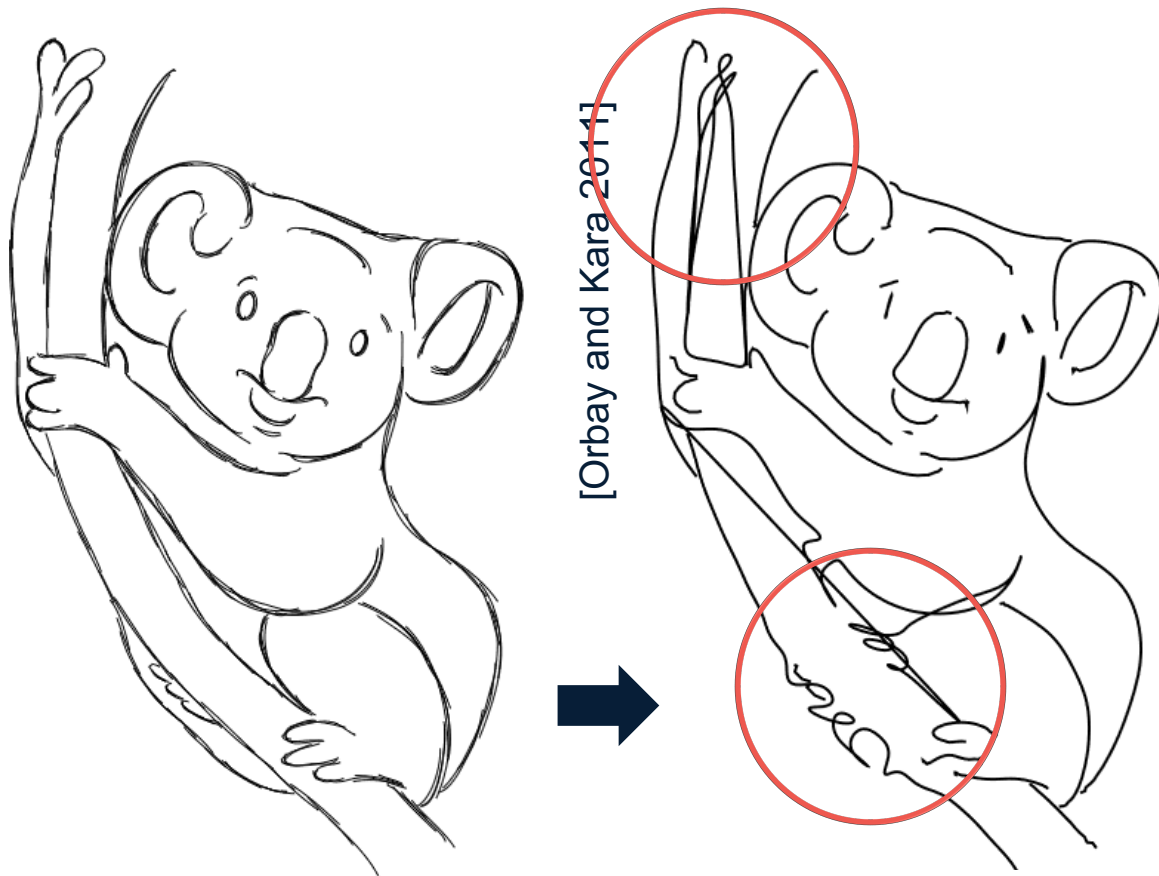


# Related Work: Consolidation

- **Vector -> Vector**

Orbay and Kara [2011]

Dependent on  
training example



# Related Work: Consolidation

- **Vector -> Vector**

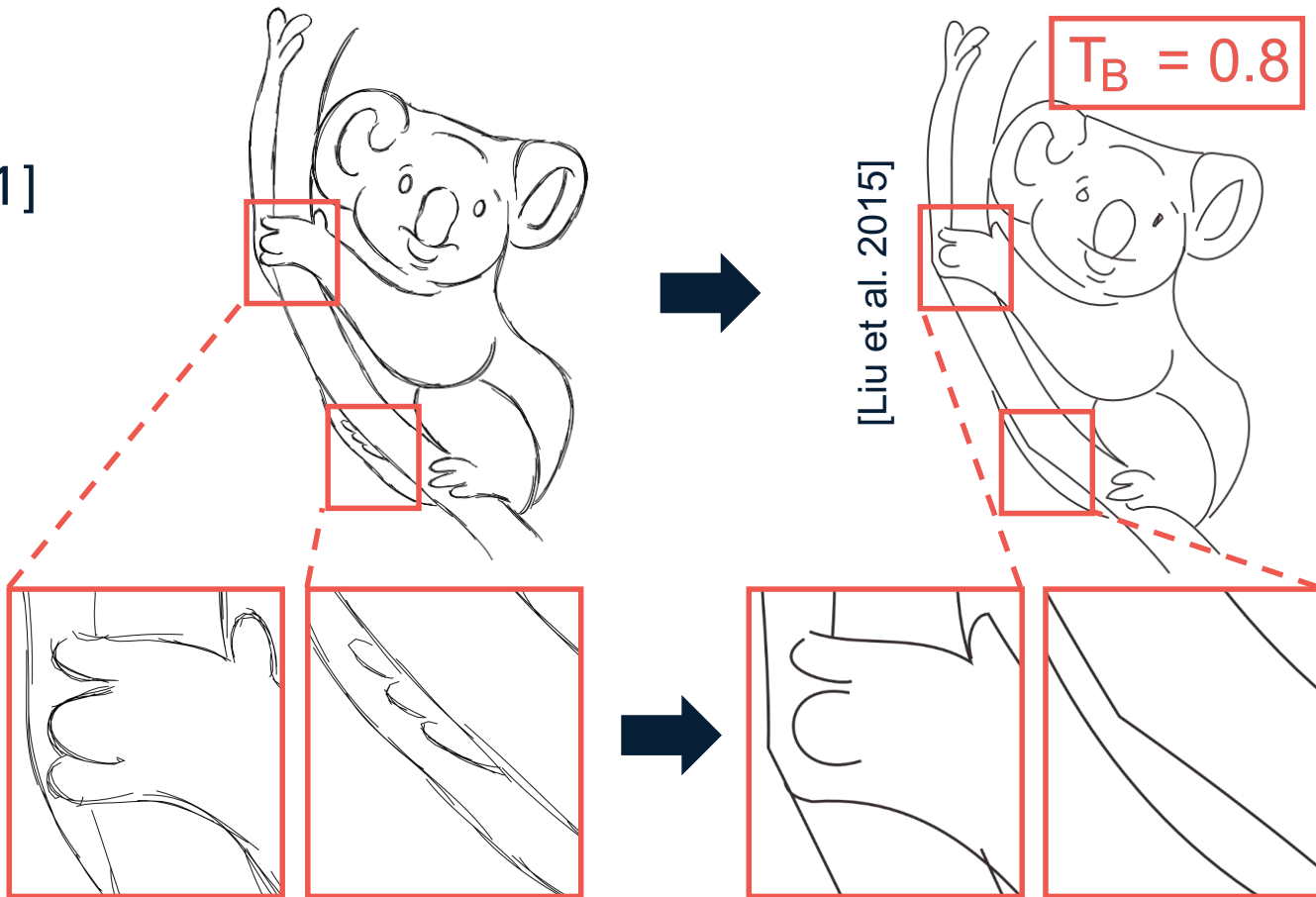
Orbay and Kara [2011]

Dependent on  
training example

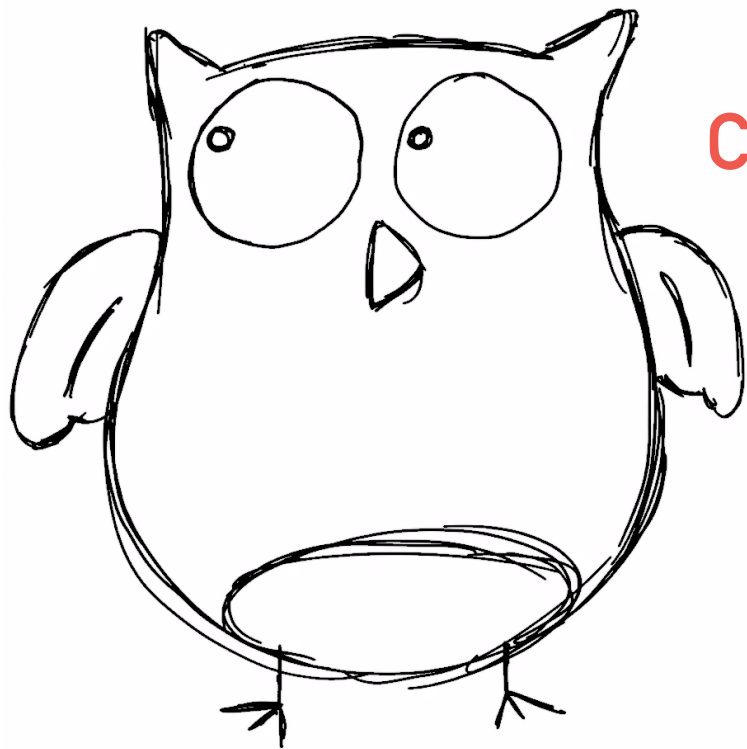
Liu et al. [2015]

Parameter dependent

Fails on fine features

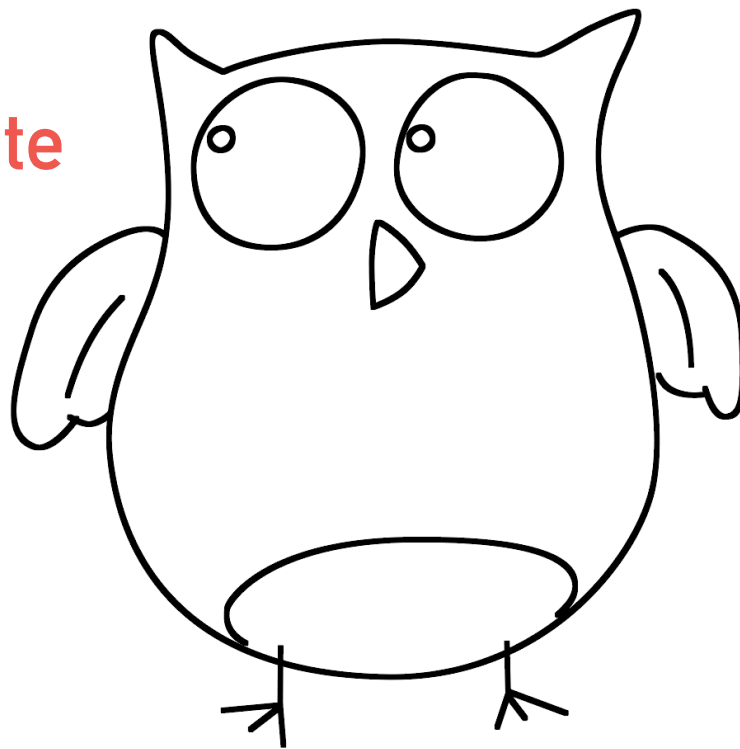


# Goal: Algorithmic Consolidation



Raw sketches:  
**Vector** format

Consolidate



Consolidated curves:  
**Vector** format

# Problem breakdown



Cluster strokes



Fit aggregate curves



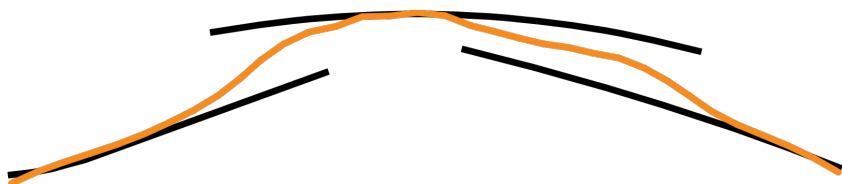


Fit aggregate curves

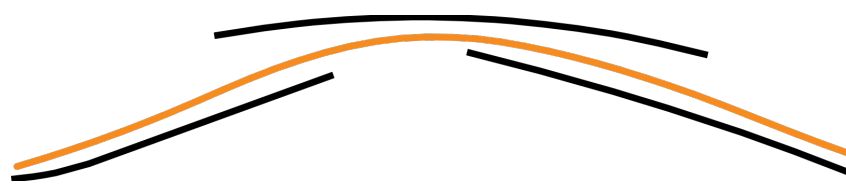


Previous:

Ours:

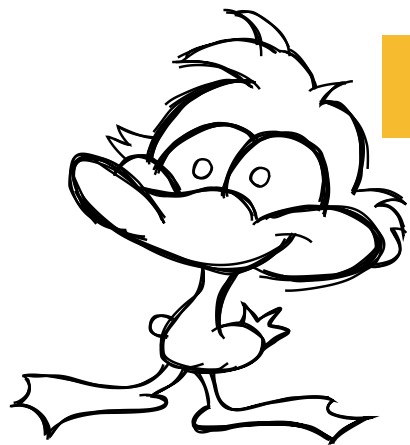


Position-based



Tangent-based

# Problem breakdown



Cluster strokes



Fit aggregate curves



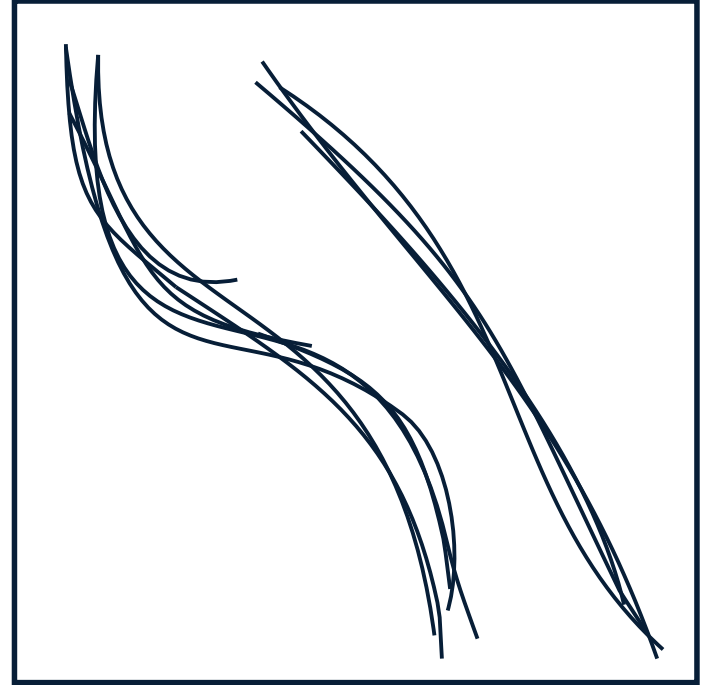
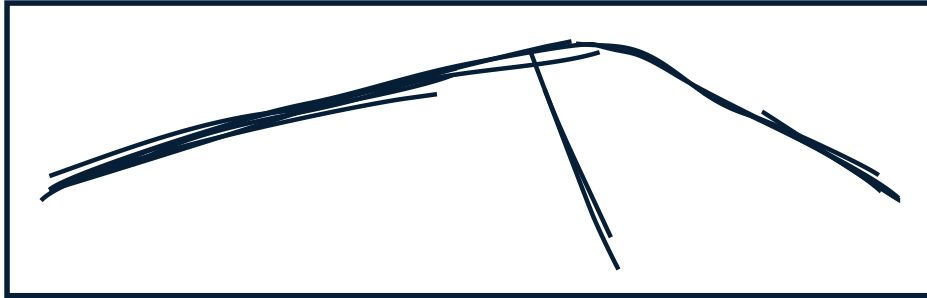
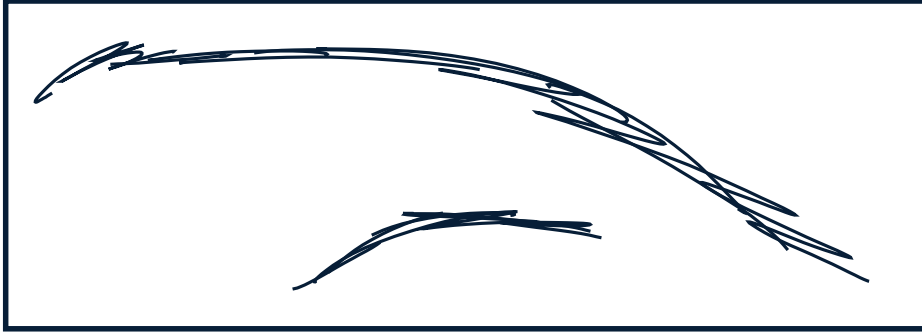
How?



# Clustering Goal

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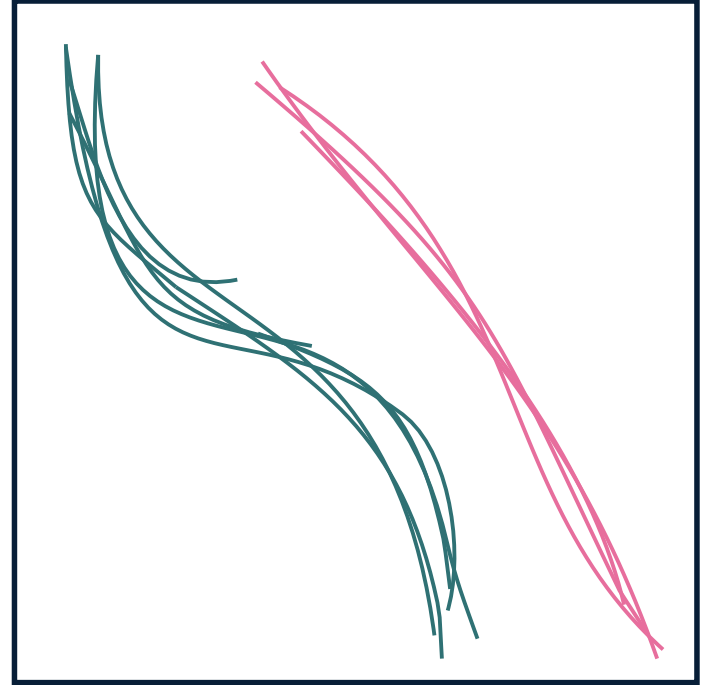
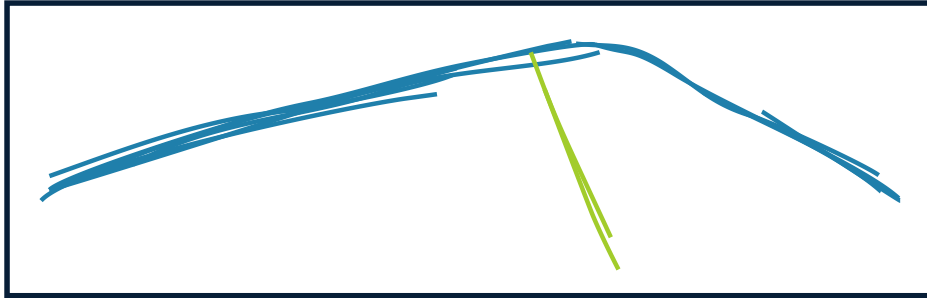
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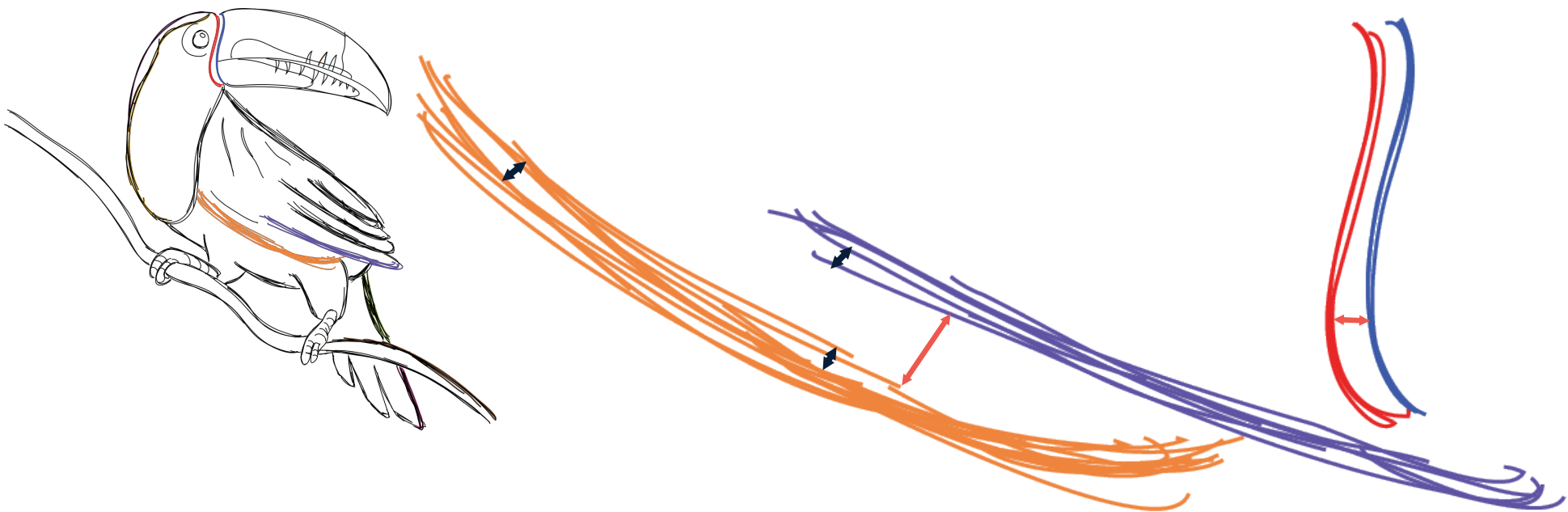
# Clustering Goal

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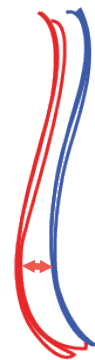
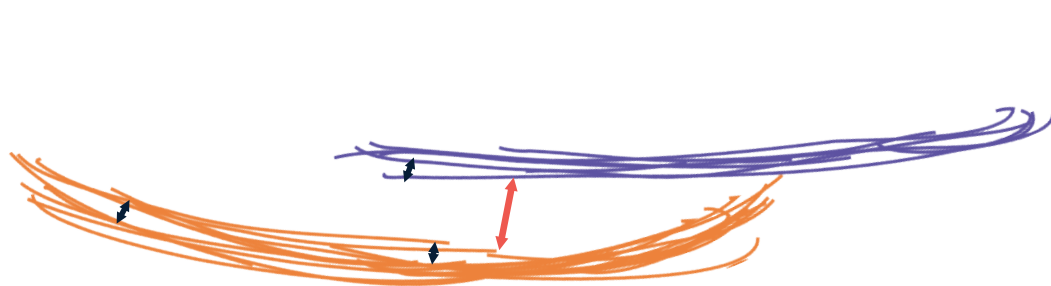
# Clustering: Relative Proximity



1) Roughly even inside density/inner-cluster distance

2) **Inner-cluster distance**  $\ll$  **Inter-cluster distance**

# Clustering: Relative Proximity



Left:

Right:

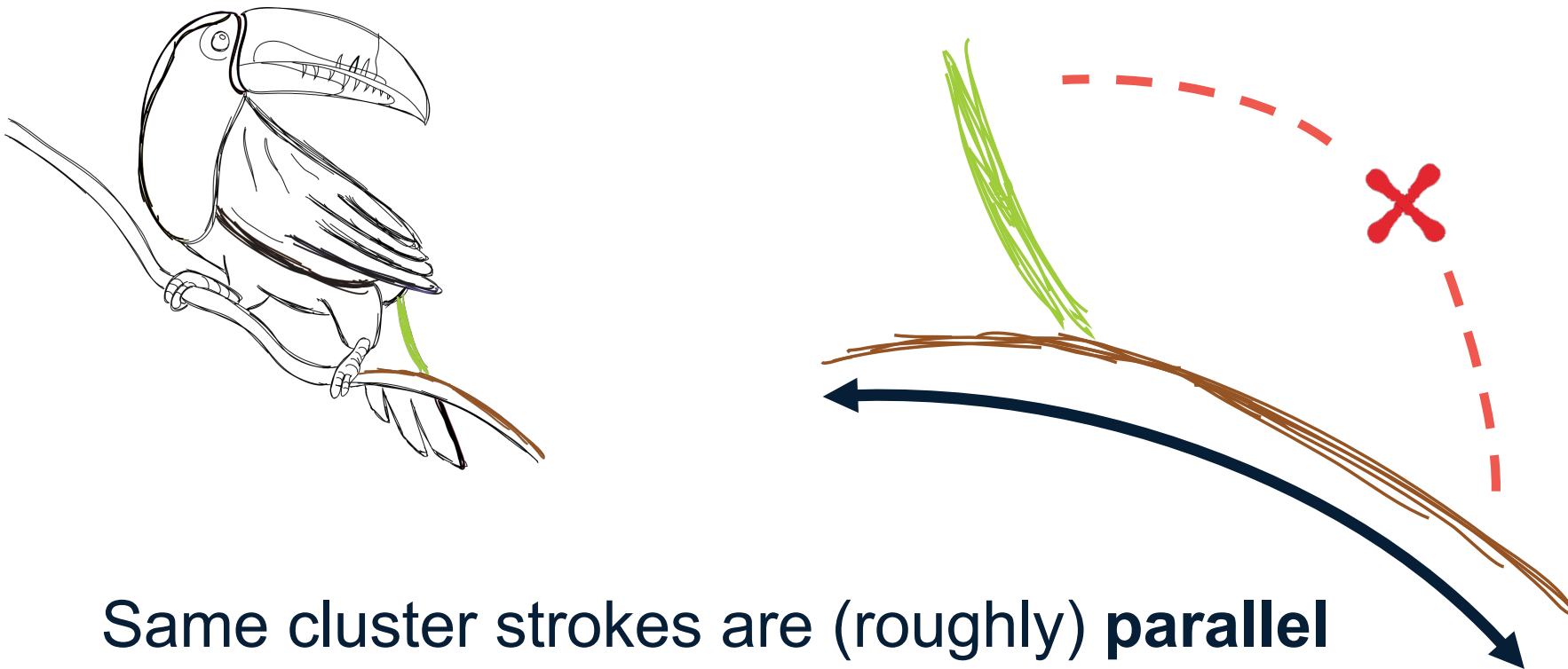
Absolute Distance



Relative Proximity

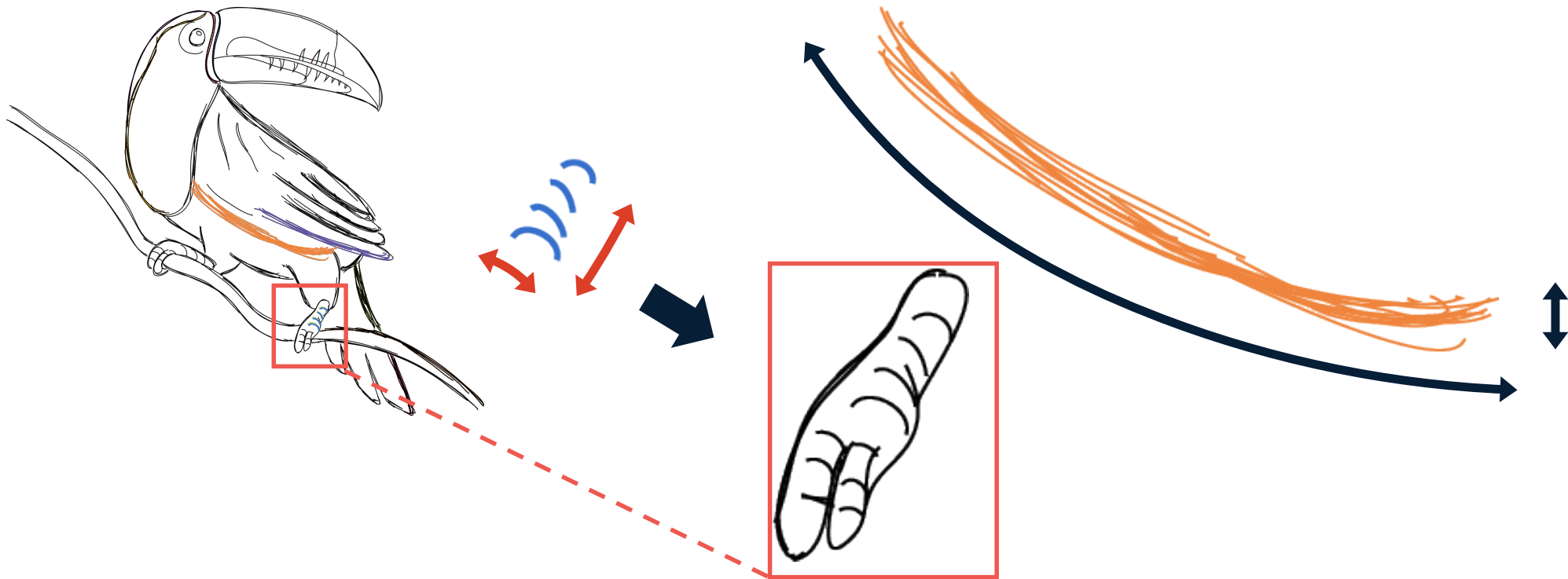


# Clustering: Angular Compatibility



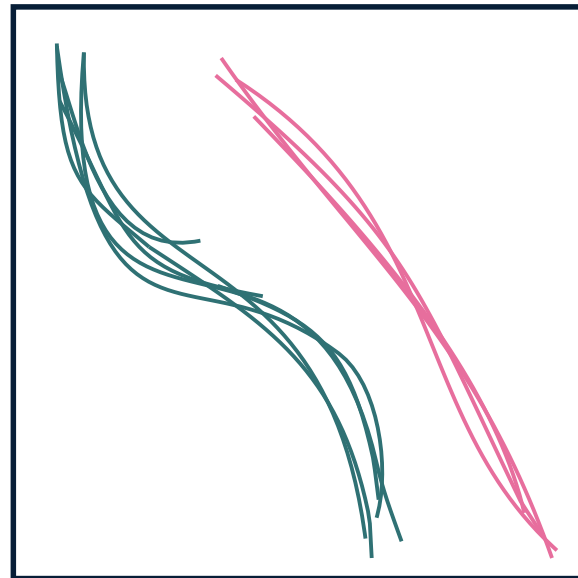
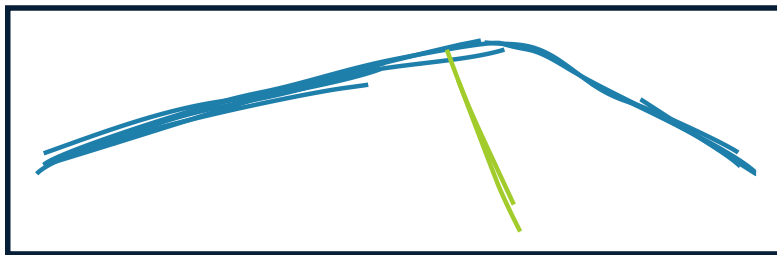
Same cluster strokes are (roughly) **parallel**  
along side-by-side sections

# Clustering: Narrowness



Stroke clusters are **narrow**

# Stroke Clusters

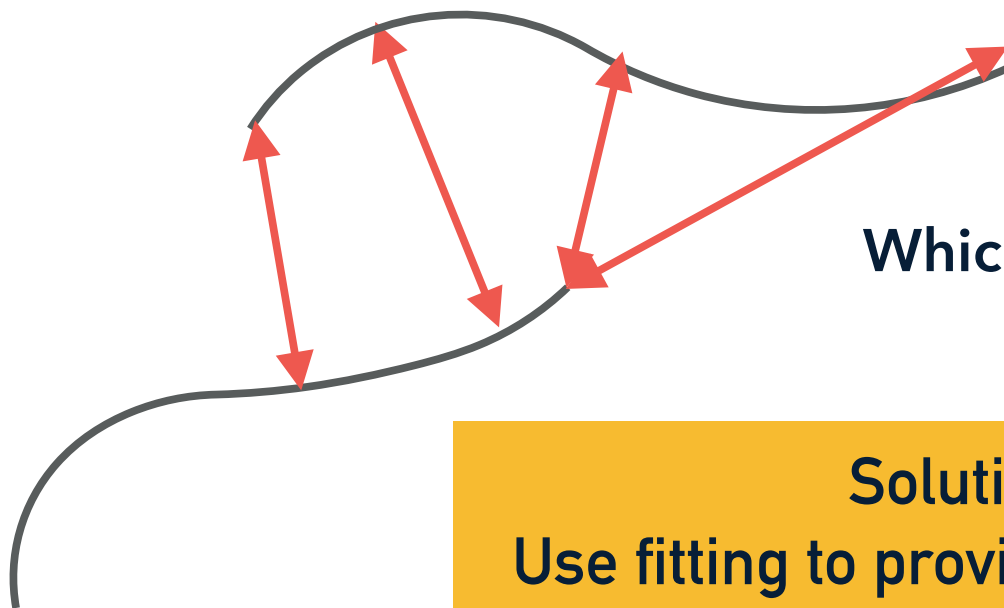


Distinct narrow clusters of roughly evenly spaced strokes



# Challenge I

Distance/angle vary along strokes



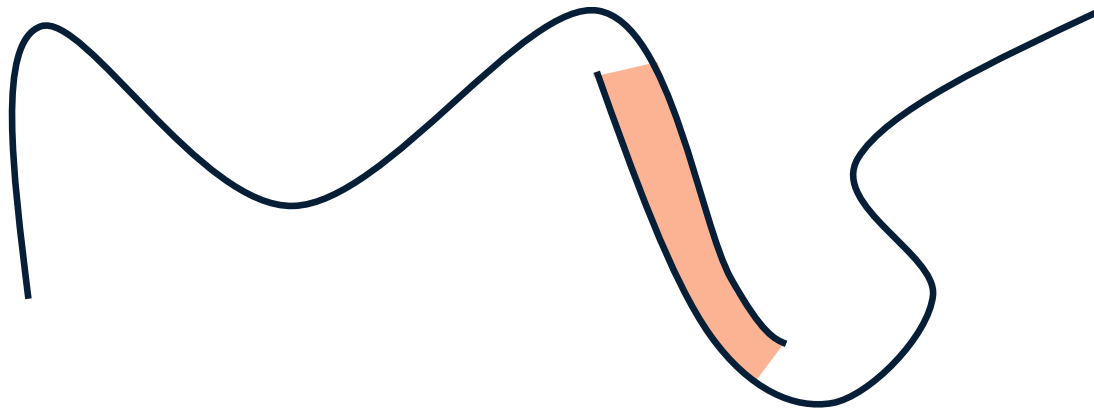
Which pair?

**Solution:**  
Use fitting to provide common 1D  
parameterization

# Coarse Clustering: Pairwise Similarity

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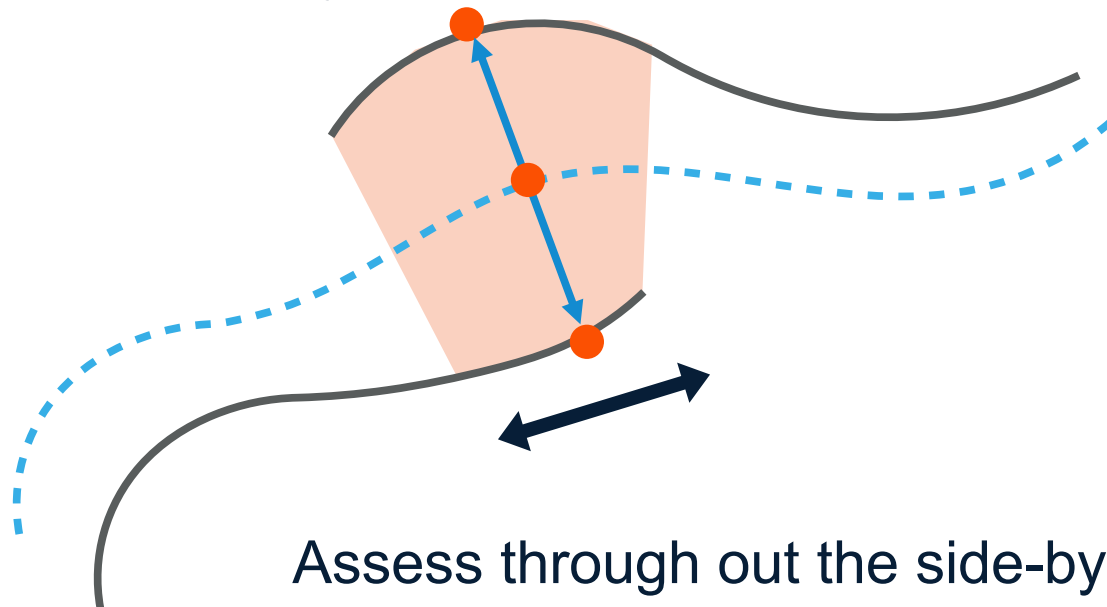


Region of Interest

# Coarse Clustering: Pairwise Similarity

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Pointwise Similarity



Assess through out the side-by-side  
region

# Challenge II

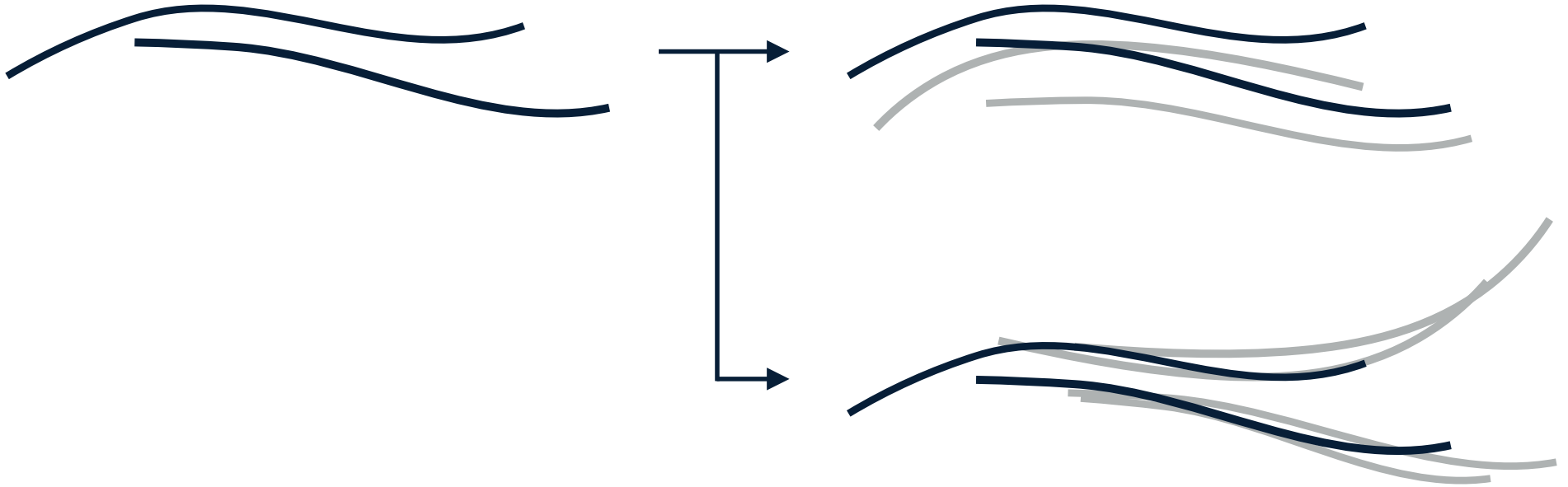
---

Assessment requires context



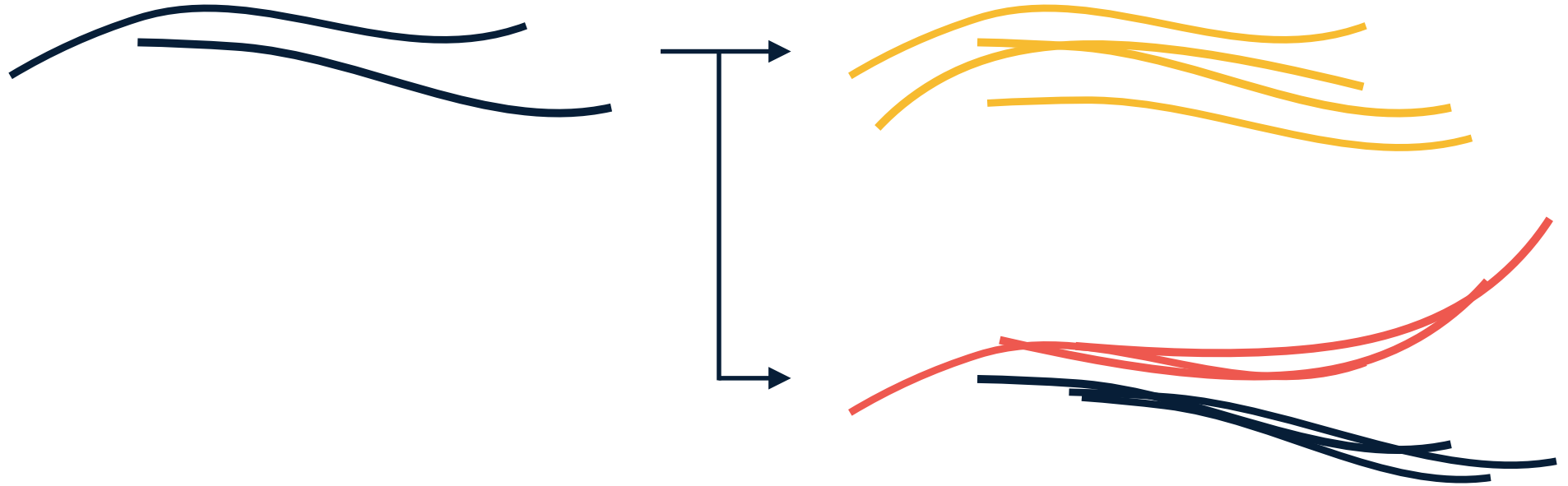
# Challenge II

Assessment requires context



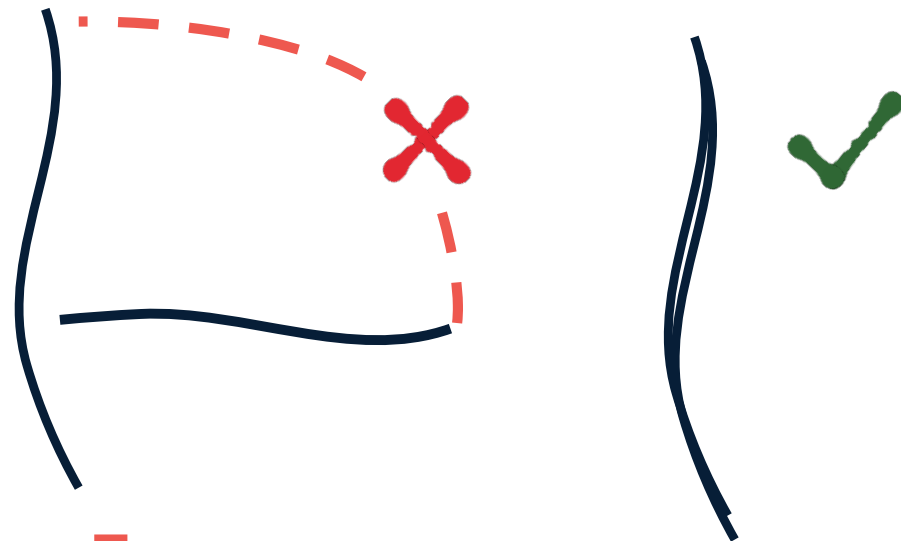
# Challenge II

Assessment requires context





V.S.



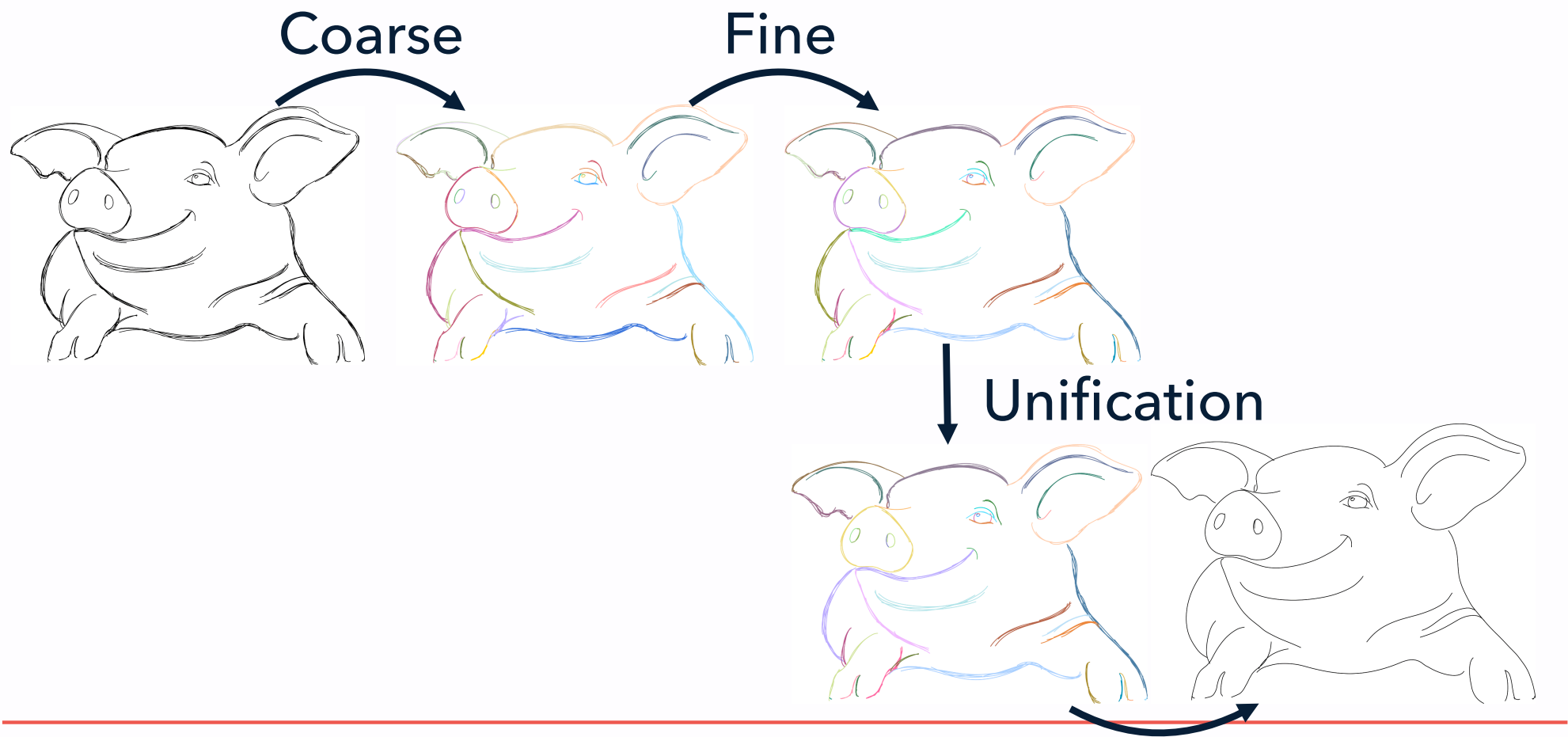
## Hard (needs context):

- Close-by strokes
- Similar tangents

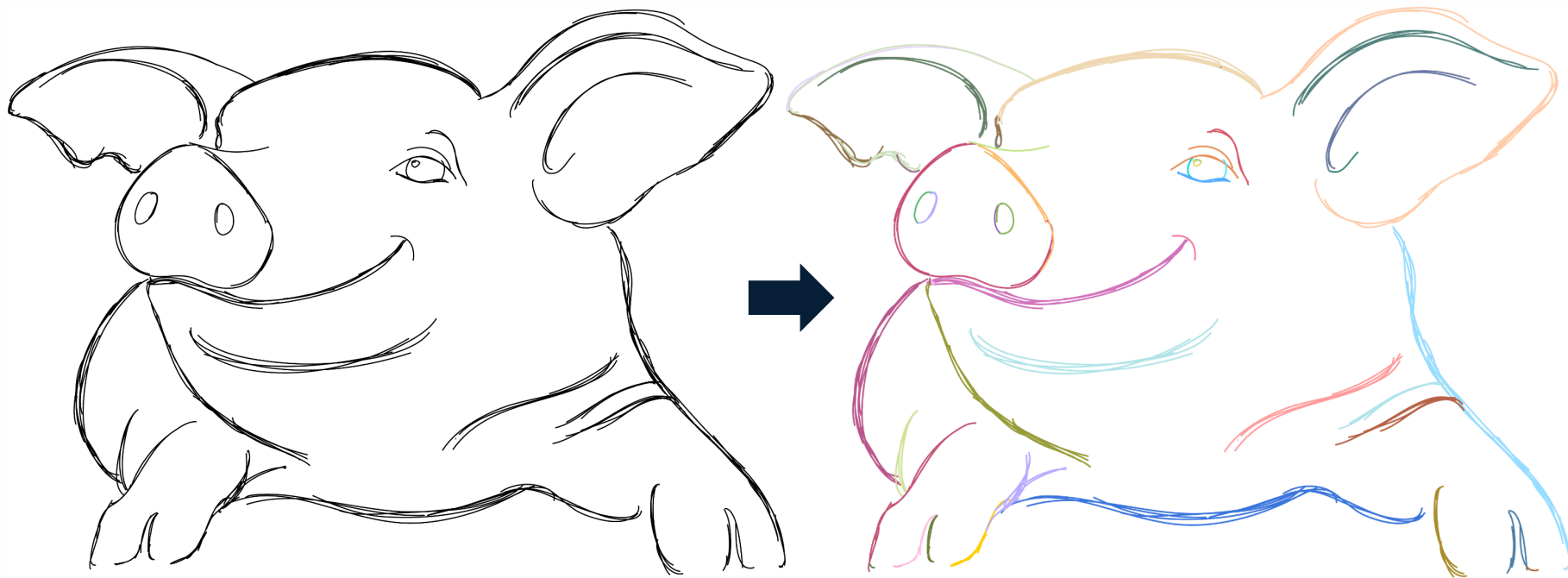
## Easy:

- Nearby strokes with large angular difference
- (Almost) overlapping strokes



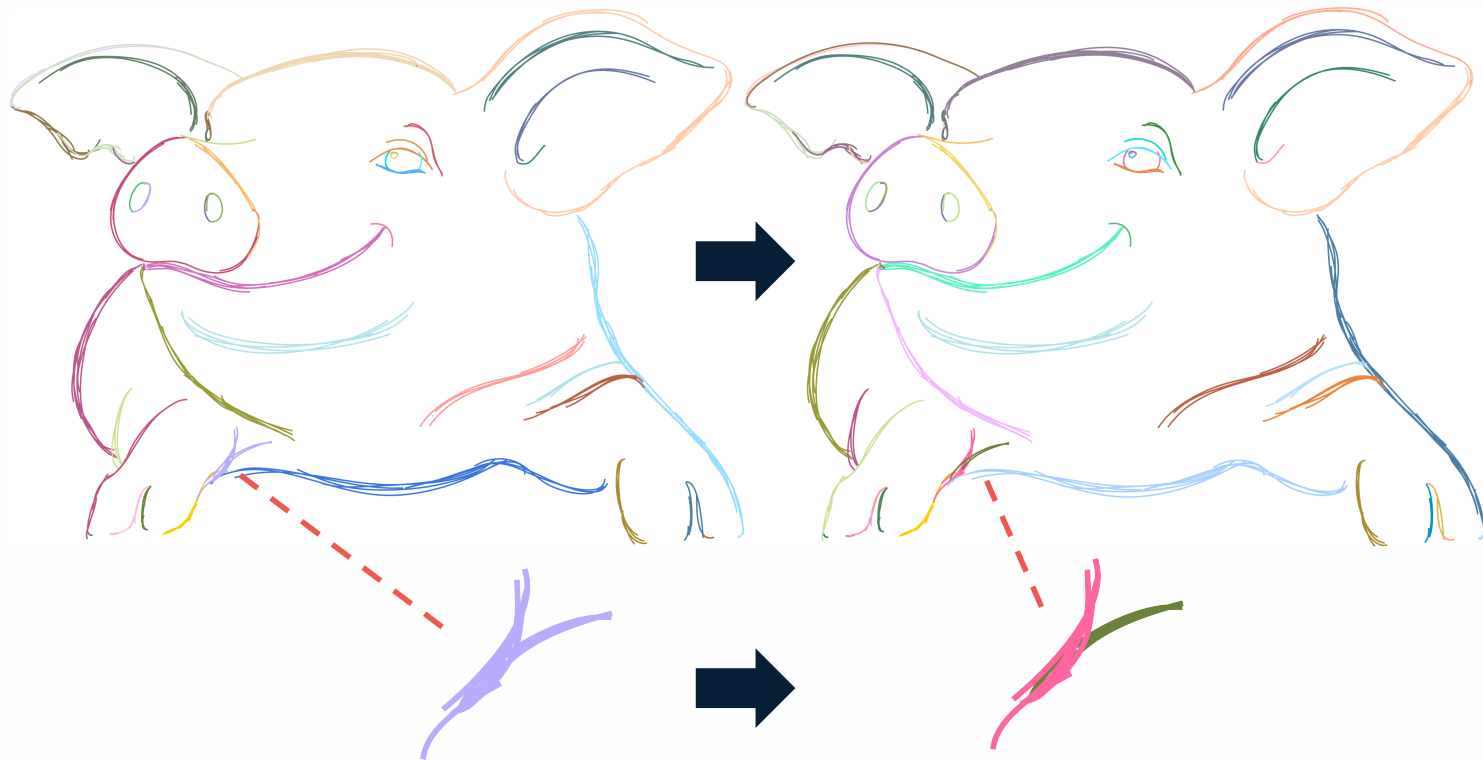


# Method Overview



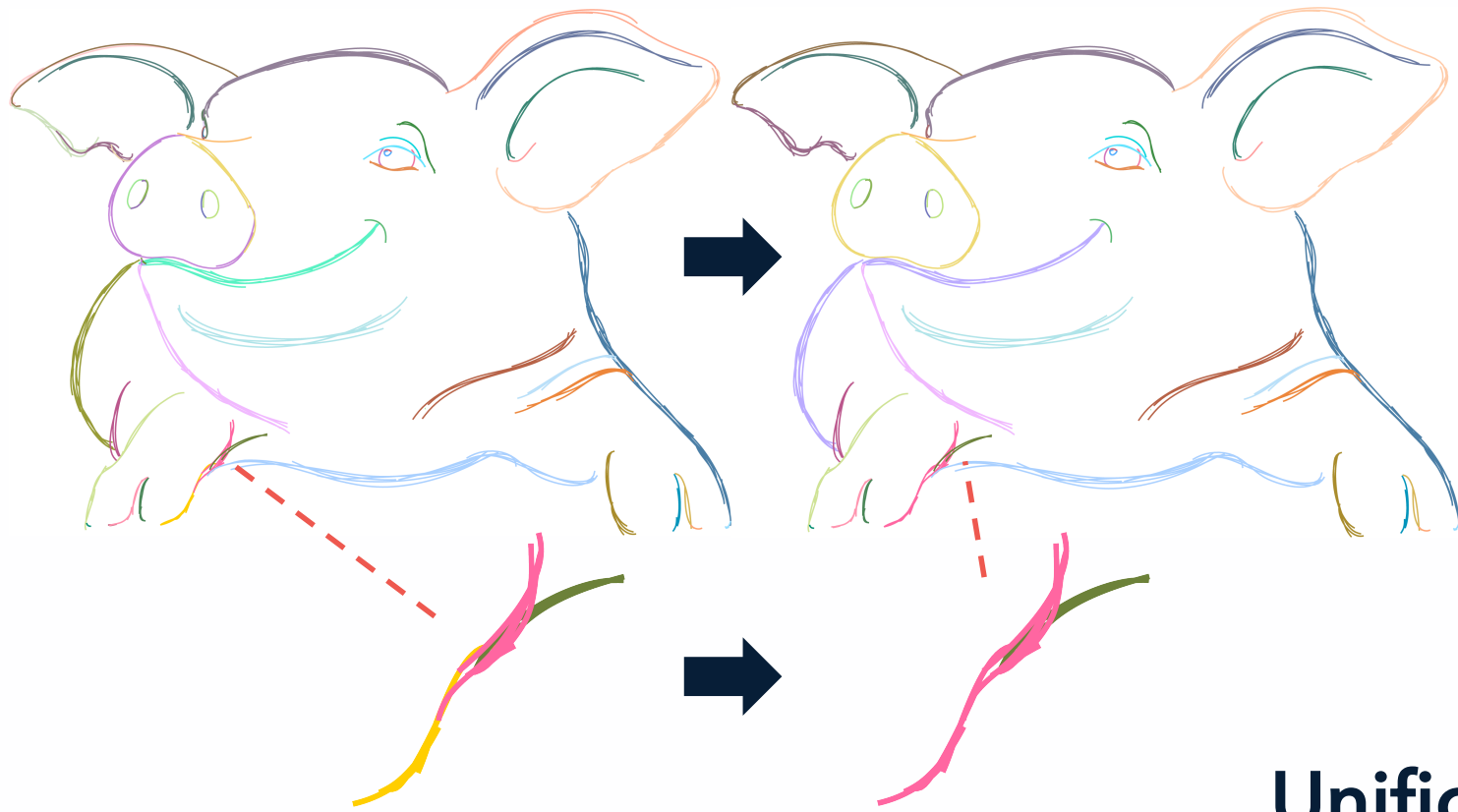
**Coarse Clustering**

# Method Overview



**Fine Clustering**

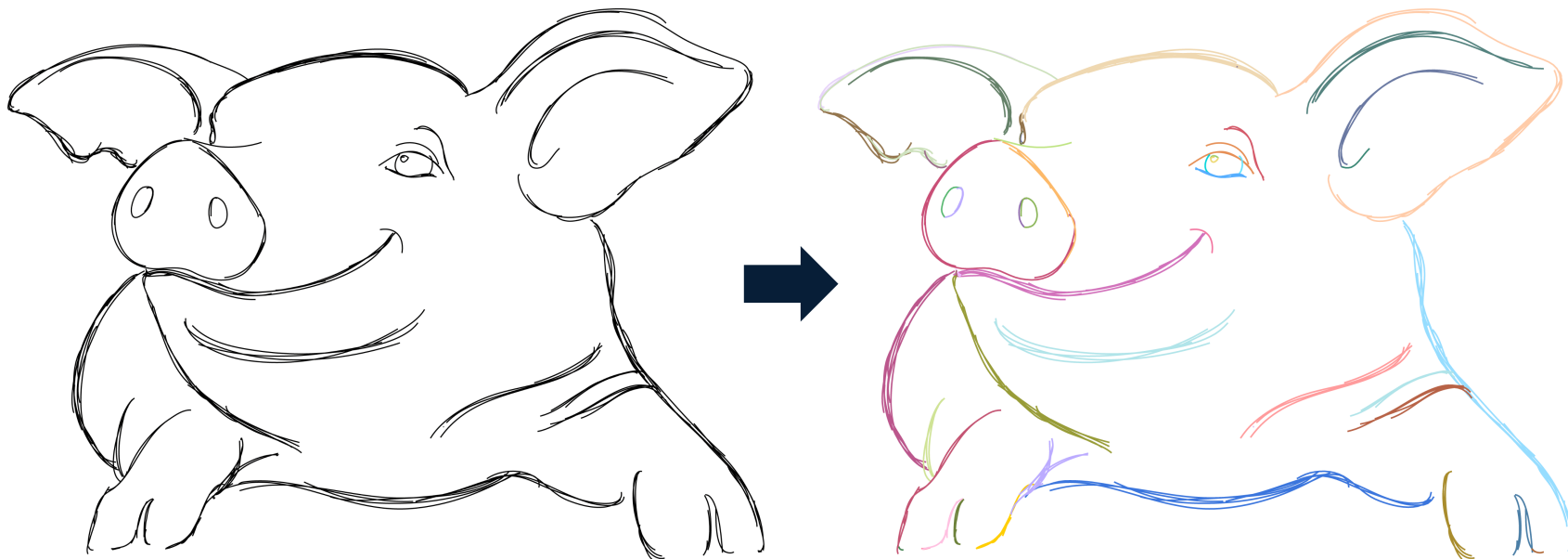
# Method Overview



**Unification**

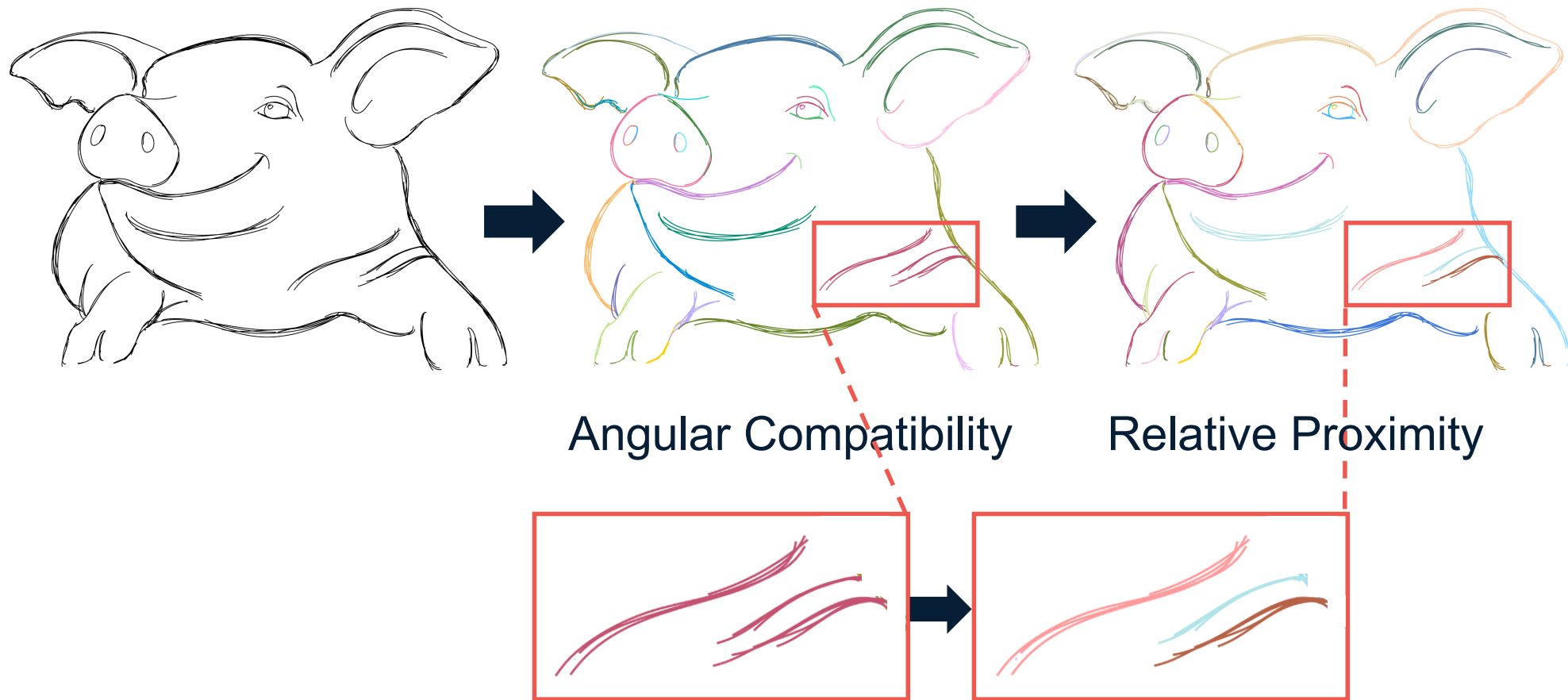
# Method Overview

# Coarse Clustering

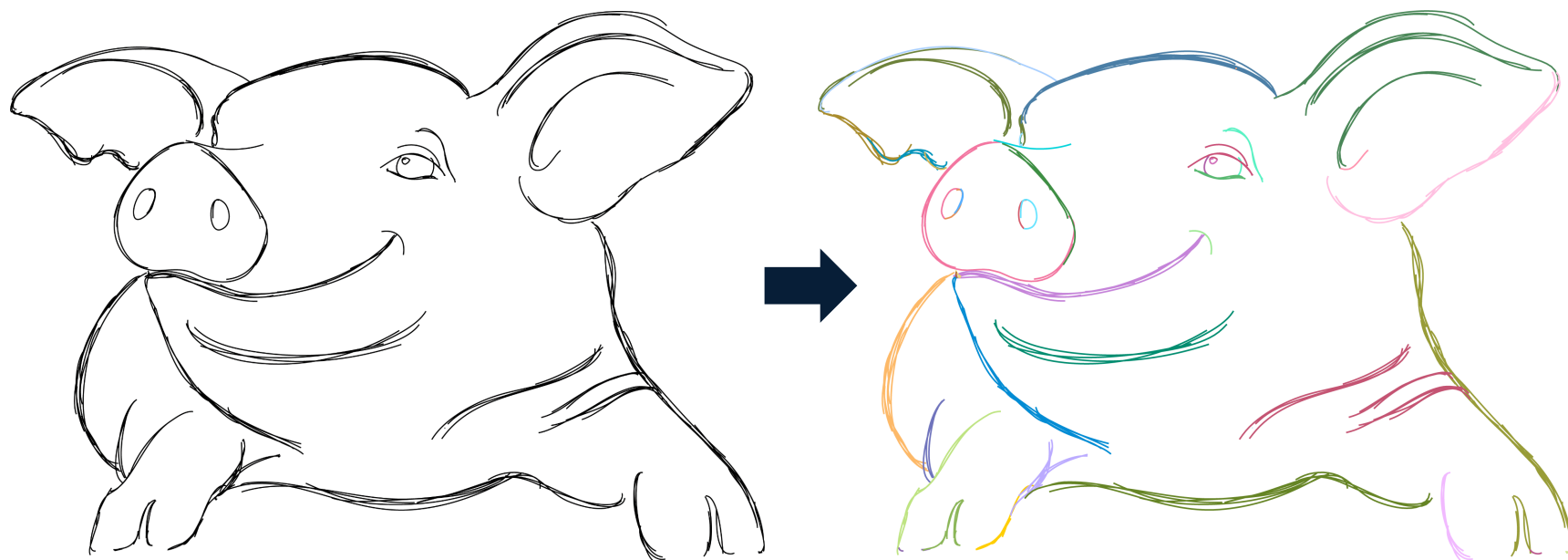


Goal: Separate strokes based on stroke-wise cues

# Coarse Clustering: Goal

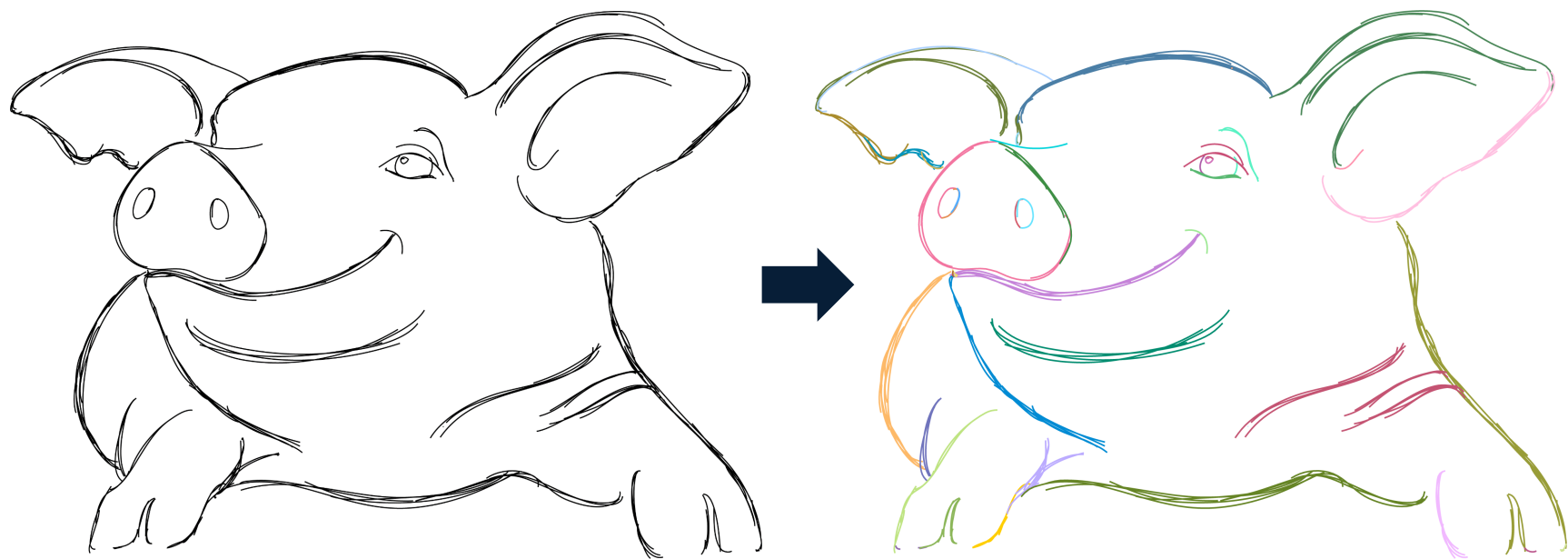


# Coarse Clustering: Goal



Angular Compatibility:

- Separate angle **incompatible** strokes
- Keep (near) parallel nearby strokes together

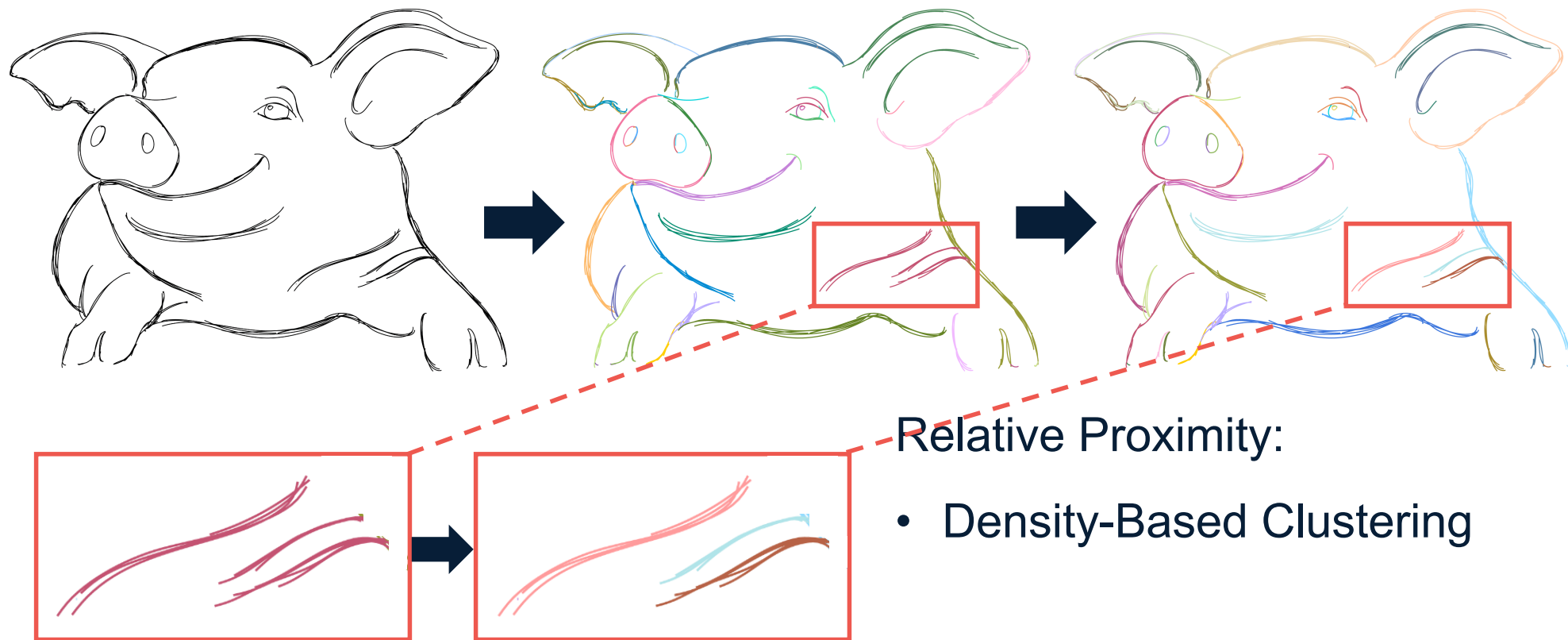


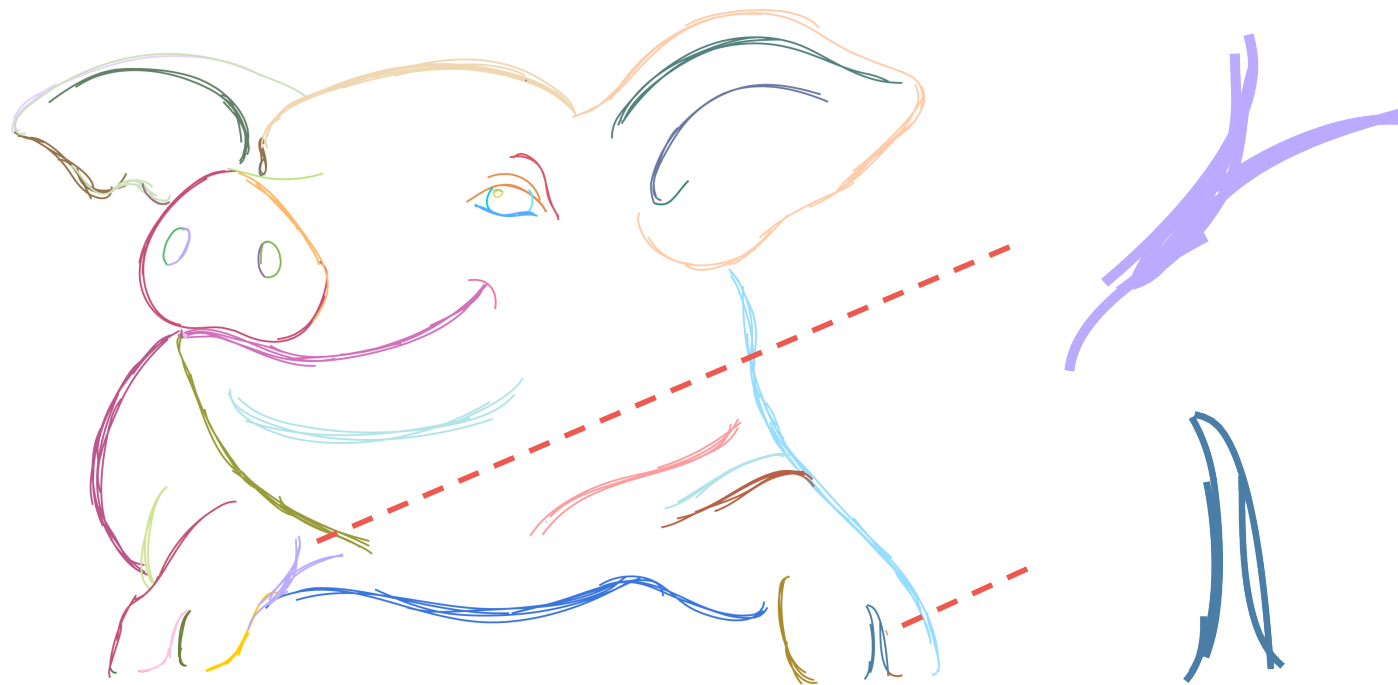
Angular Compatibility:

- Correlation Clustering  
[Bansal et al. 2004] [Keuper et al. 2015]

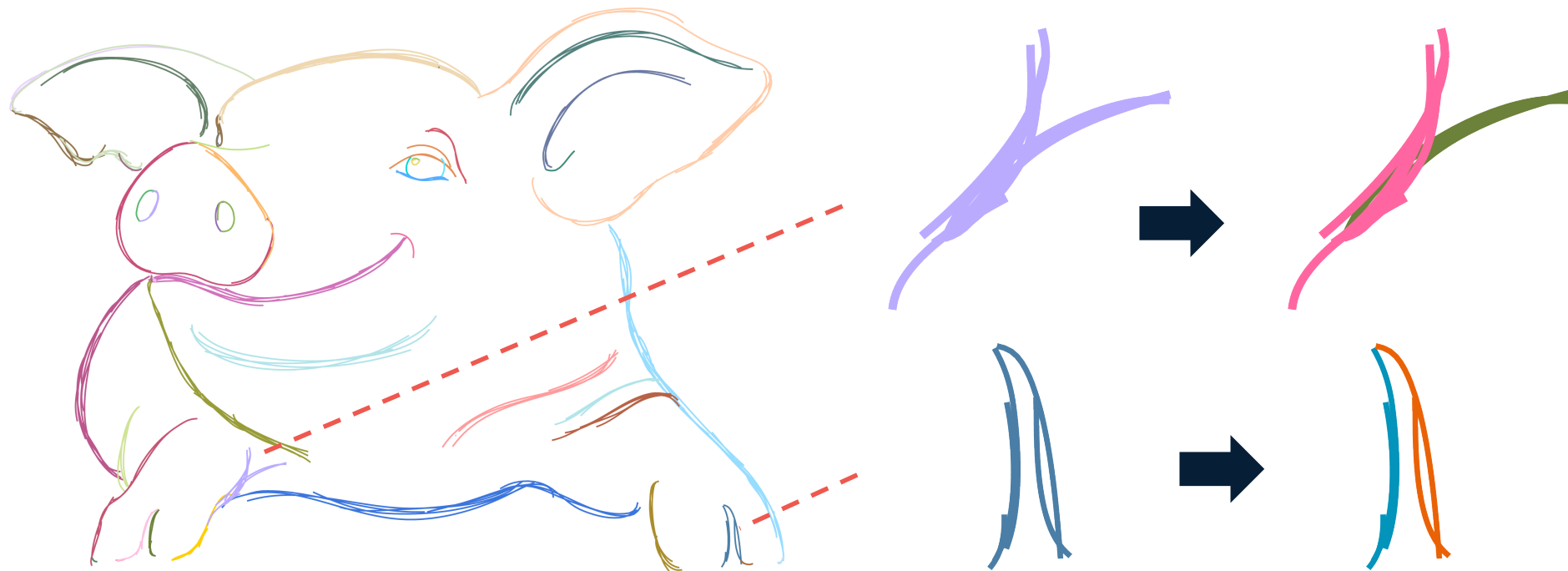


# Coarse Clustering: Implementation

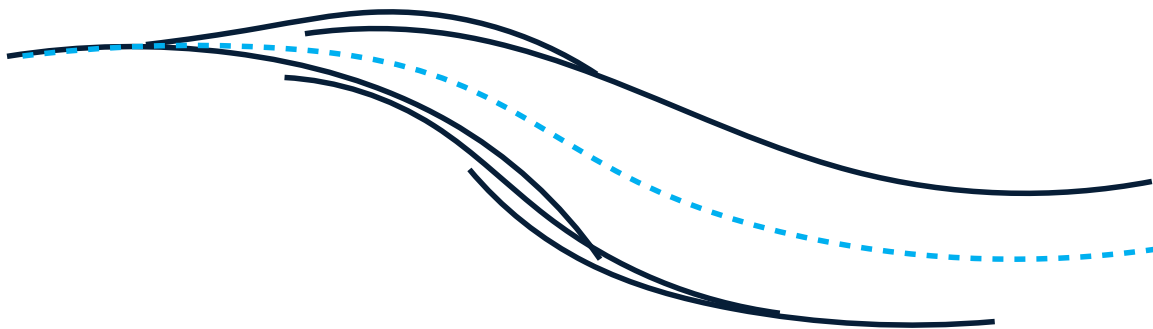




**Branching  
with locally varying proximity**



Recursively separate branches based on  
**Local Contextualized Relative Proximity**



## Local:

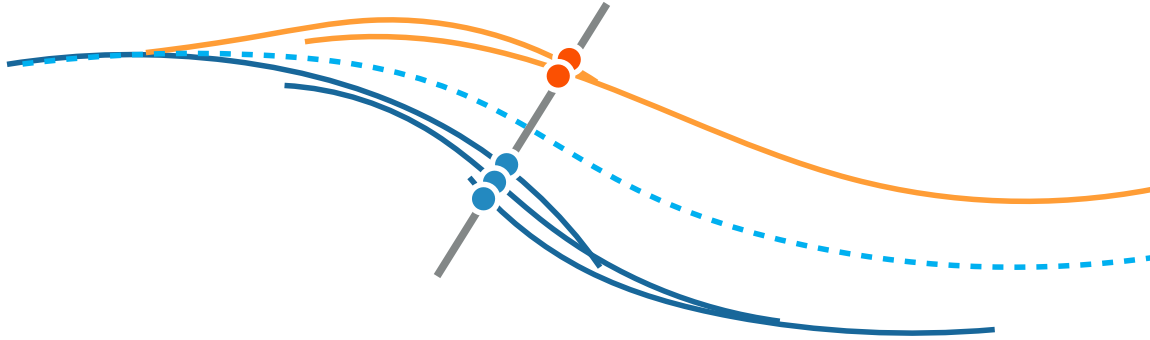
- Point-wise (1D parameterization)

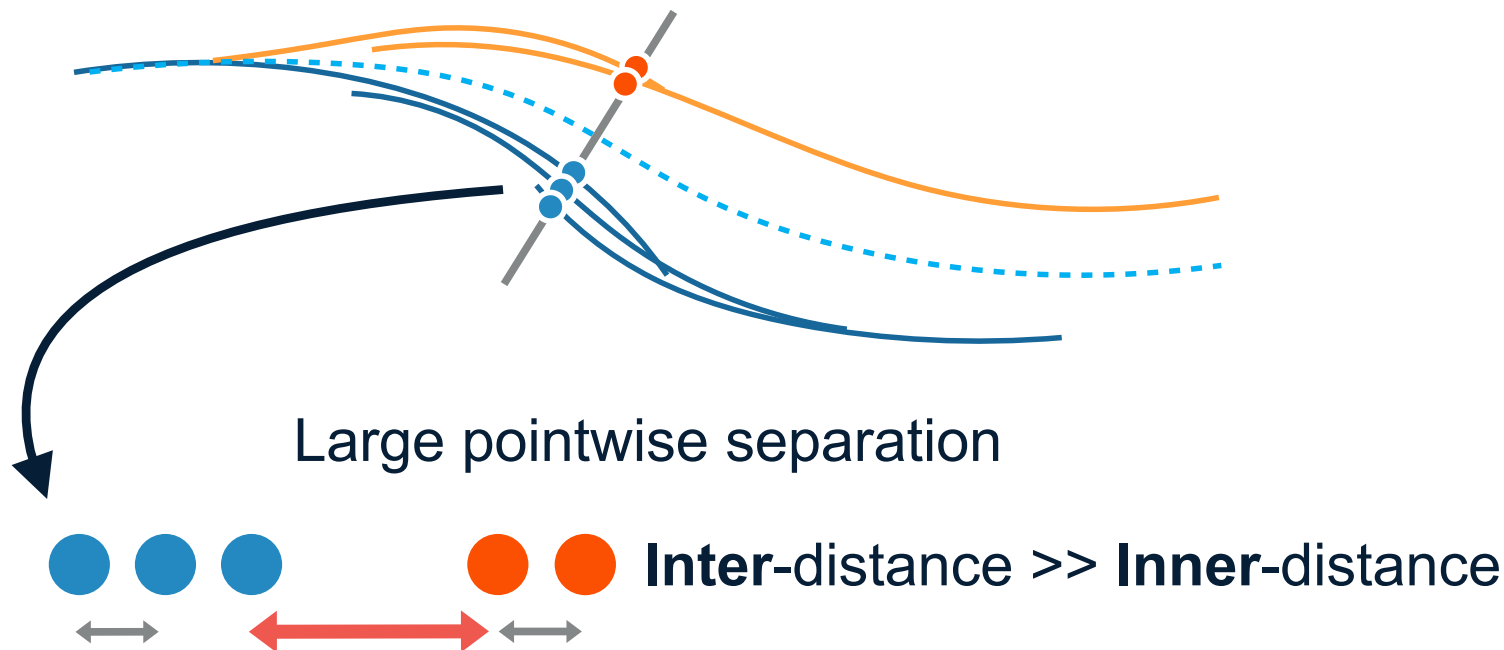
## Contextualized:

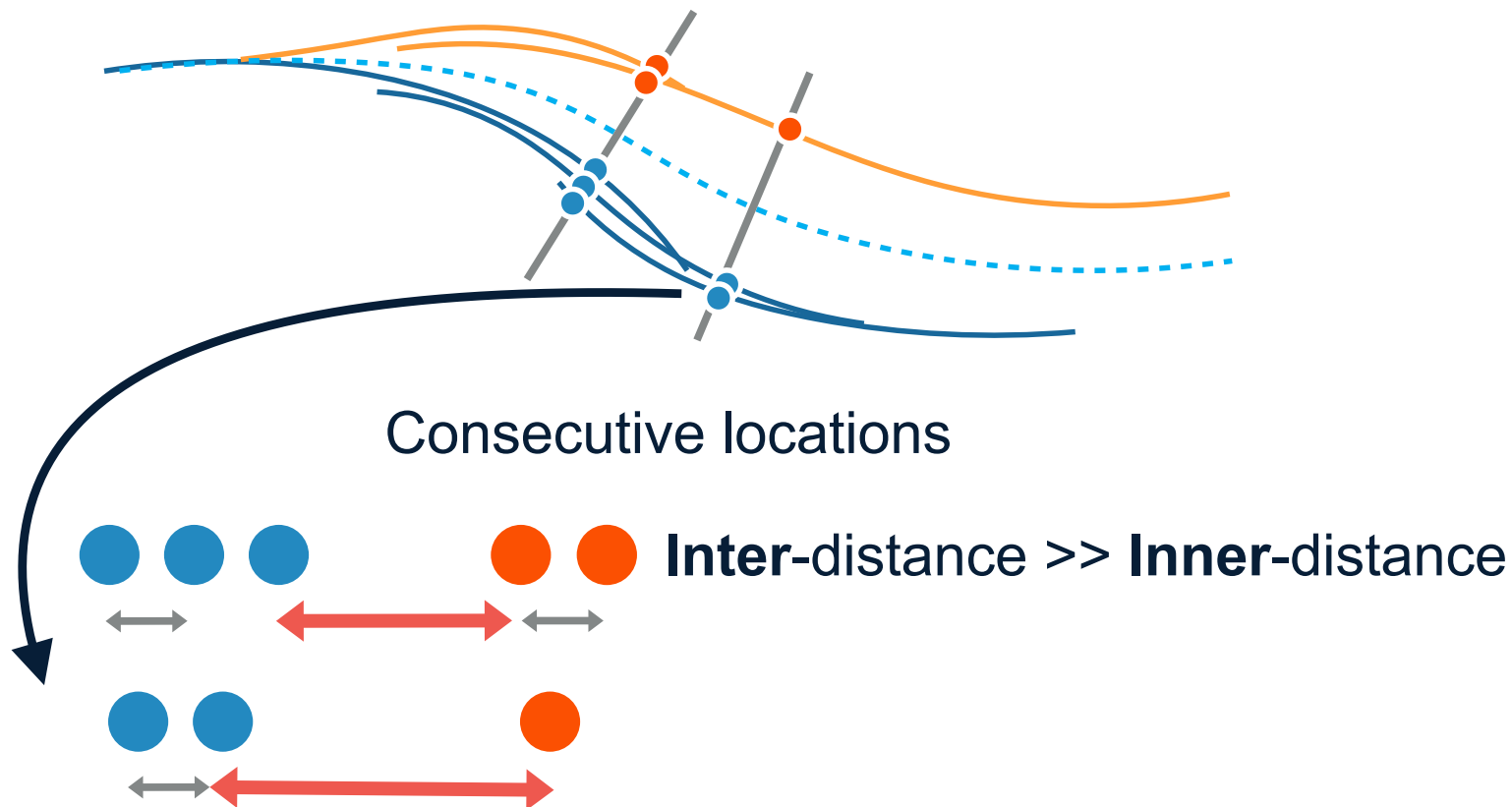
- Proximity with respect to **all** strokes in the cluster

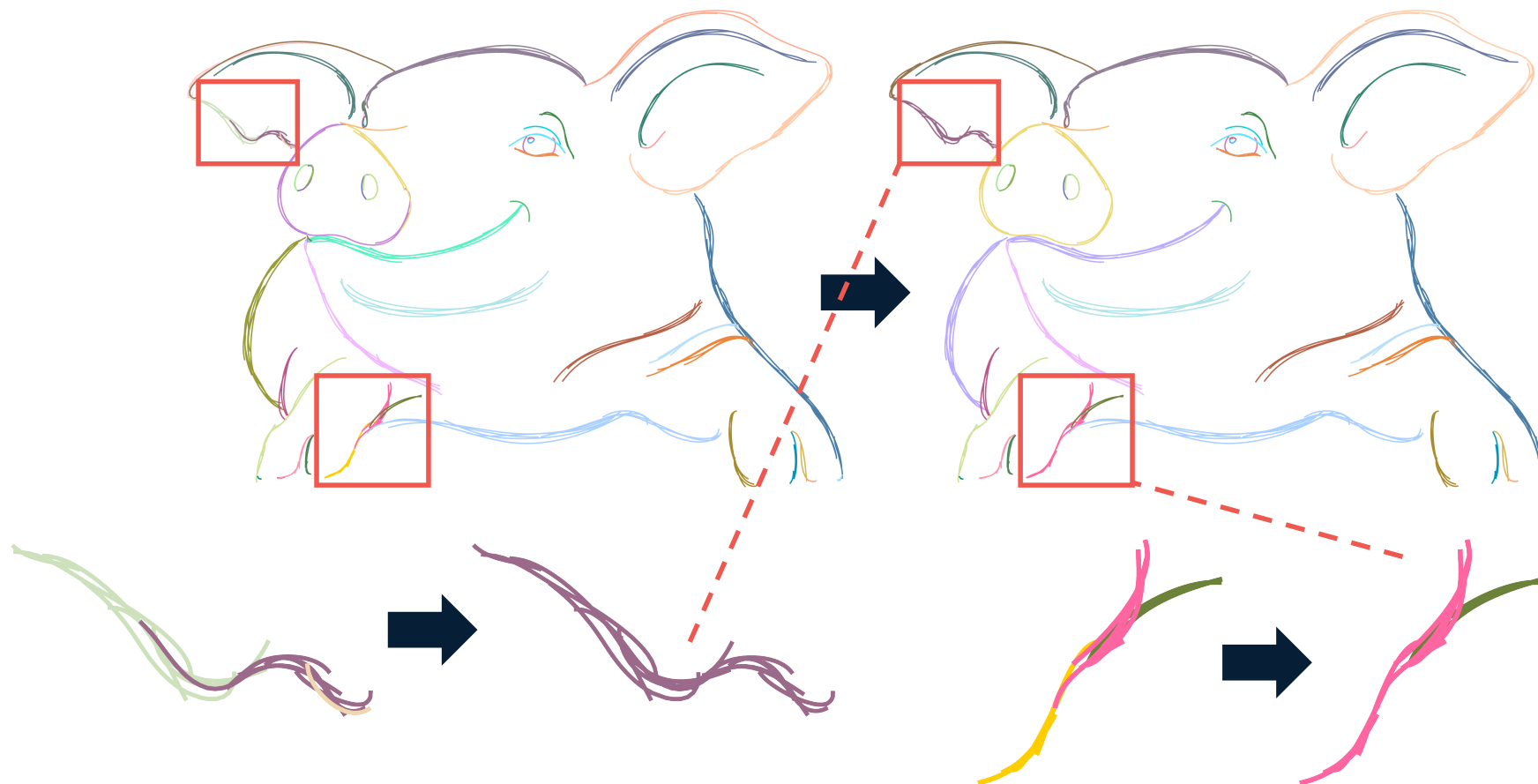
# Local Analysis

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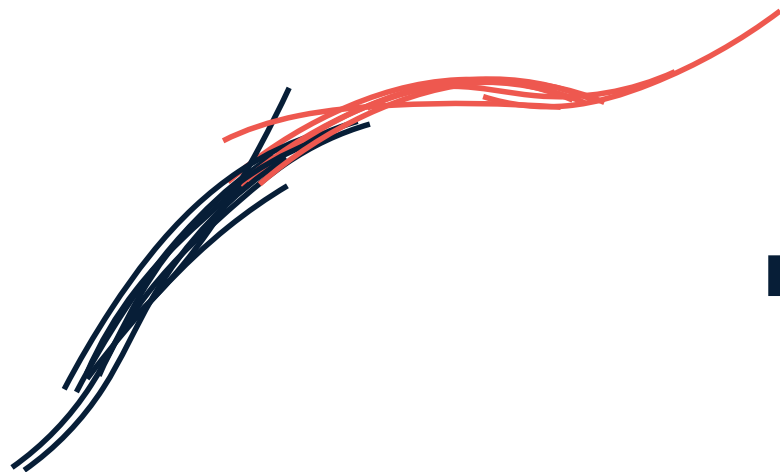












**Conservative**  
coarse-to-fine clustering



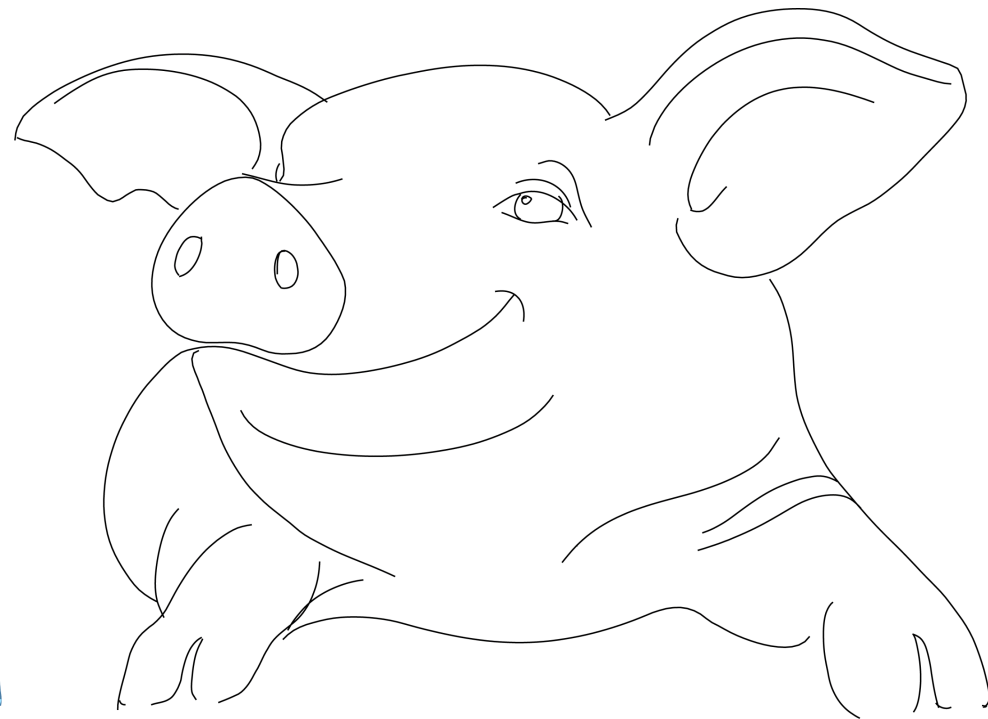
**Merge IF clusters** satisfy all our cues

# Final Result

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Final Clustering



Final Consolidated Sketch

Angle?


From perception  
literature  
[Hess and Field 1999]

Relative Proximity?

Narrowness?


Establish via human studies

How many groups of lines do you see in this image?



1 2 3 4 5 more than 5

Does the image below show a line (thick or thin) or a rectangle?

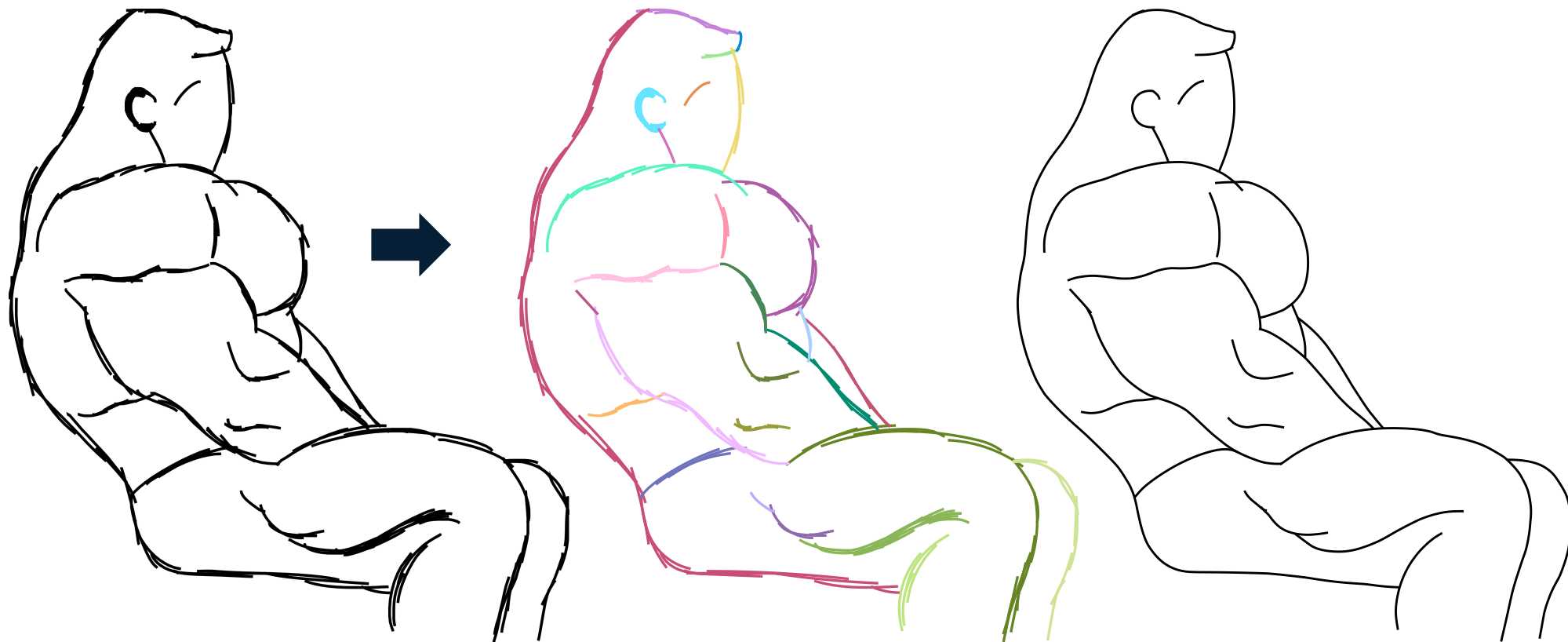


A thin line A thick line A rectangle

---

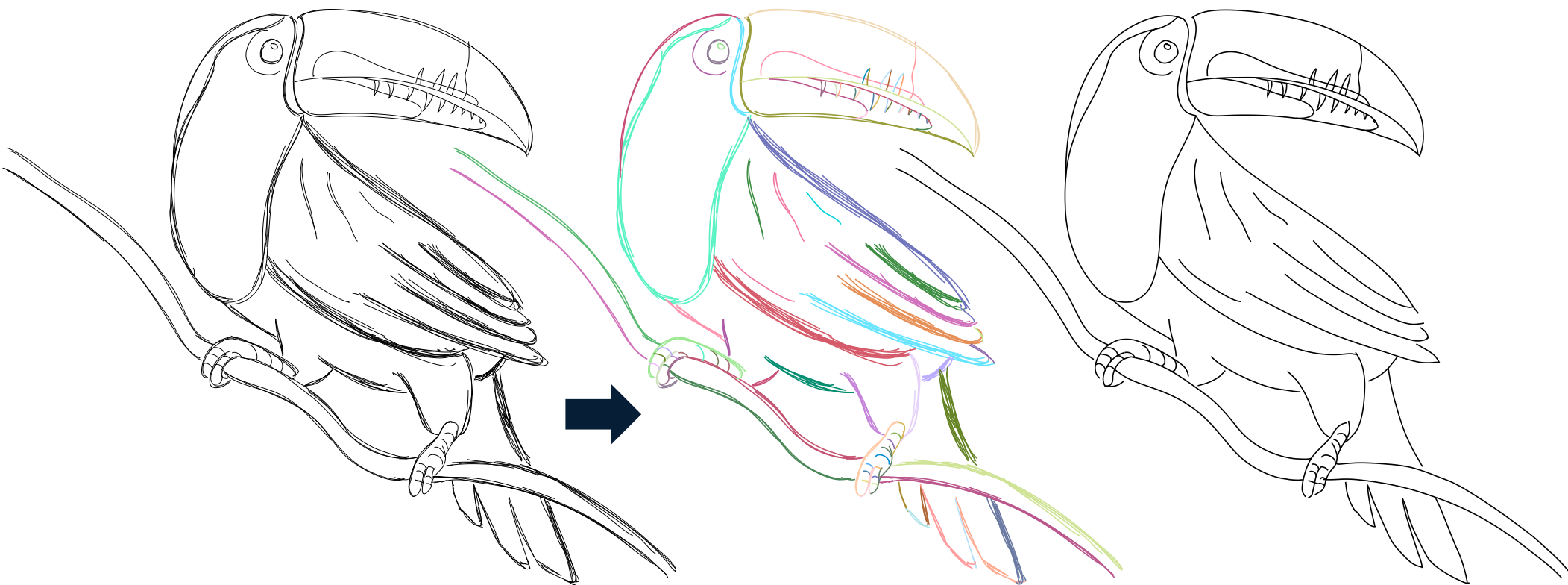
# Results

# Results



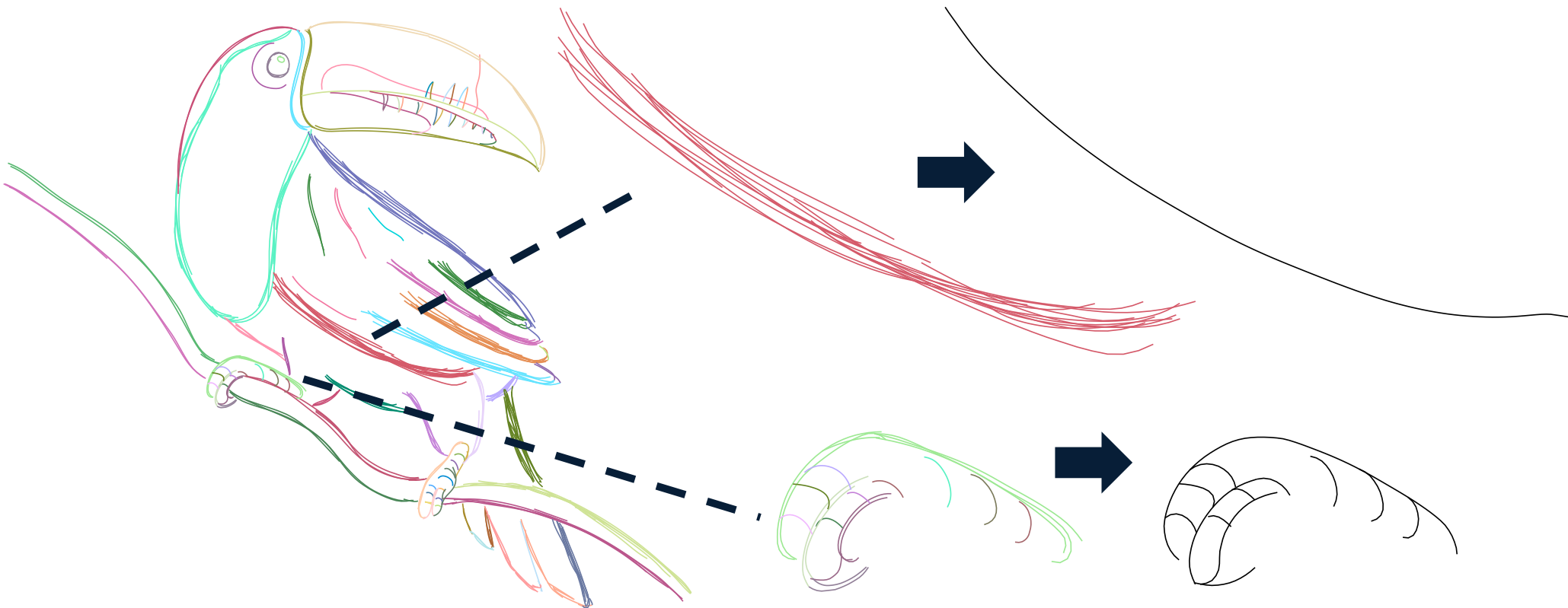
# Results

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# Results

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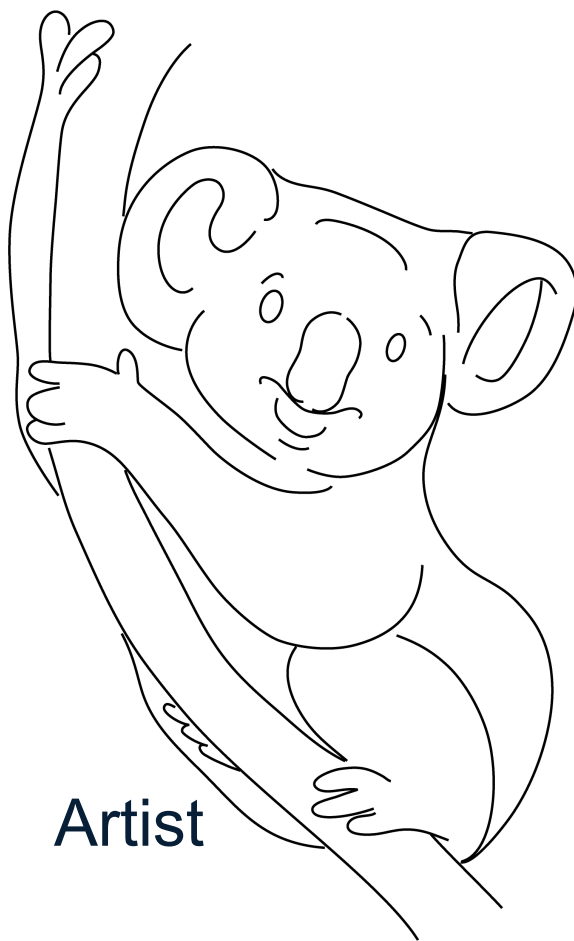


# Comparison to Artists

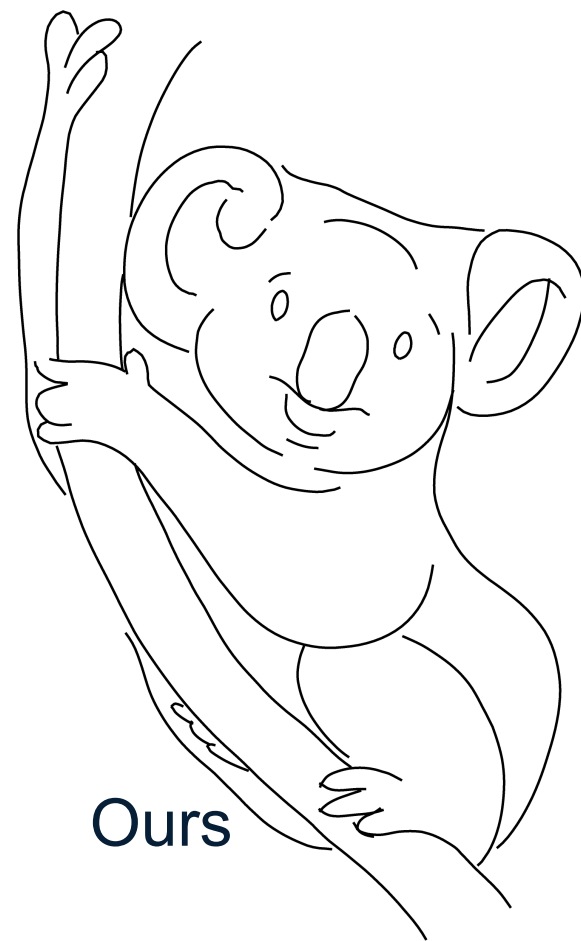
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Input



Artist

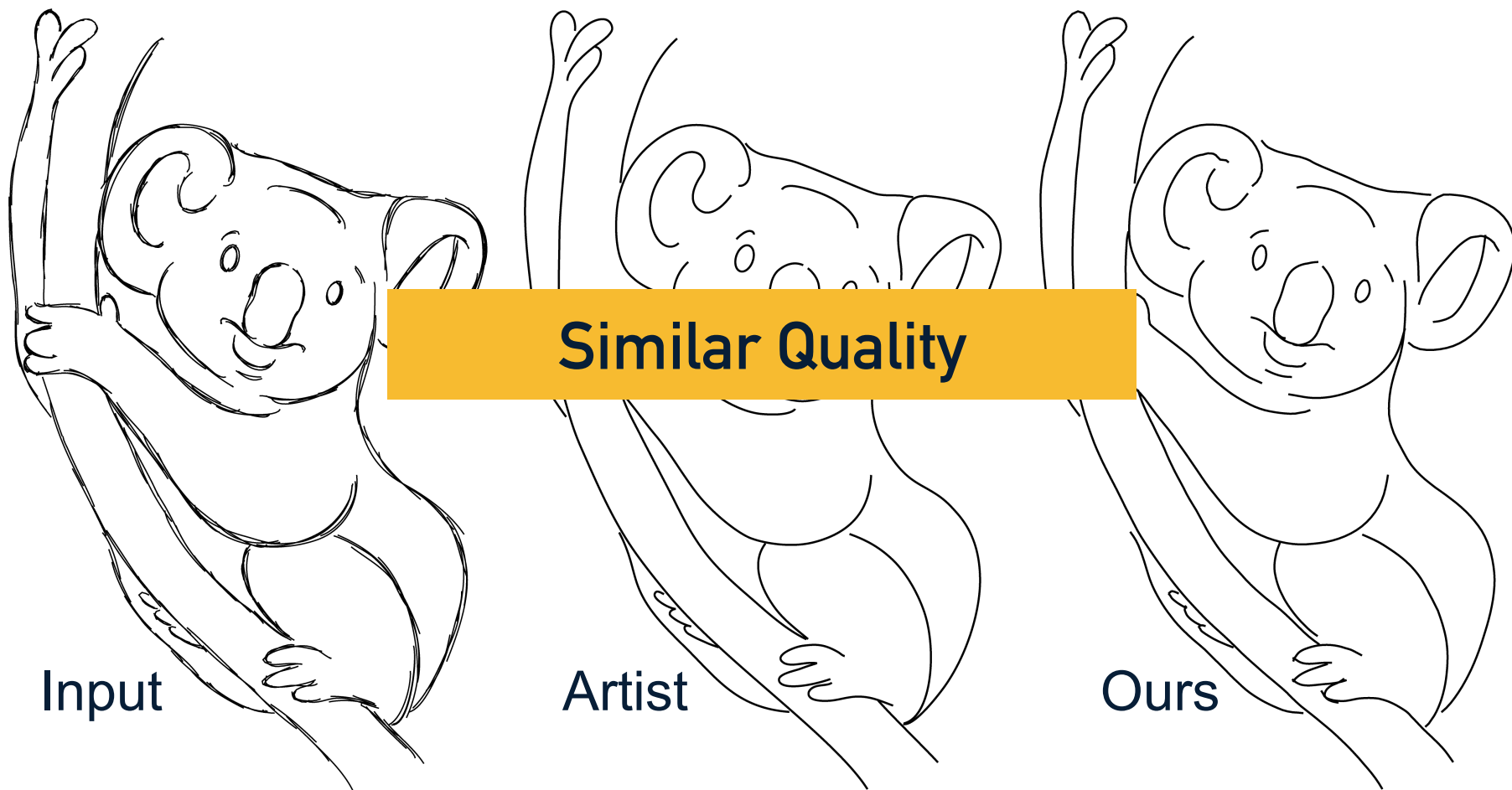


Ours



# Comparison to Artists

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# Comparison to Artists



Input



Artist

~16 min



Ours

2 min

# Comparison to Prior Arts: Raster Input

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Input



Favreau et al.  
[2016]



Simo-Serra et al.  
[2017]



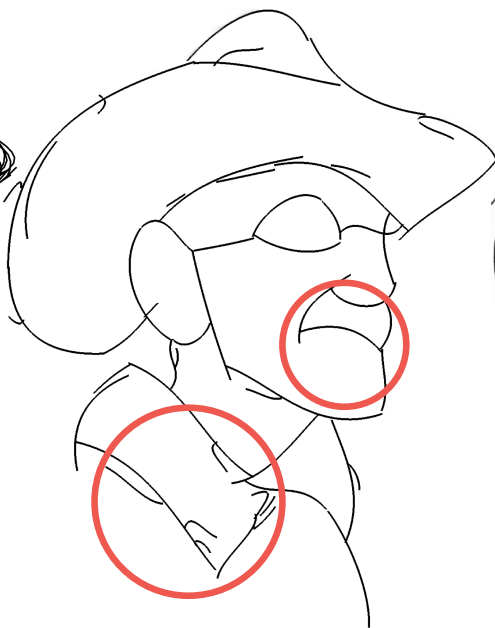
Ours

# Comparison to Prior Arts: Raster Input

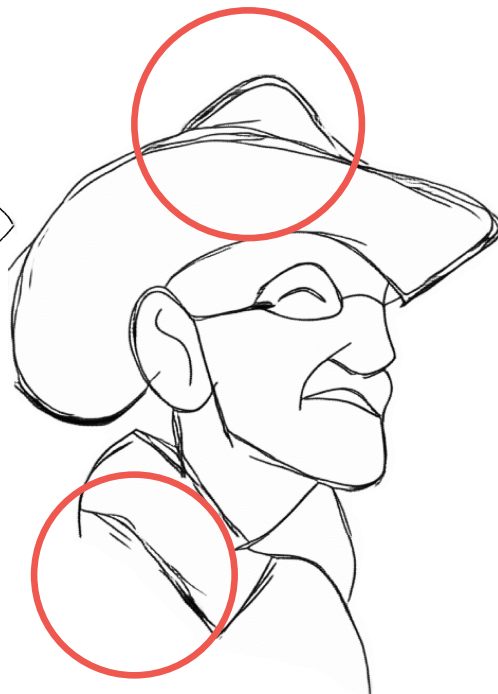
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Input



Favreau et al.  
[2016]



Simo-Serra et al.  
[2017]



Ours

# Comparison to Prior Arts: Consolidation

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Input



Orbay and Kara  
[2011]



Ours

# Comparison to Prior Arts: Consolidation

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Input



Orbay and Kara  
[2011]



Ours

# Comparison to Prior Arts: Consolidation



Input



Liu et al.  
[2015]

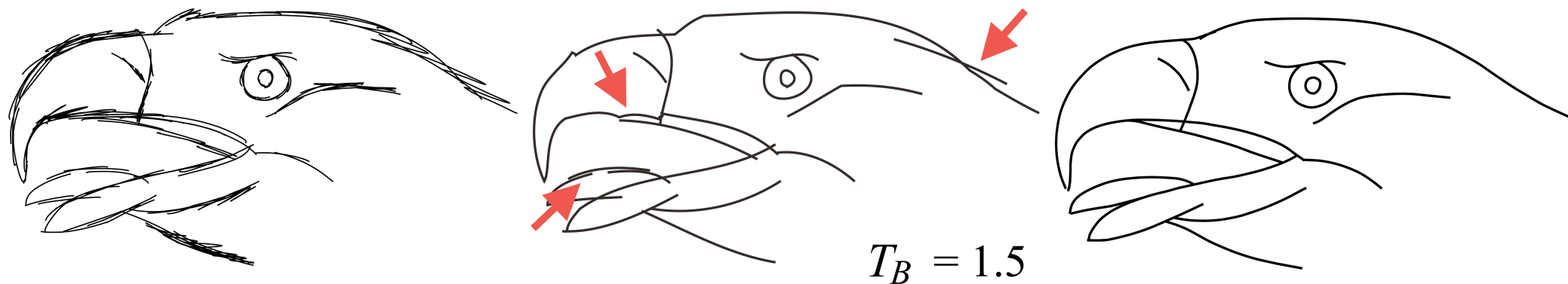
$T_B = 1.5$



Ours

# Comparison to Prior Arts: Consolidation

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Input

Liu et al.  
[2015]

Ours

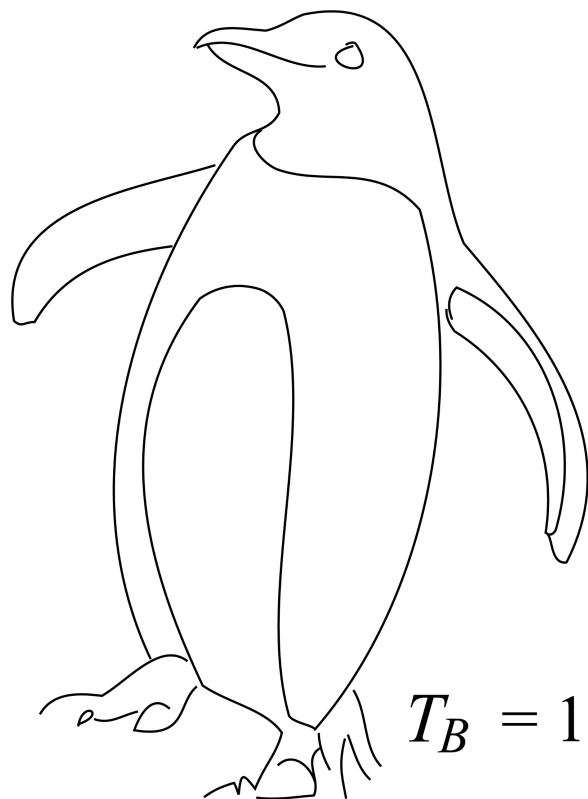


# Comparison to Prior Arts: Consolidation

GENERATIONS / VANCOUVER  
12-16 AUGUST  
SIGGRAPH2018

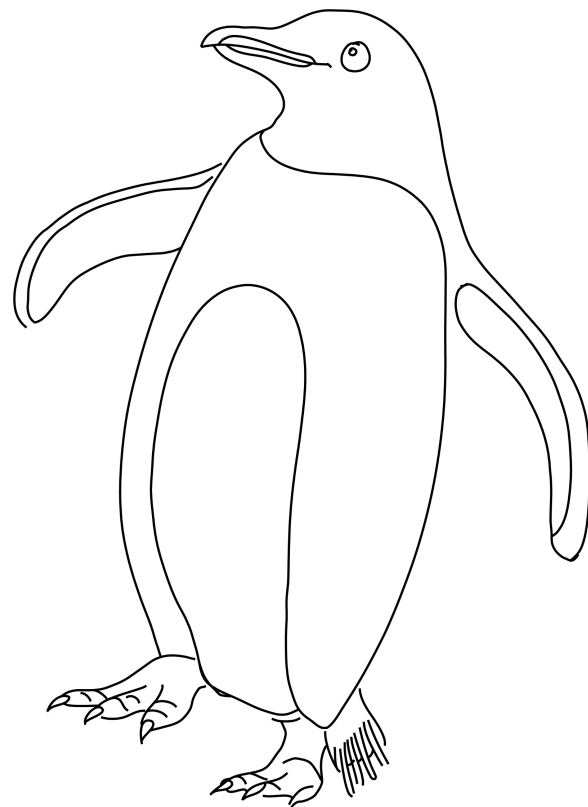


Input



$T_B = 1.1$

Liu et al.  
[2015]



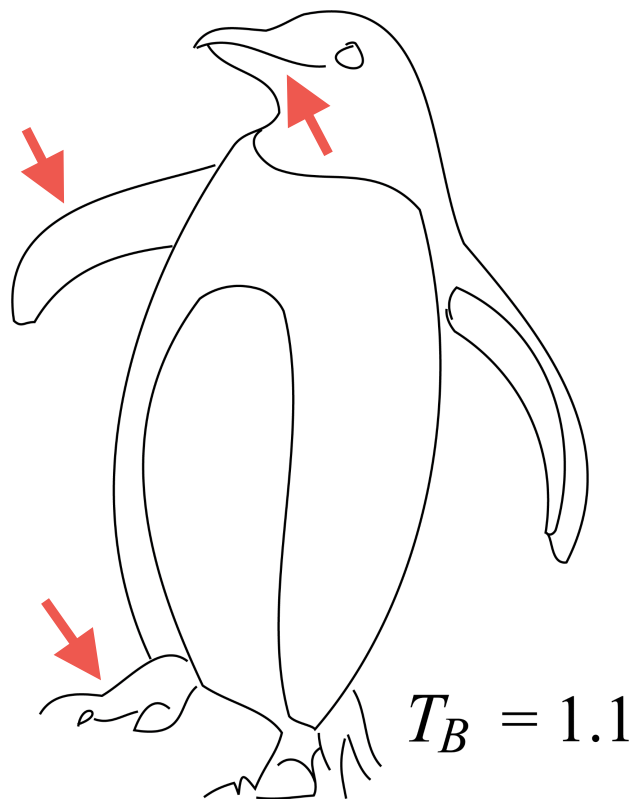
Ours

# Comparison to Prior Arts: Consolidation

GENERATIONS / VANCOUVER  
12-16 AUGUST  
SIGGRAPH2018

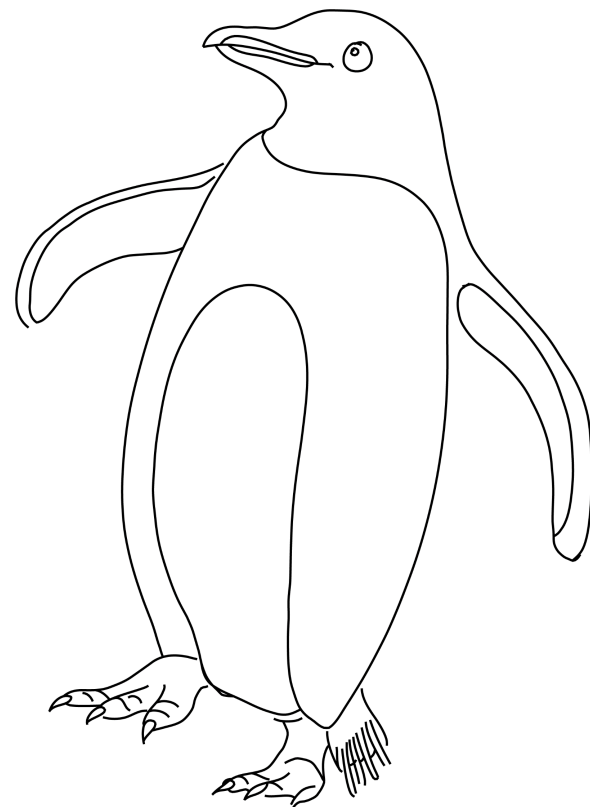


Input



$T_B = 1.1$

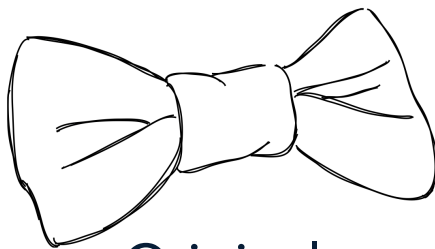
Liu et al.  
[2015]



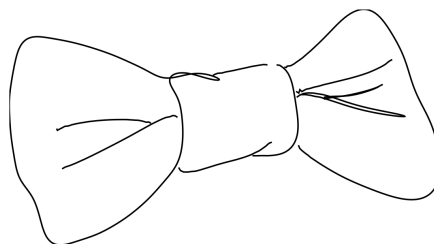
Ours

# Qualitative Evaluation

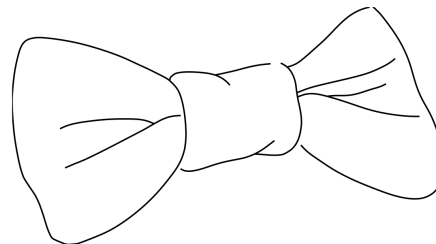
Q: Which of the drawings below, “(a)” or “(b)” is a cleaner and accurate version of the drawing on top “Original”? If both are, please select “both” if neither select “neither”.



Original



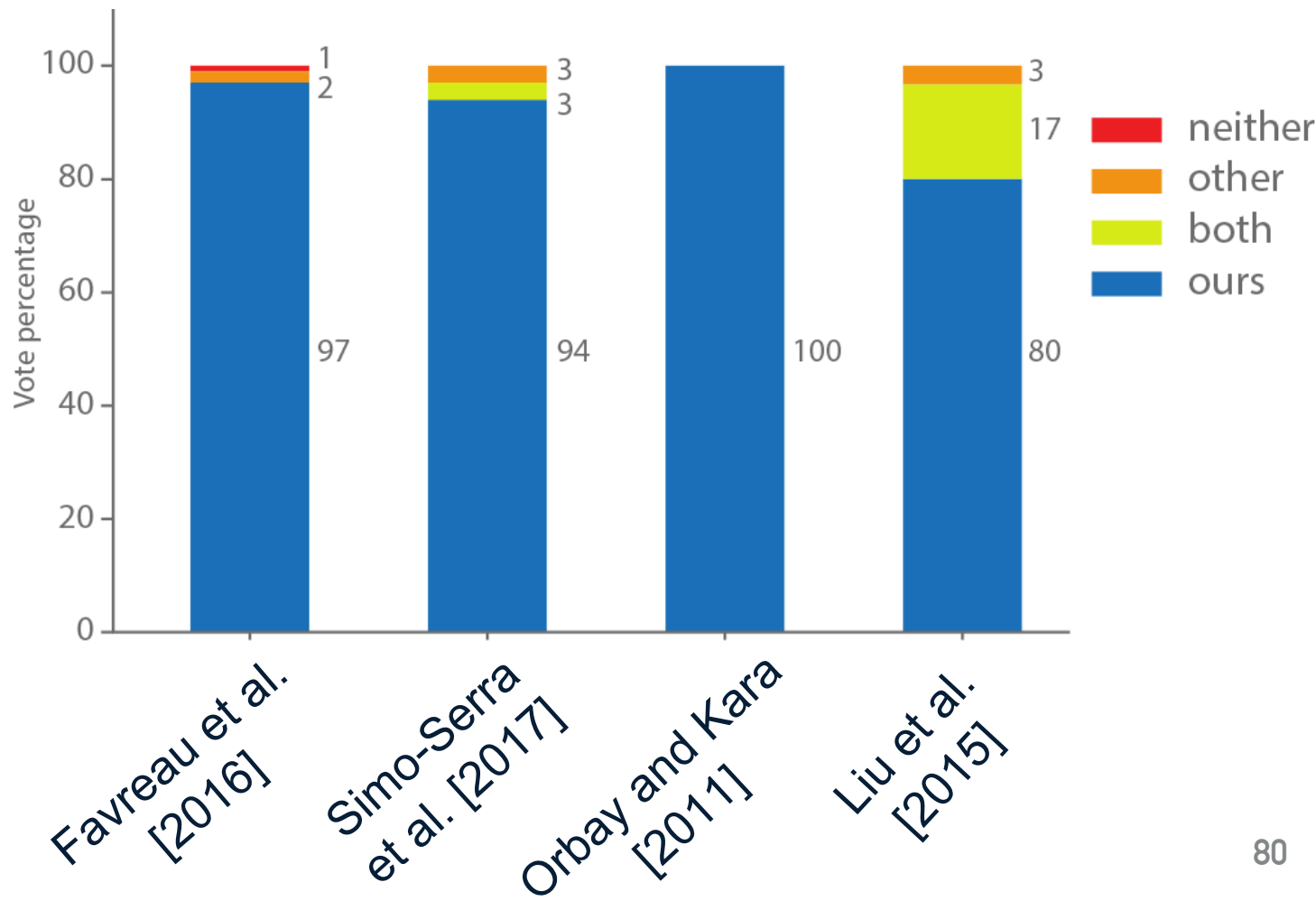
(a)



(b)

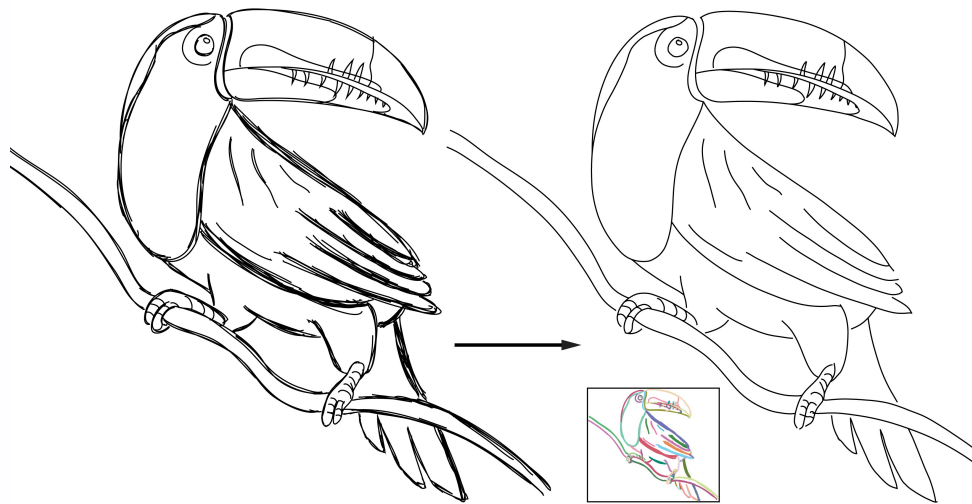
# Qualitative Evaluation

Q: Which of the drawings below, “(a)” or “(b)” is a cleaner and accurate version of the drawing on top “Original”? If both are, please select “both” if neither select “neither”.



1. Analysis of perceptual cues that guide human viewers in consolidating overdrawn sketches.
2. A method that mimics human mental consolidation by measuring these cues in the context of stroke clusters.





## StrokeAggregator

A method for consolidating raw sketches into artist-intended curve drawings.

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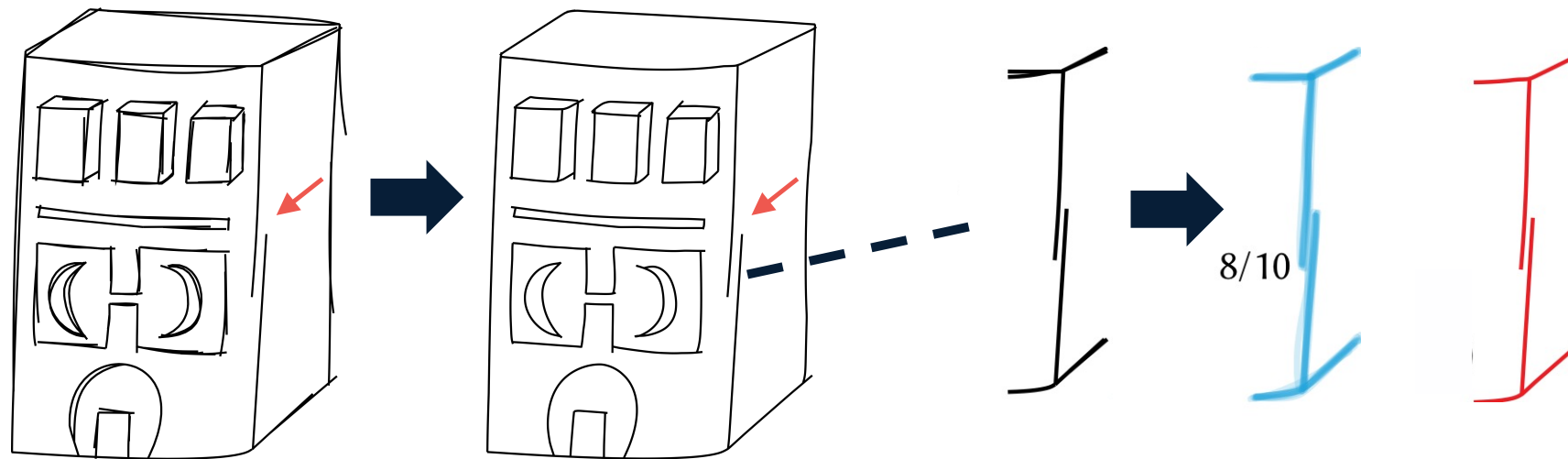
# Thank you!

Chenxi Liu, Enrique Rosales, Alla Sheffer  
{ chenxil | albertr | sheffa }@cs.ubc.ca



## Stylized Line Drawings:

- “Non-typical” Clusters violating angular, proximity cues



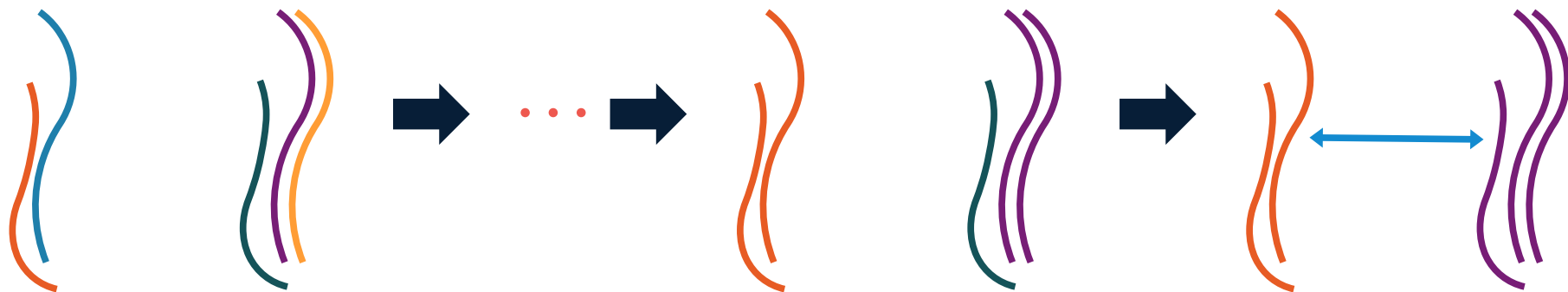
## Global Ambiguity:

- Ambiguity that needs global knowledge to resolve



# Density-Based Clustering

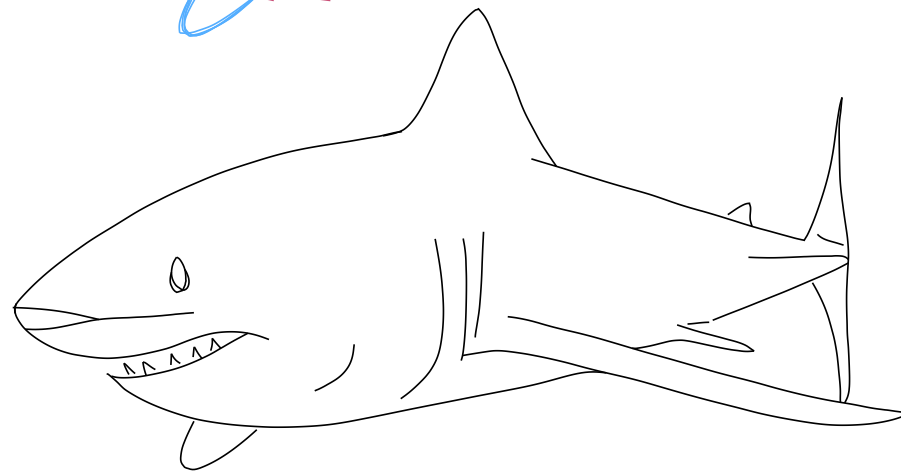
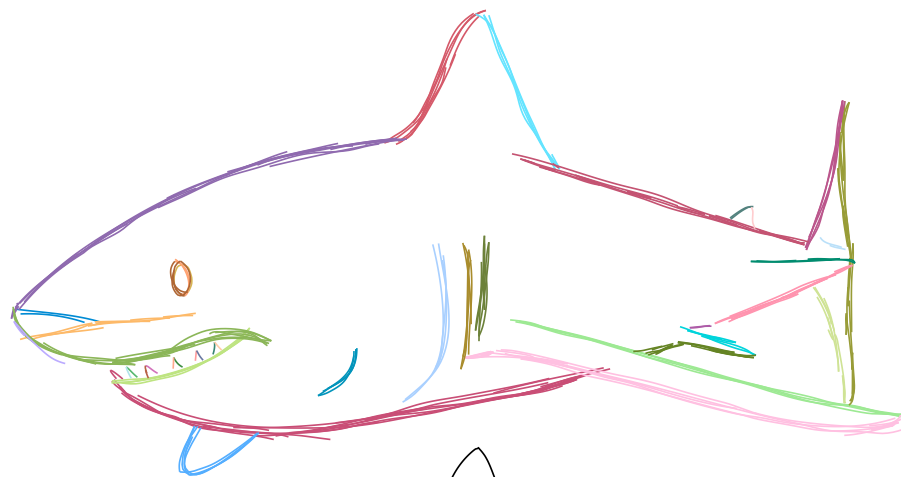
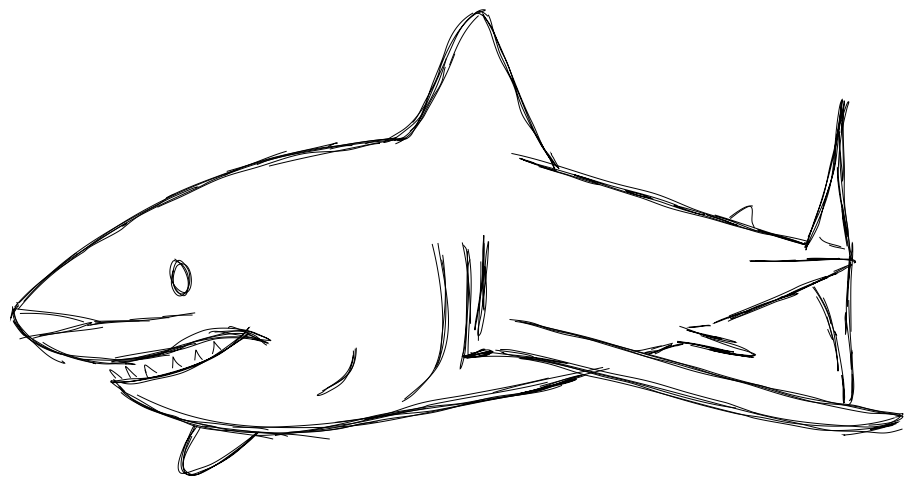
Bottom-up merge



Until a large change in distance

# Results

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**SIGGRAPH**2018



# Results

