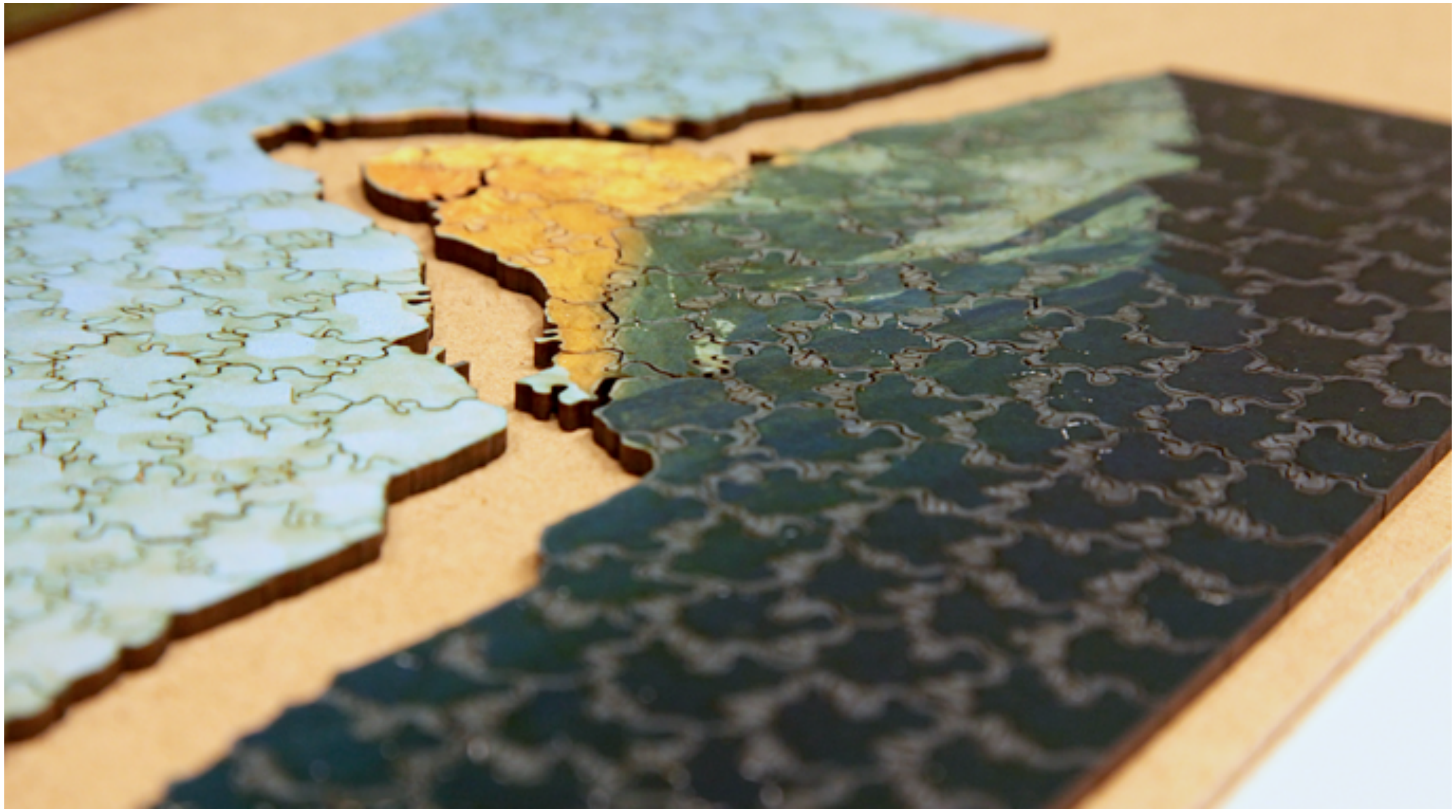


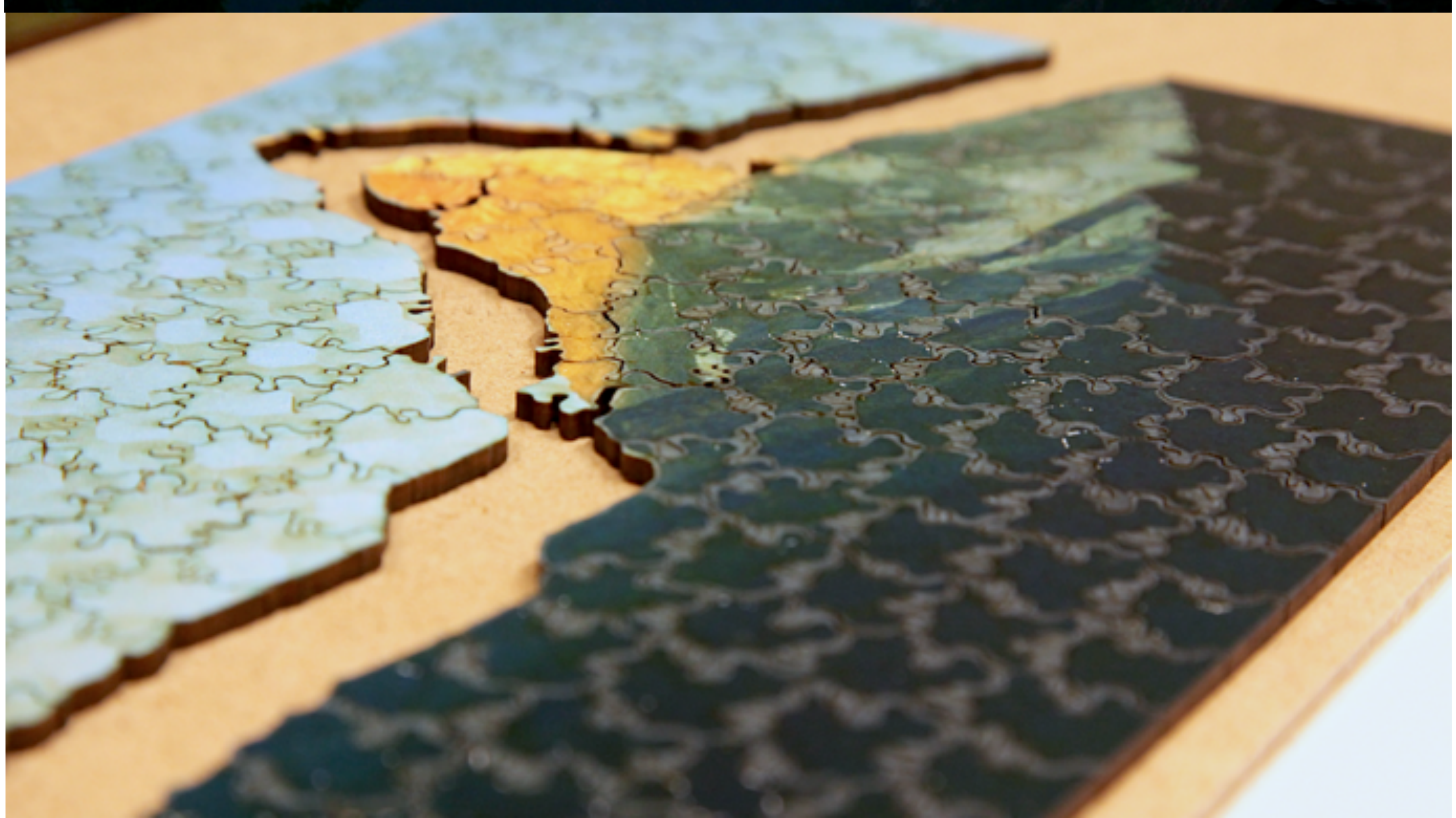
Creating Personalized Jigsaw Puzzles

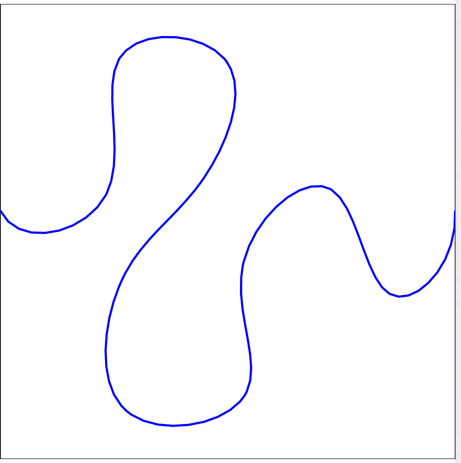
Cheryl Lau, Yuliy Schwartzburg, Appu Shaji, Zahra Sadeghipoor, Sabine Süsstrunk

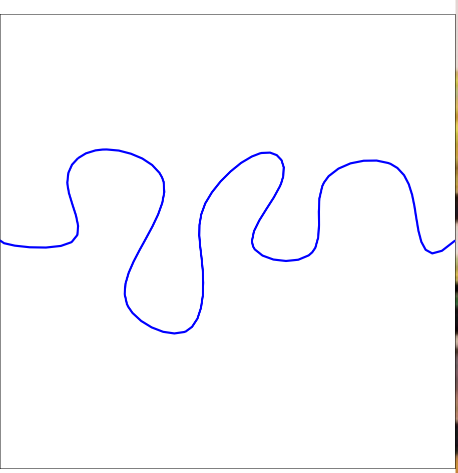
École Polytechnique Fédérale de Lausanne (EPFL)

ÉCOLE POLYTECHNIQUE FÉDÉRALE DE LAUSANNE


Flickr user outdoorPDK







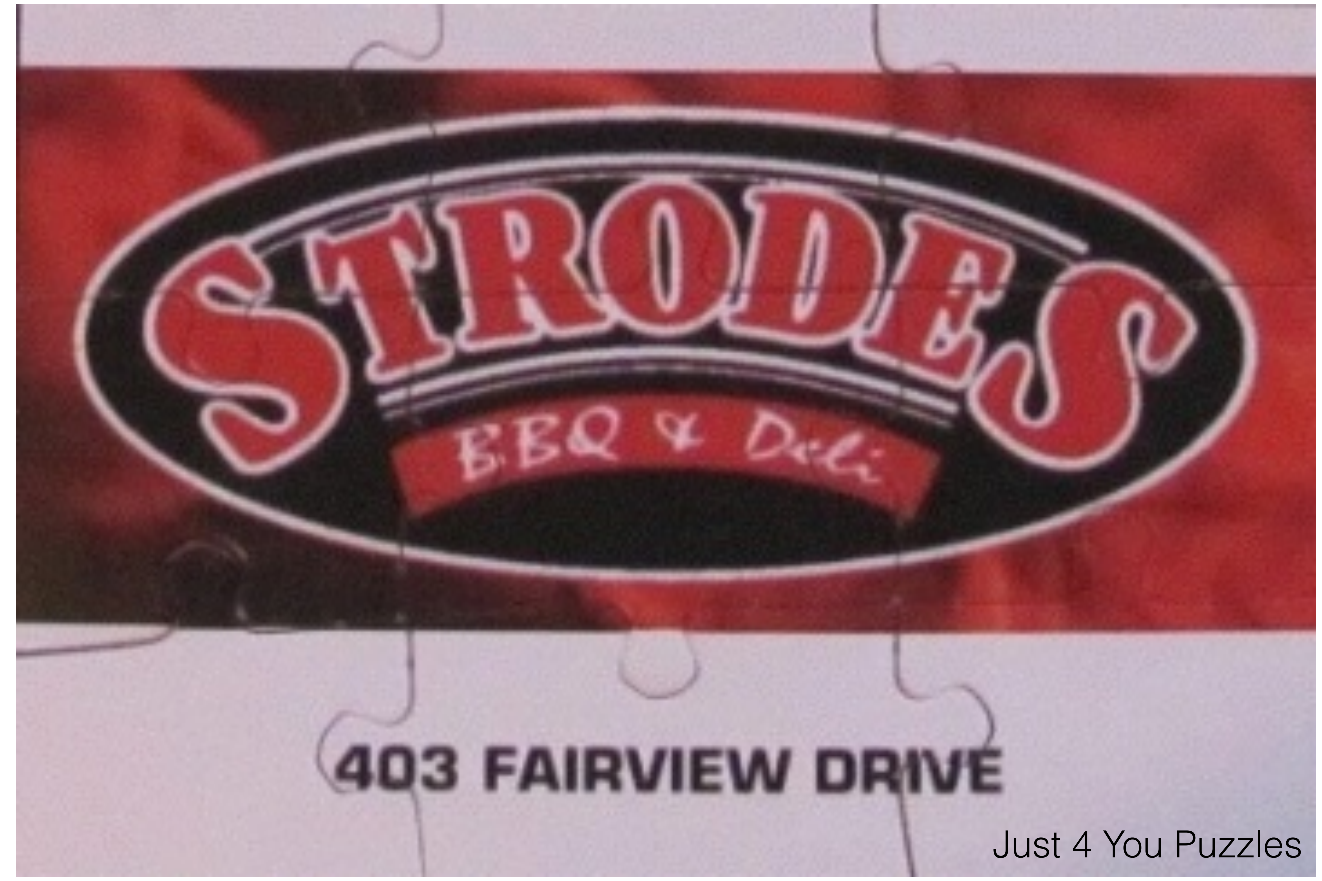
British Library Board


Ravensburger

Keystone Puzzles

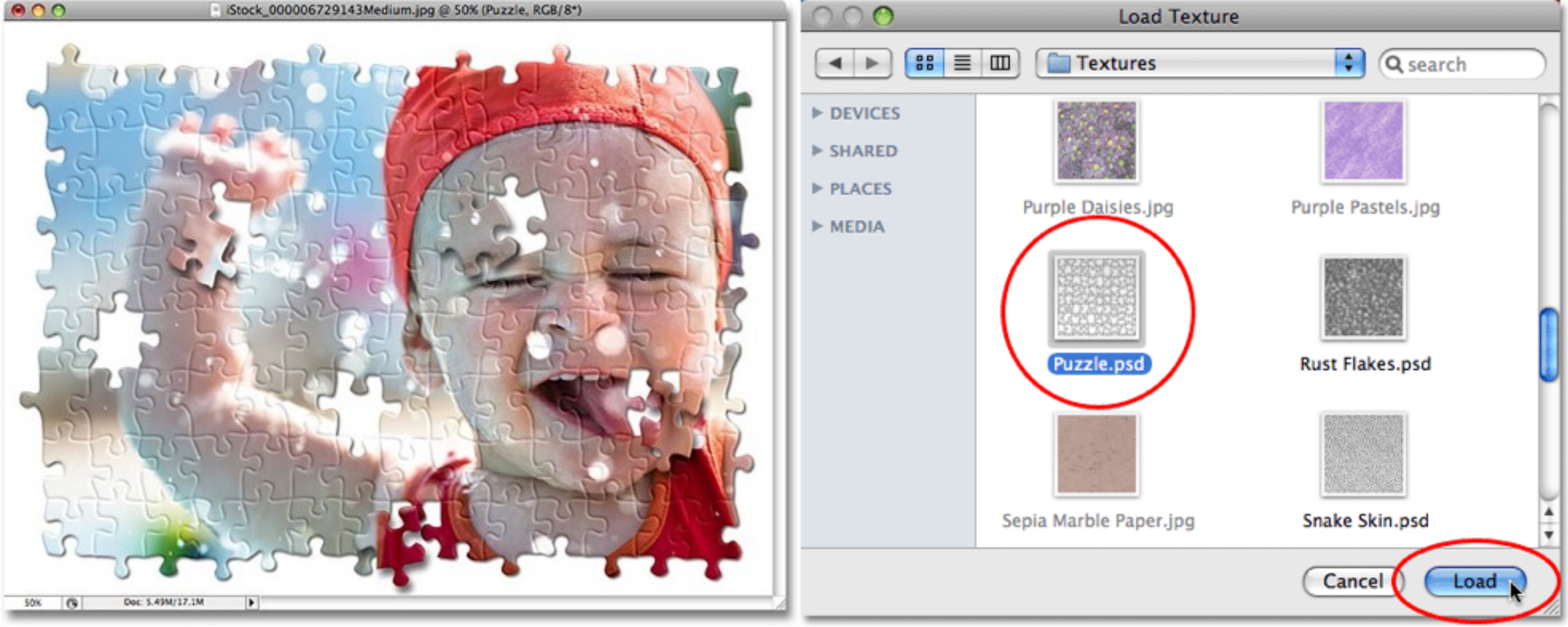
Anderson Woodcrafts

Graffiti Graphics Puzzle Machine



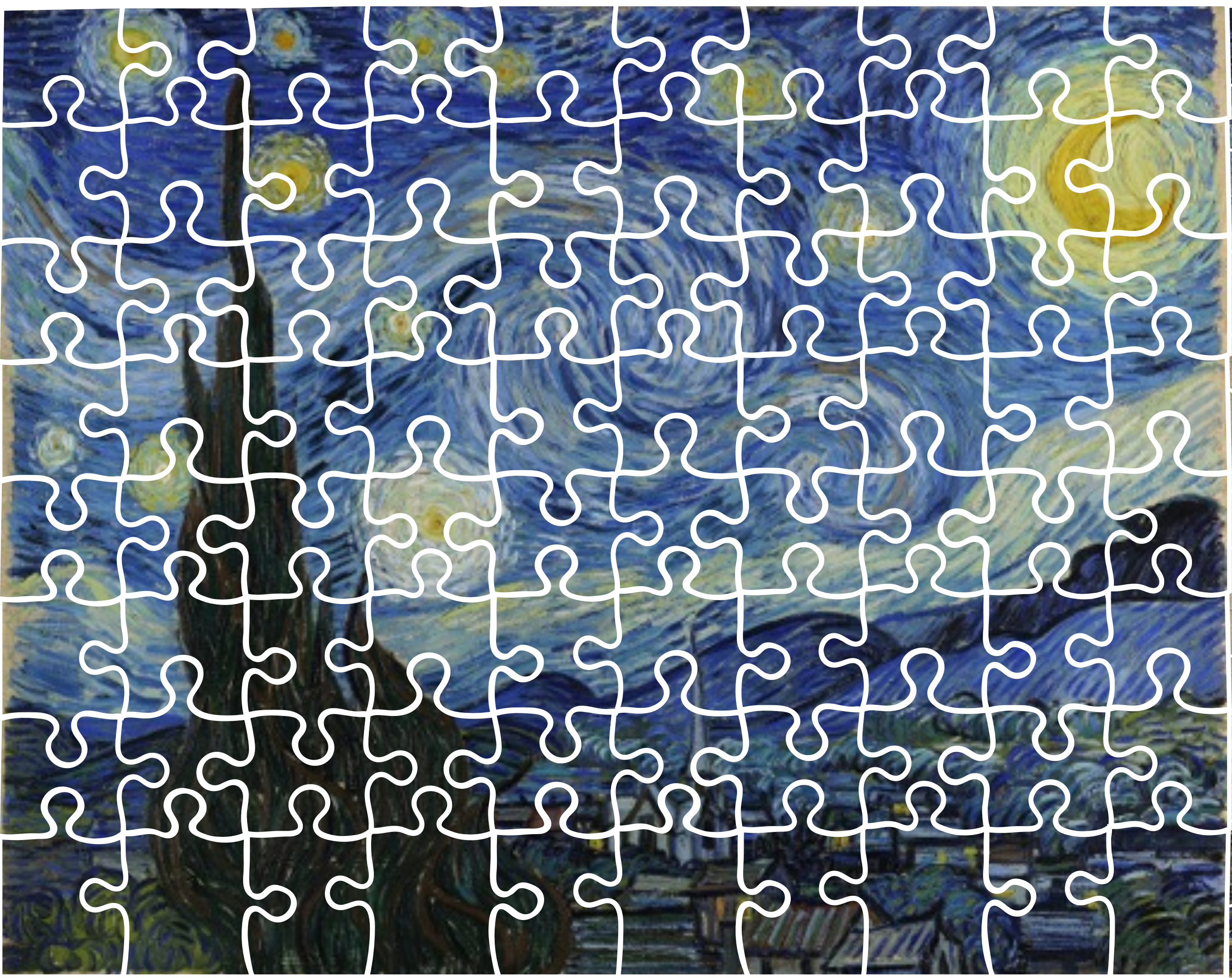
Just 4 You Puzzles

Big Picture Promotions



Adobe Photoshop

Ravensburger



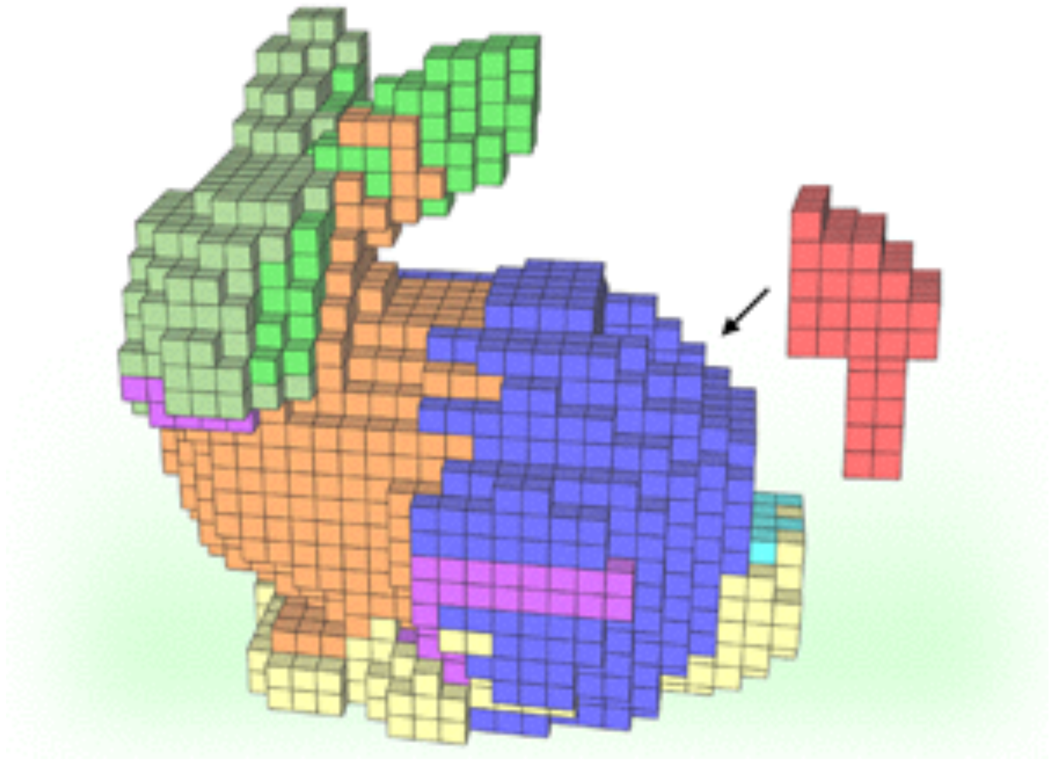

Liberty Puzzles


Artifact Puzzles

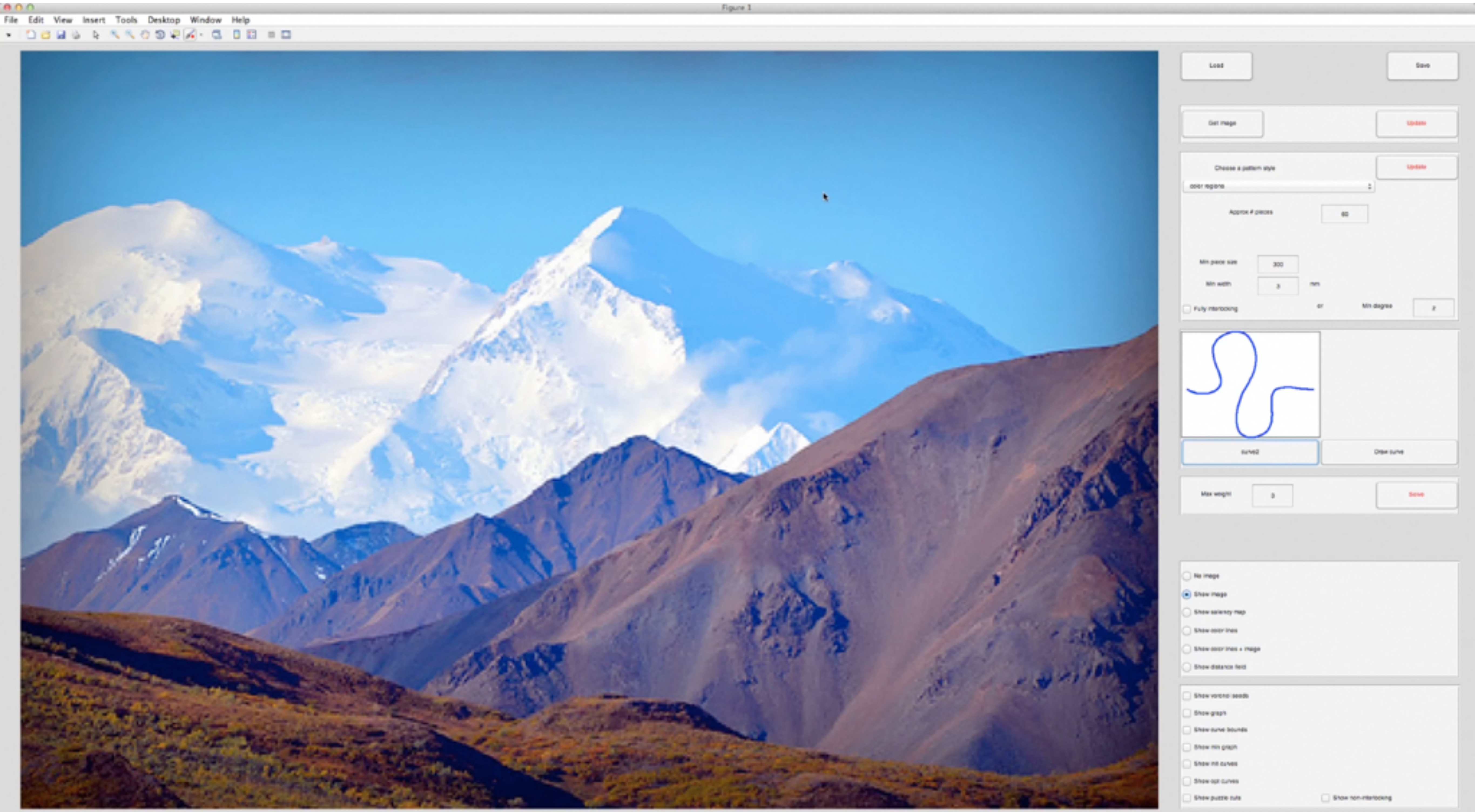

Wentworth Wooden Puzzles

[Xin et al. 2011]

[Lo et al. 2009]



[Song et al. 2012]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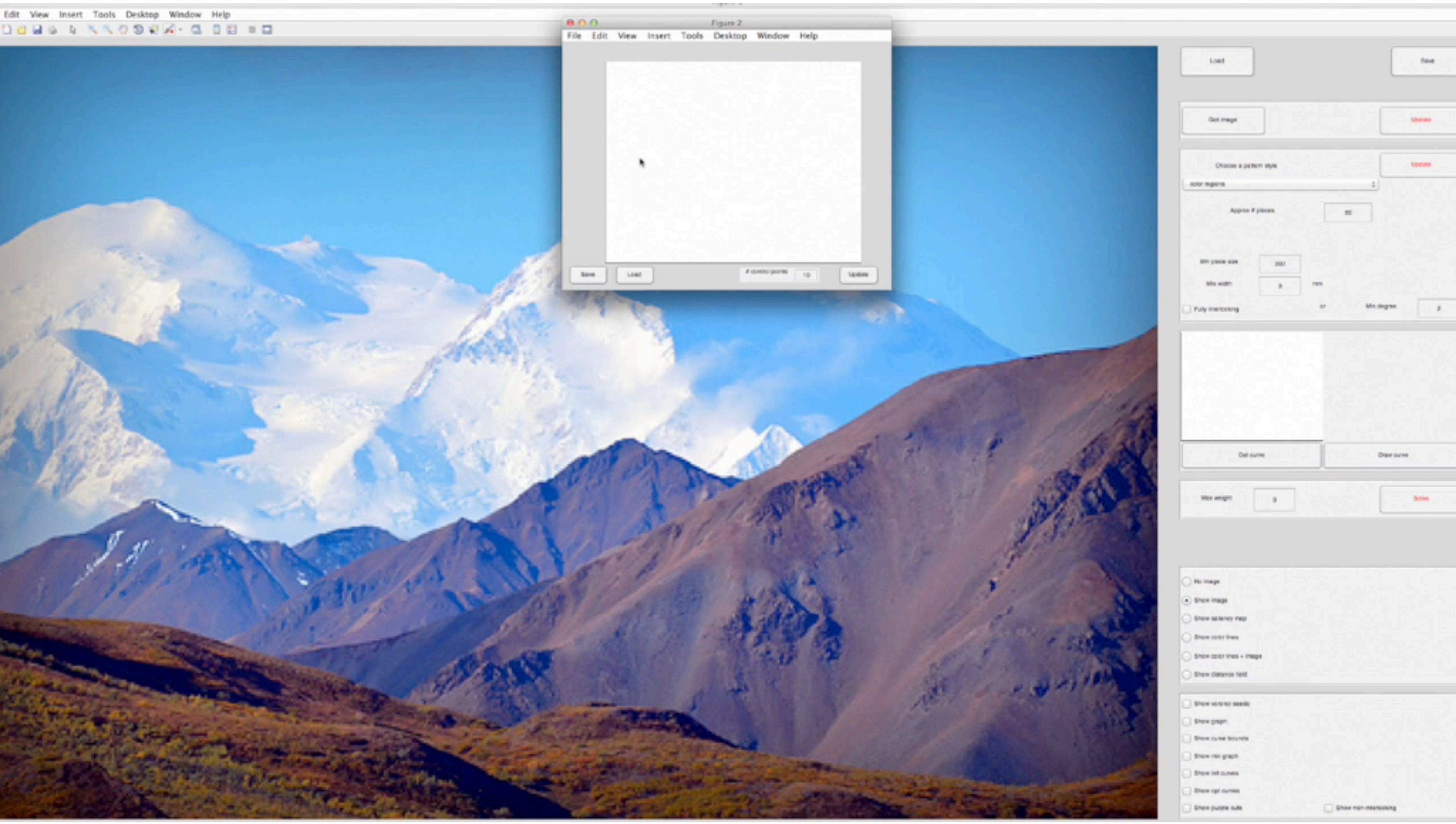
Edit View Insert Tools Desktop Window Help
Figure 2
File Edit View Insert Tools Desktop Window Help

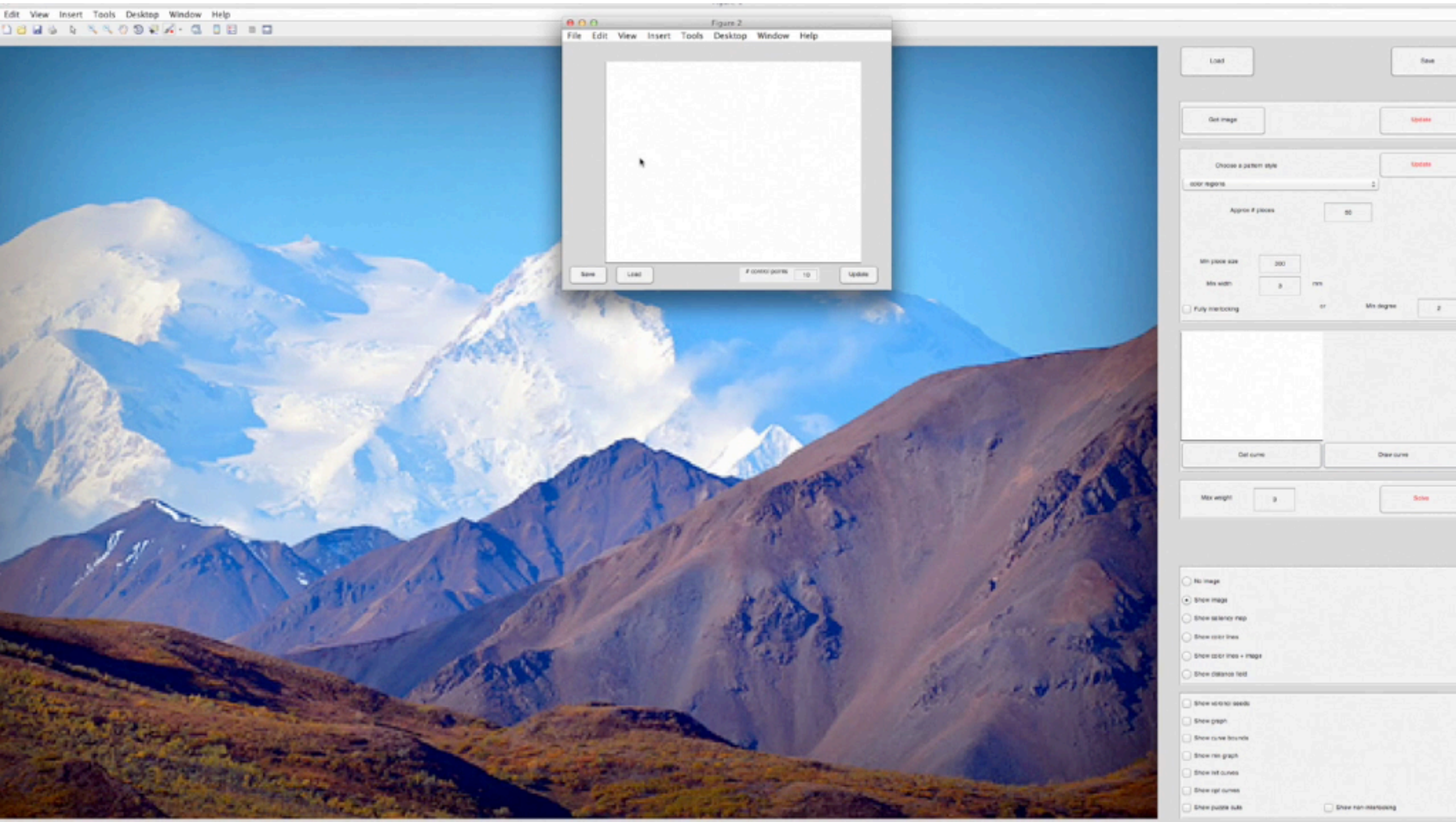
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Figure 2
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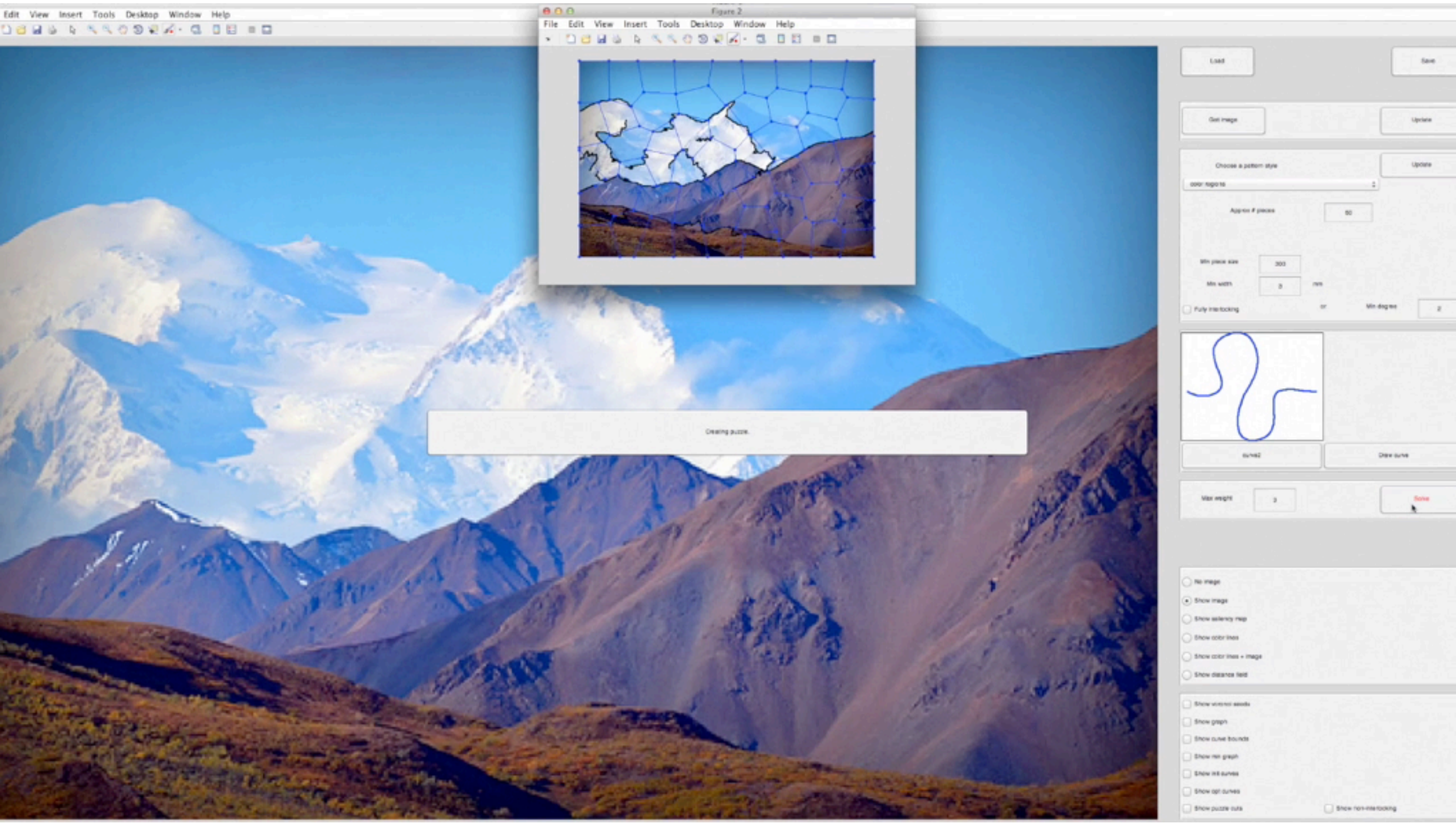
Edit View Insert Tools Desktop Window Help
Figure 2
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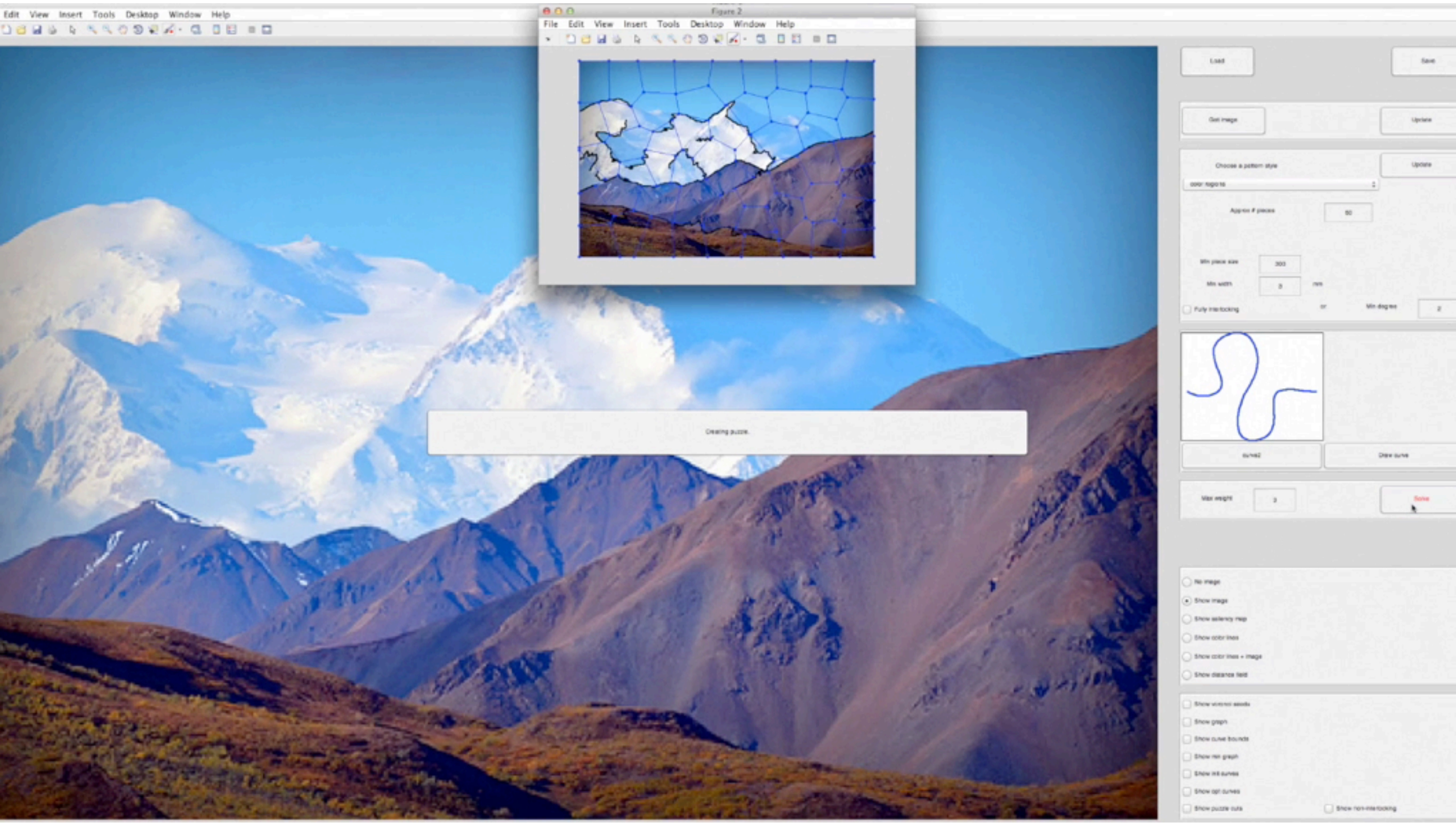
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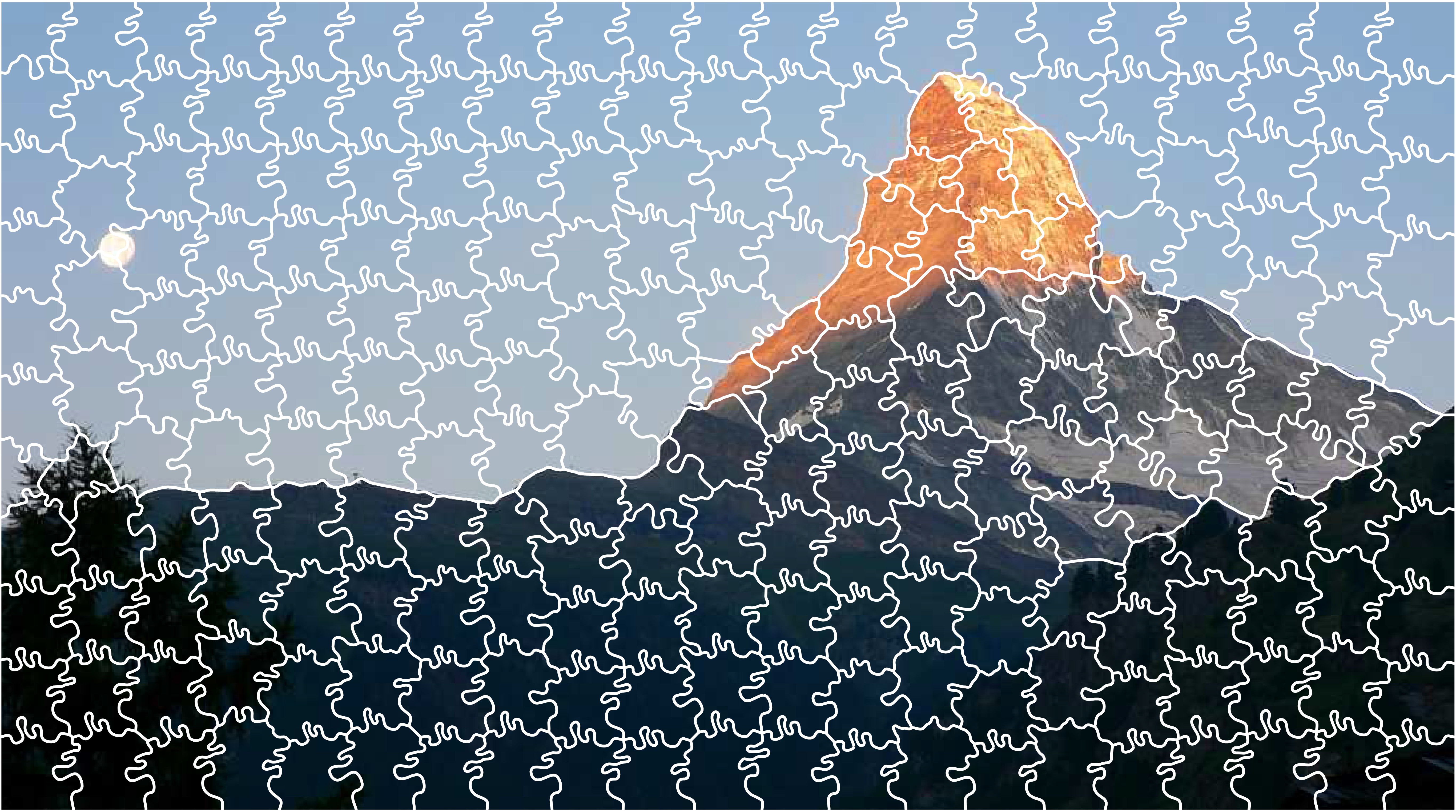
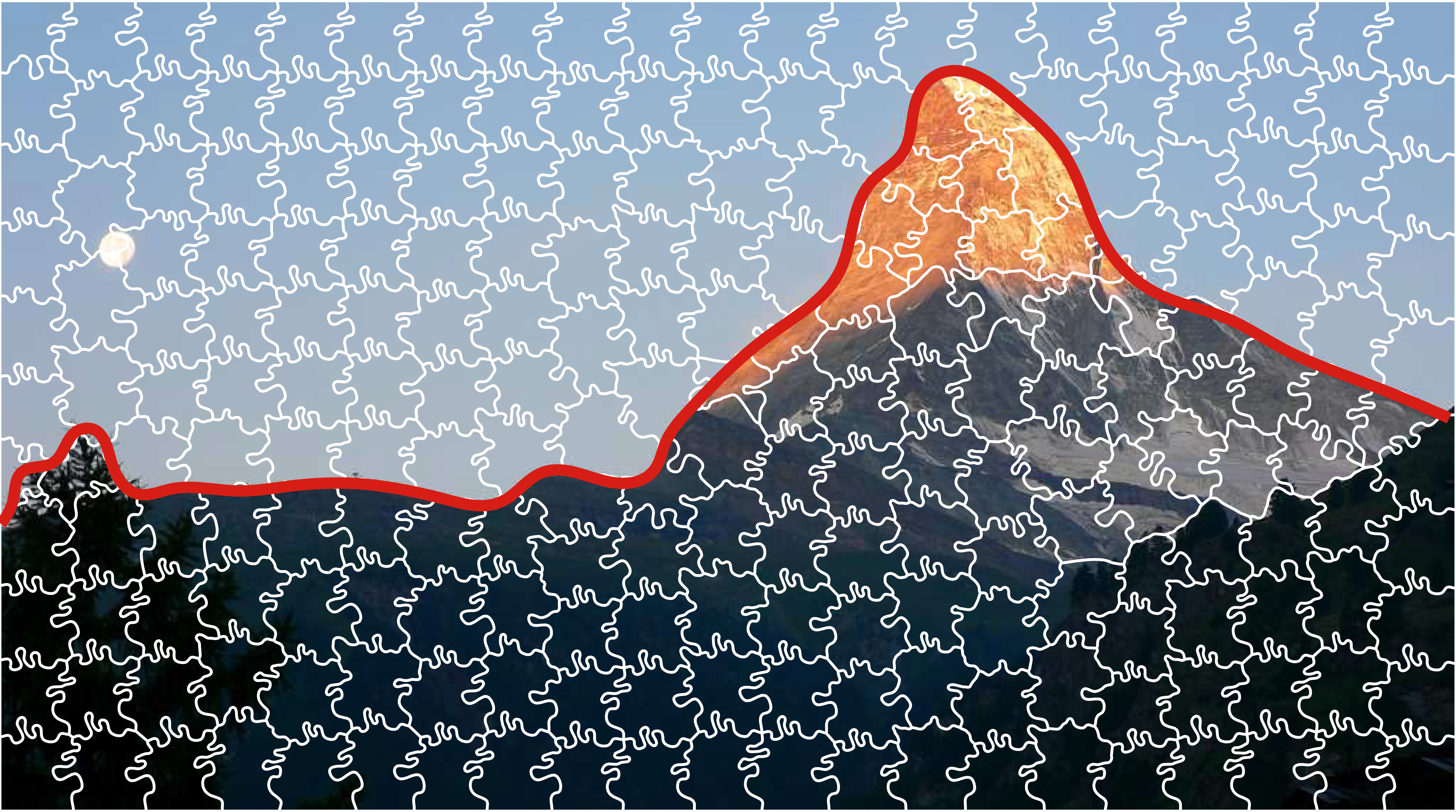
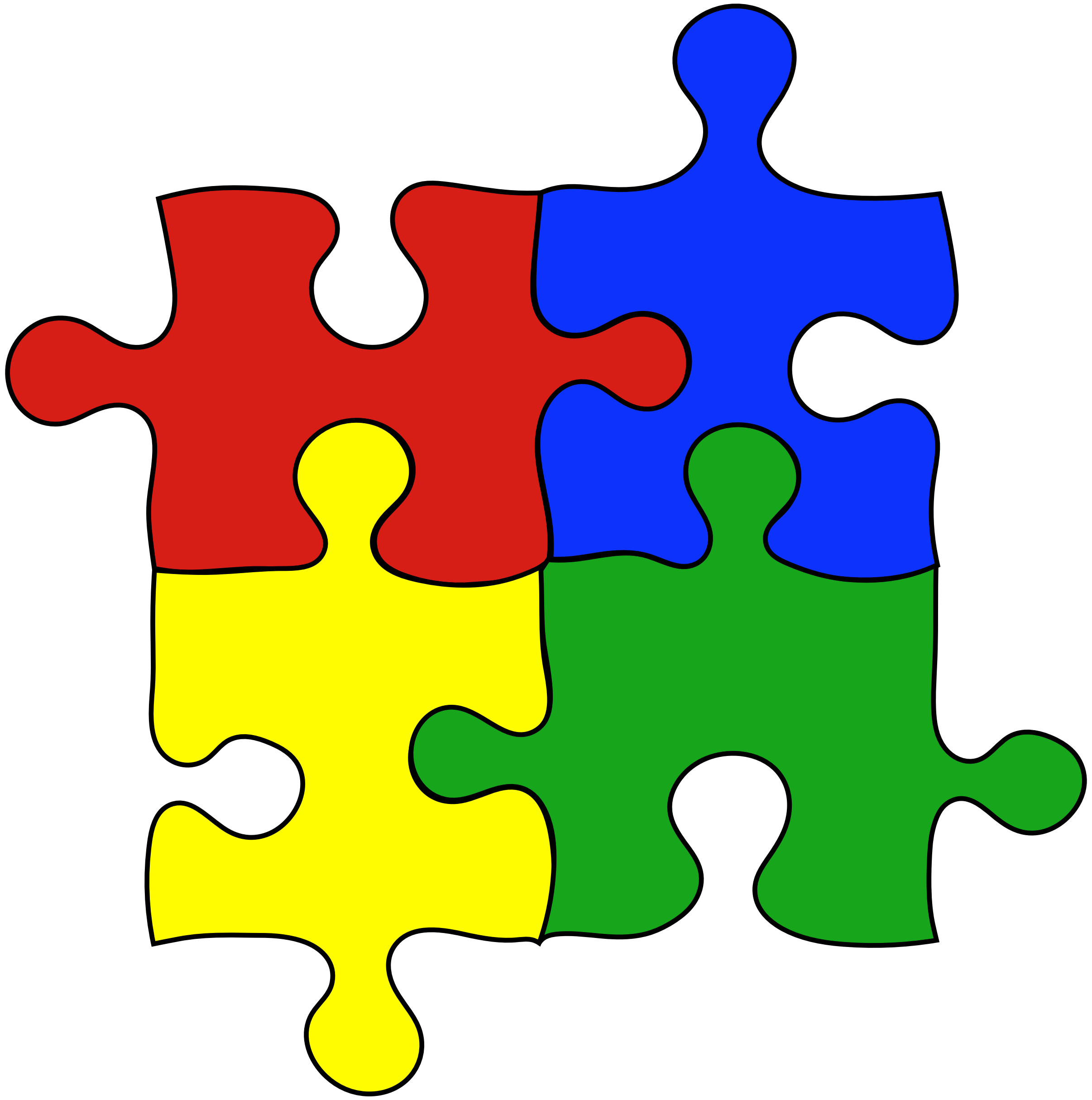
Figure 2
File Edit View Insert Tools Desktop Window Help



color line cutting

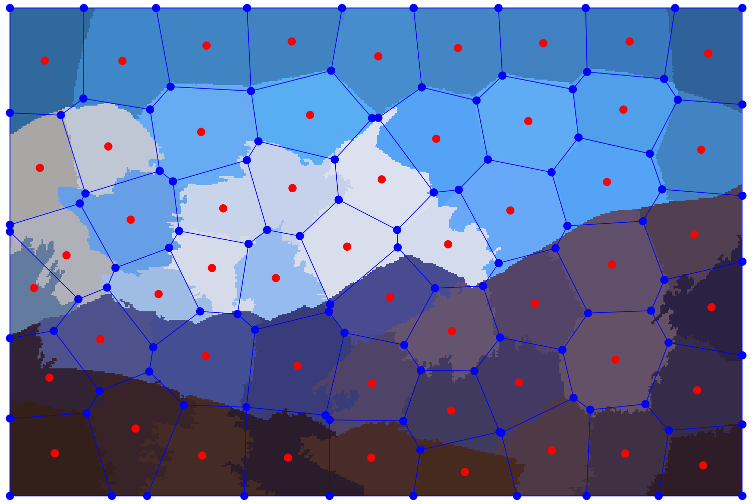


color line cutting



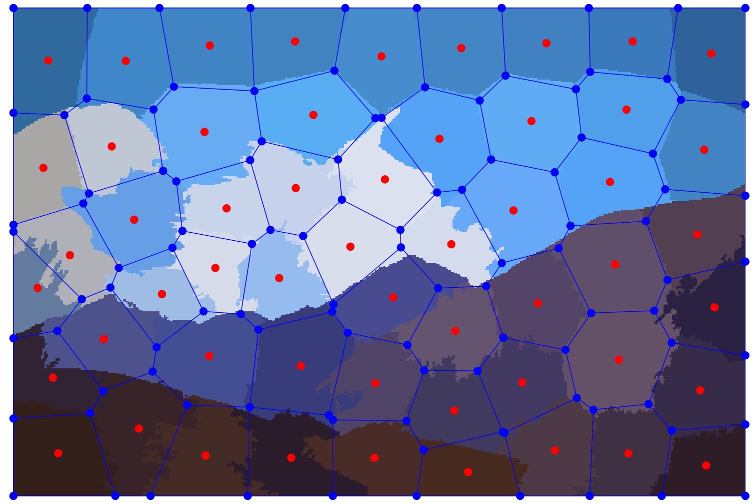
interlocking

input



graph

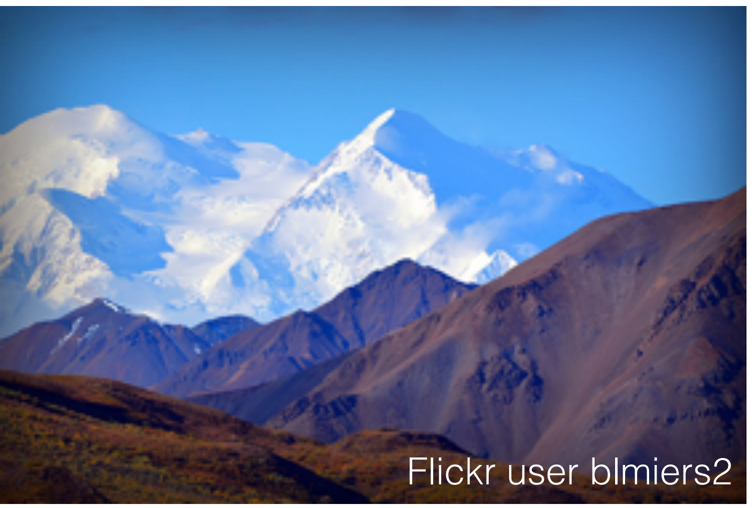
input



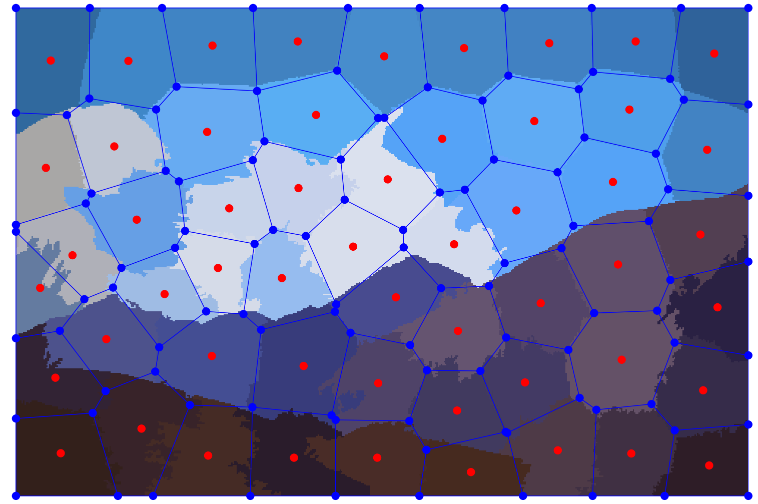
graph

input

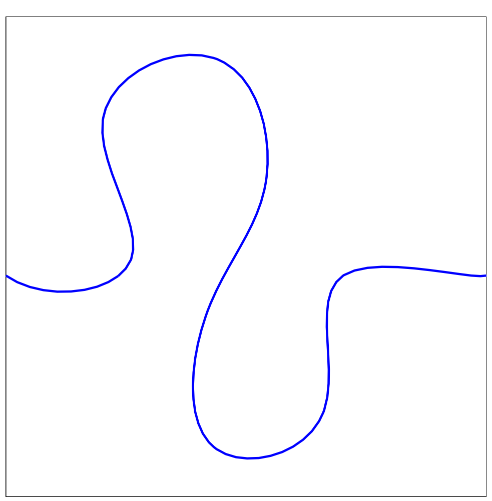
color lines

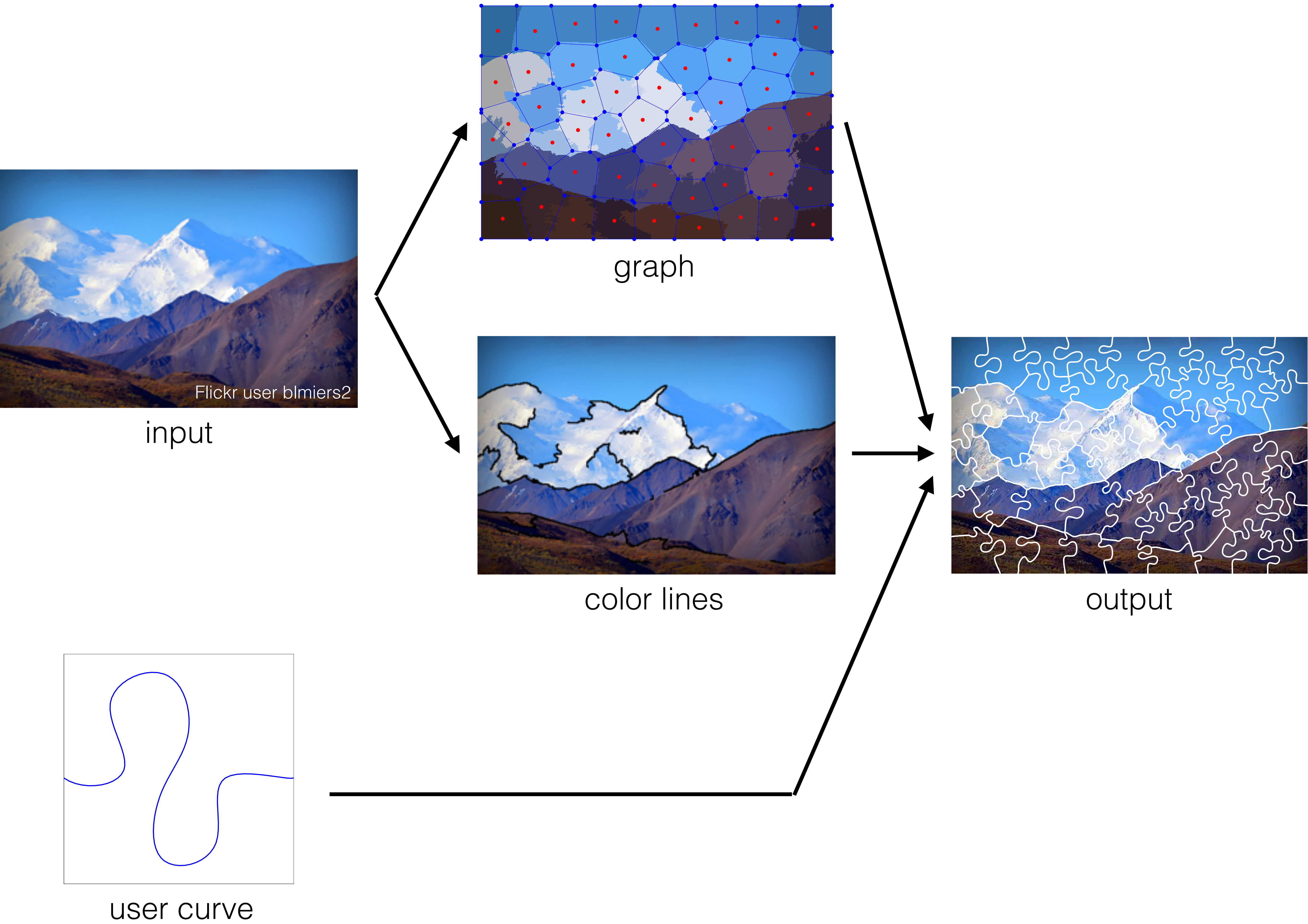


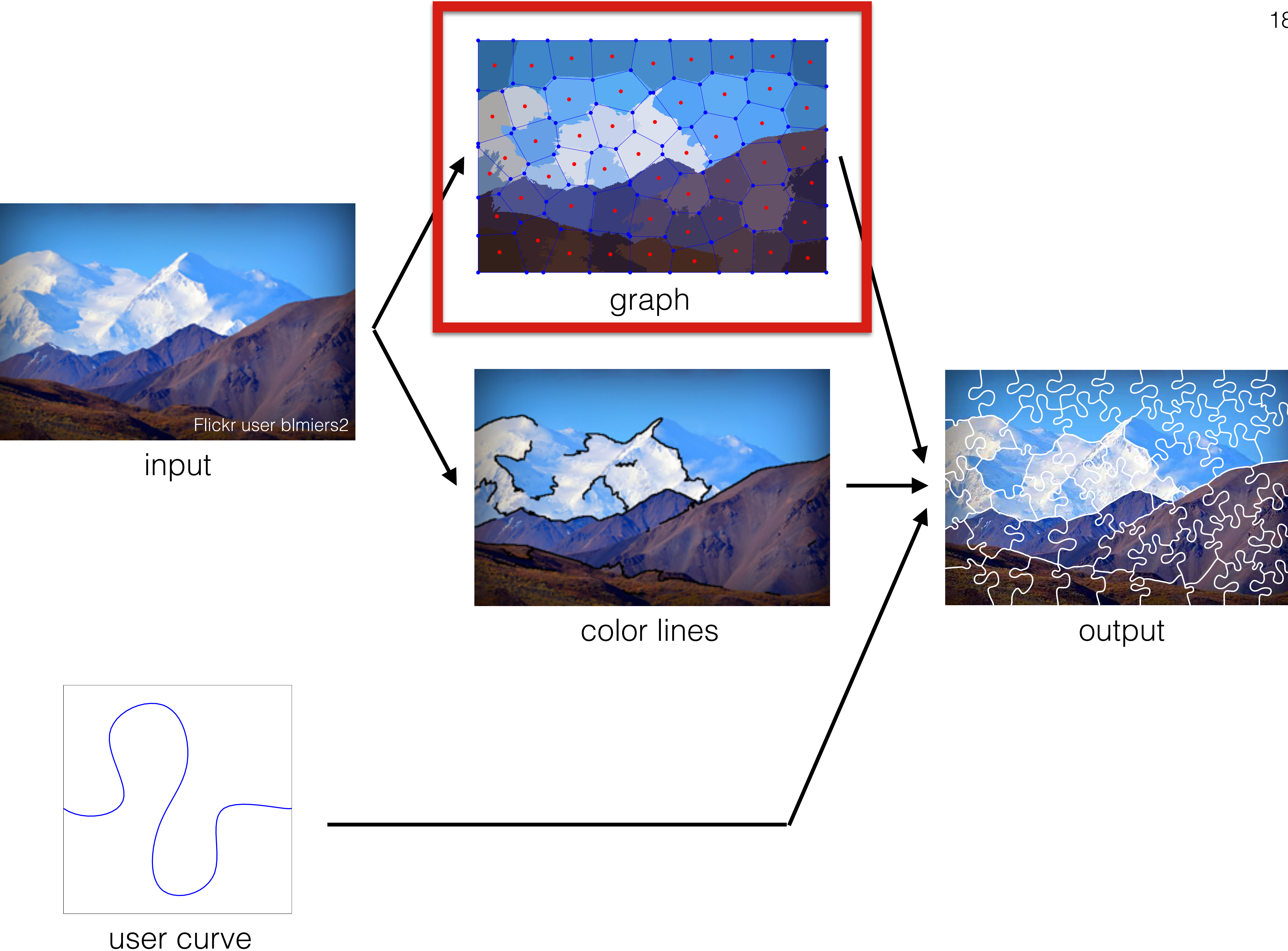
input


graph


color lines


user curve


graph
Flickr user blmiers2
input
color lines
output
user curve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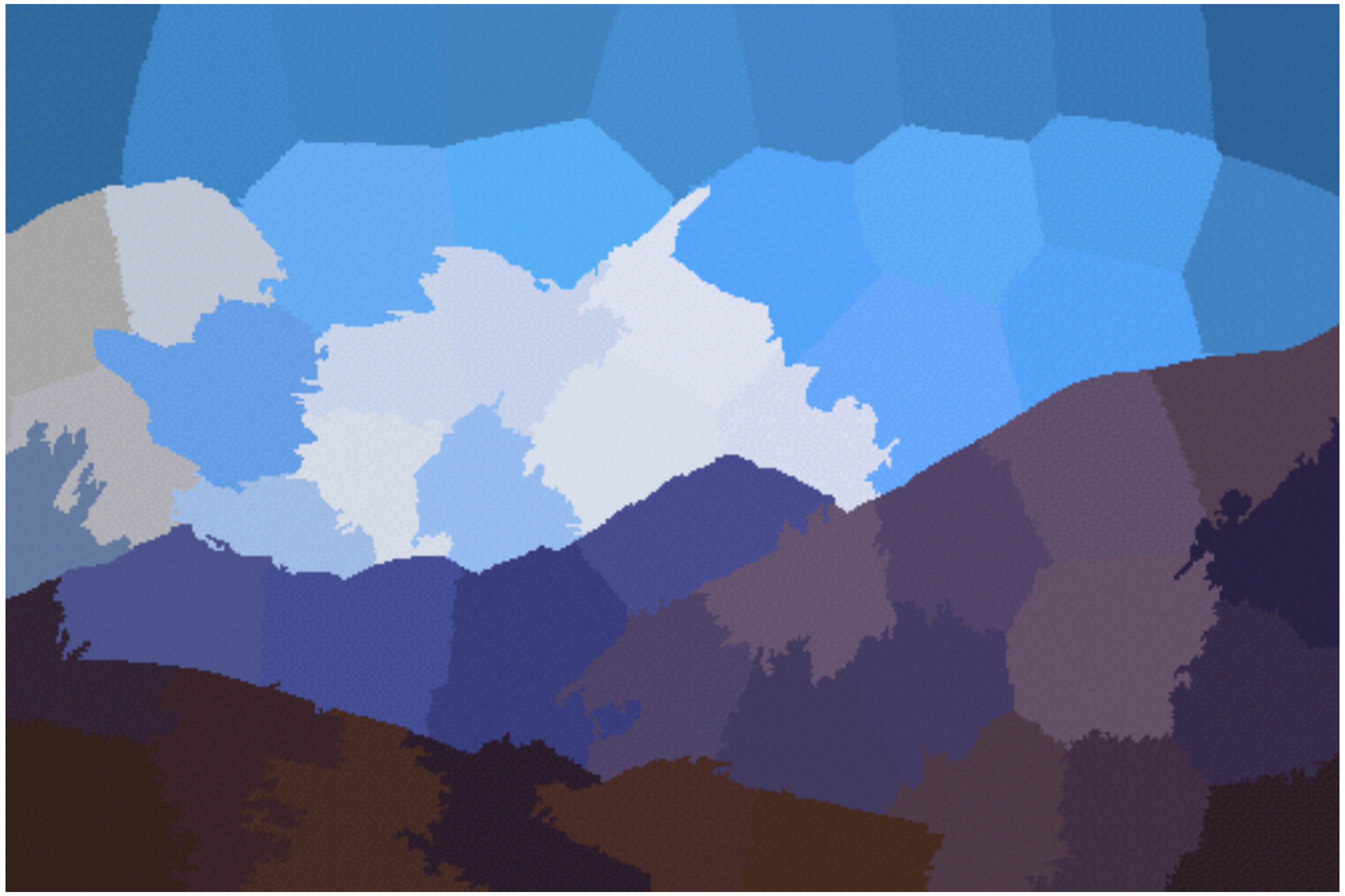
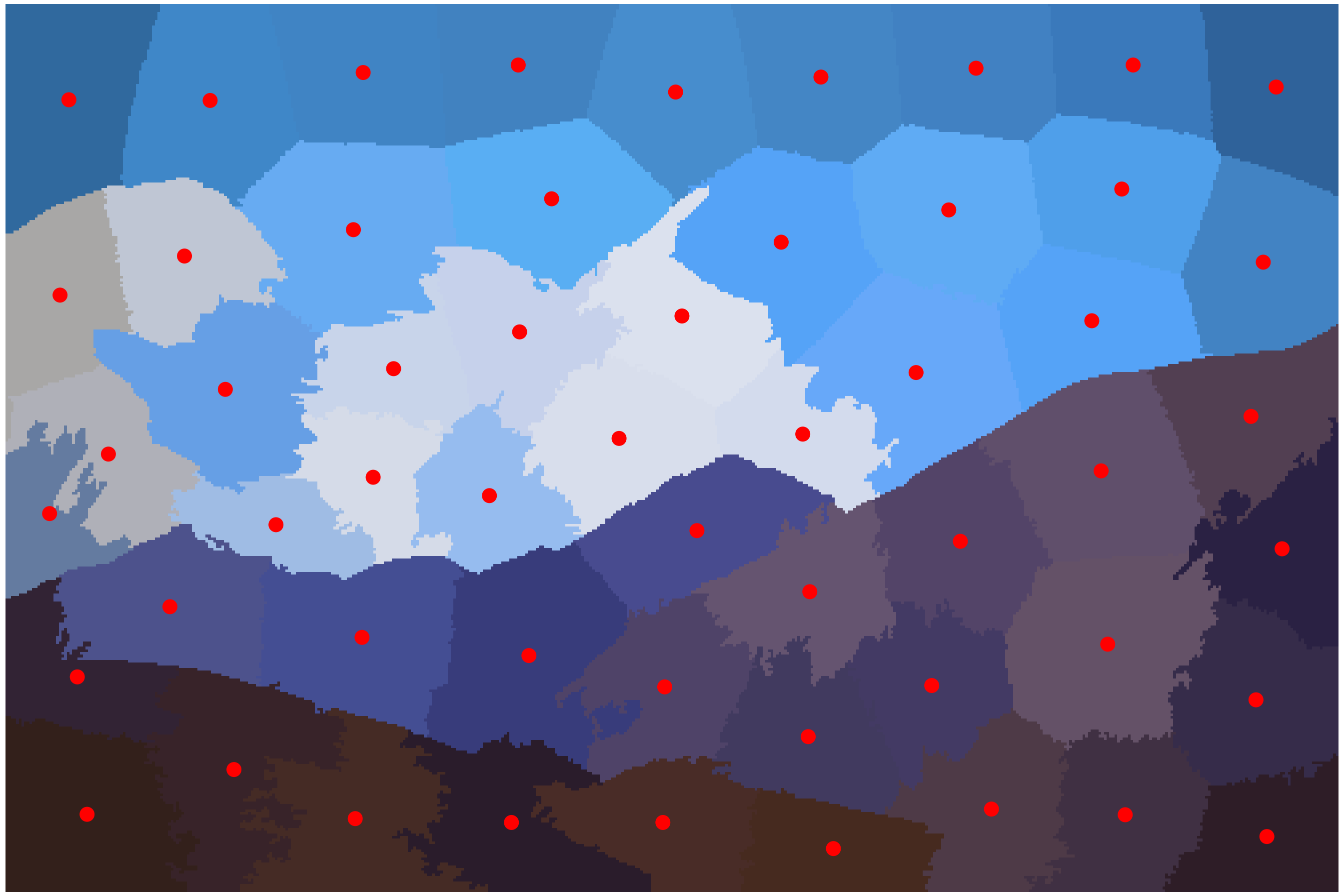
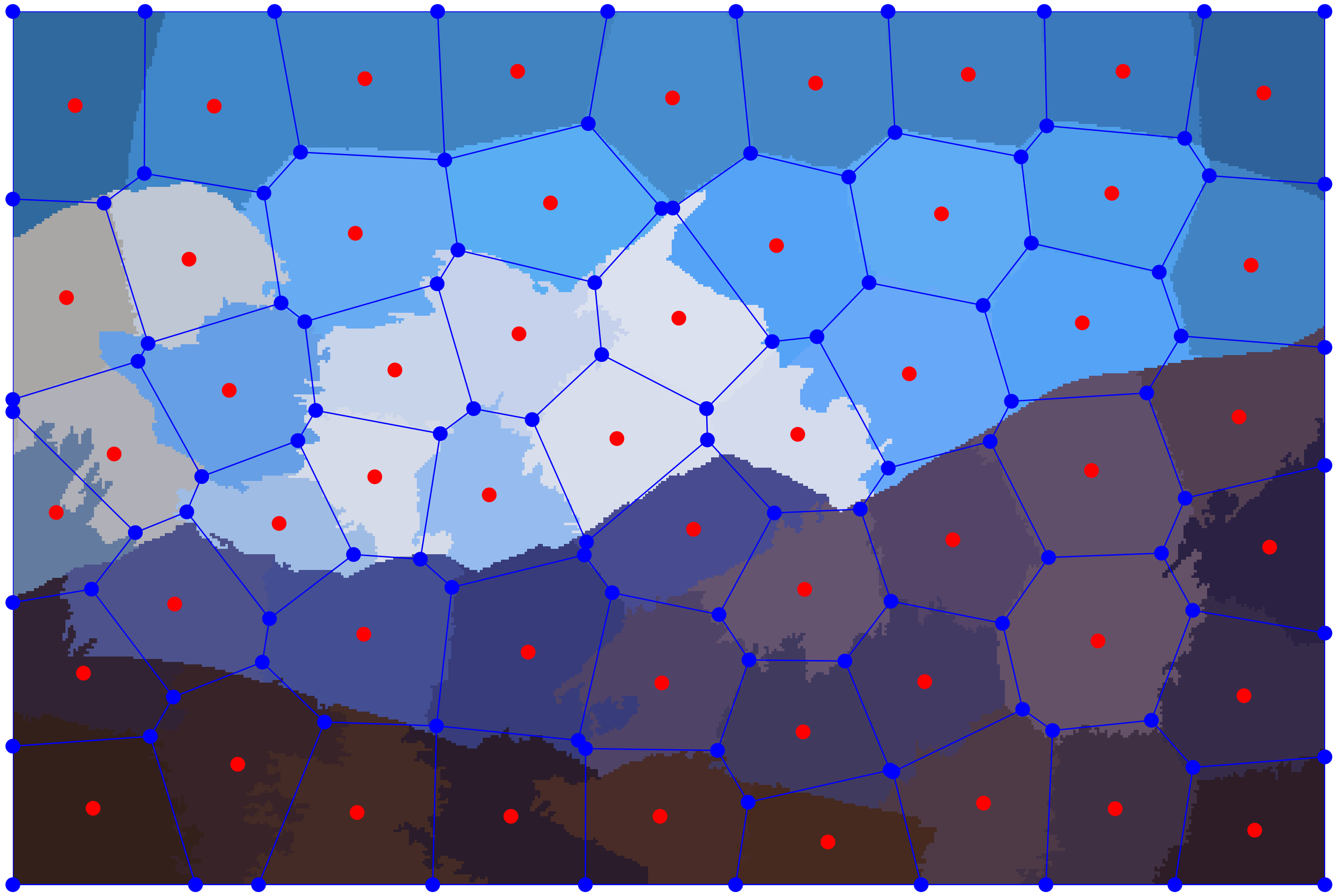
Flickr user blmiers2



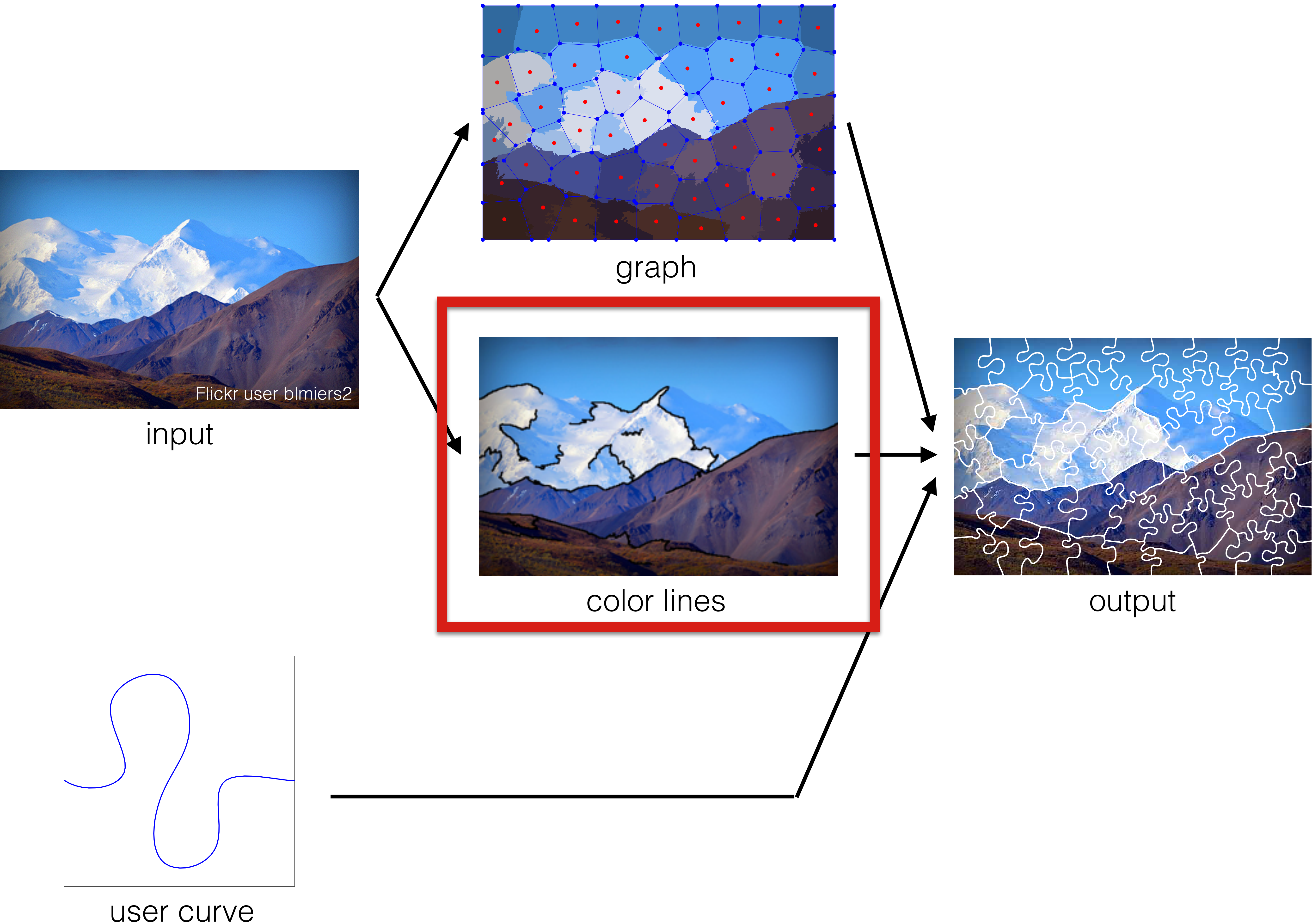
superpixels [Achanta et al. 2012]





Voronoi graph

Voronoi graph

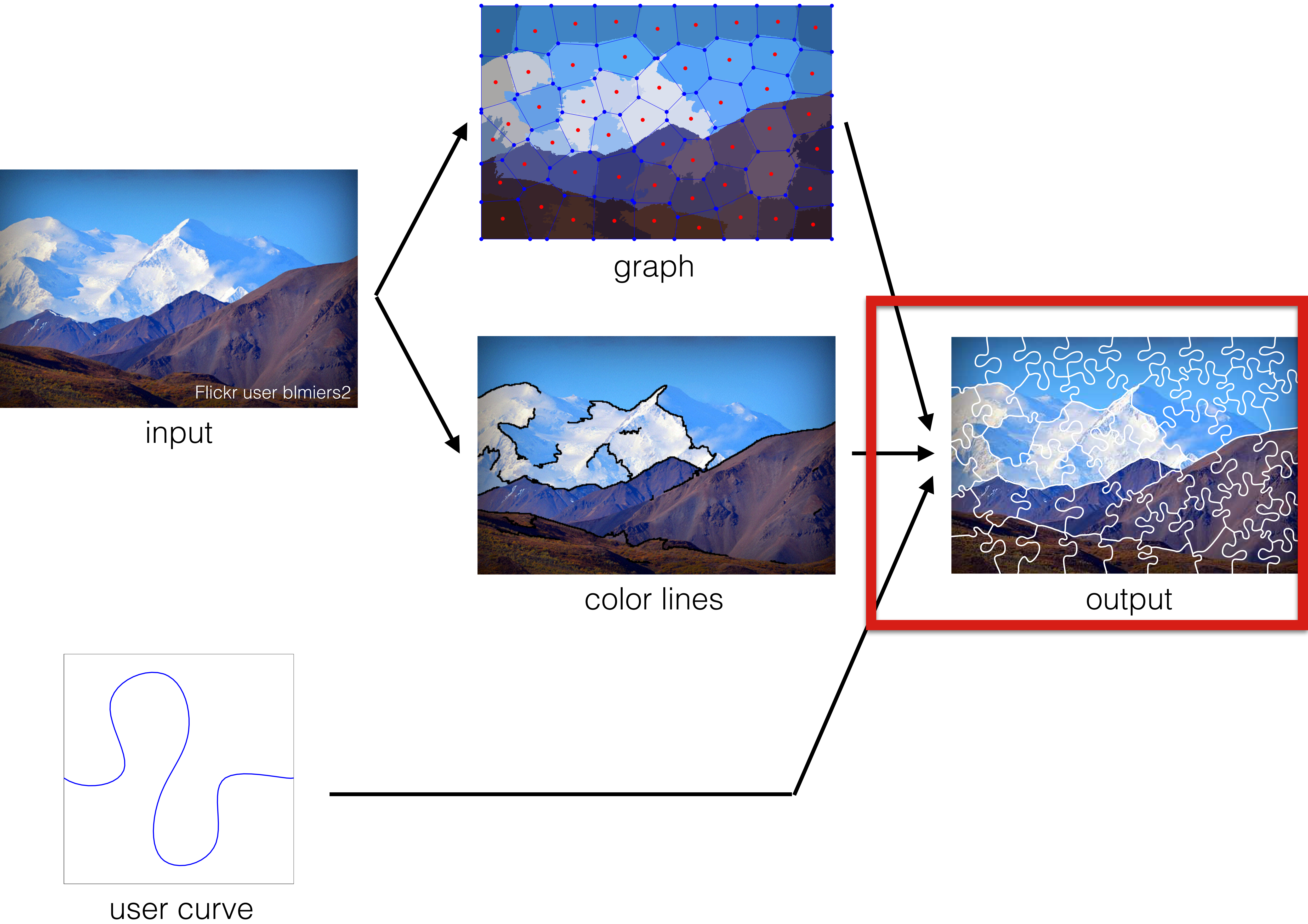

graph
Flickr user blmiers2
input
color lines
output
user curve


Flickr user blmiers2

superpixels [Achanta et al. 2012]

color lines

color lines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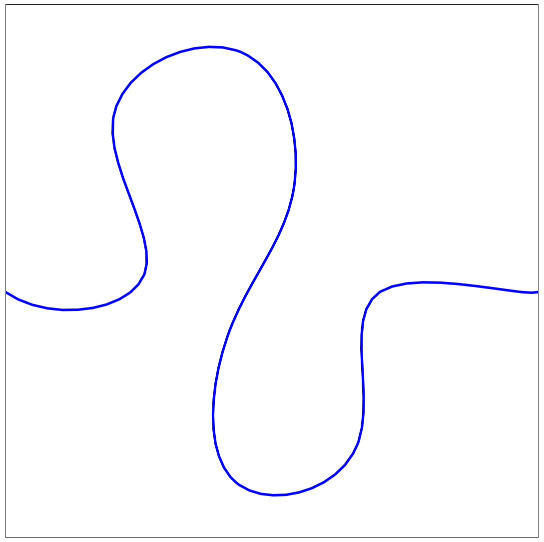
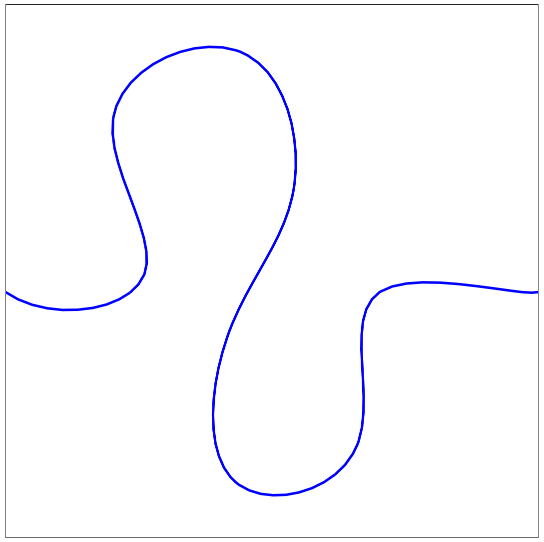


user curve

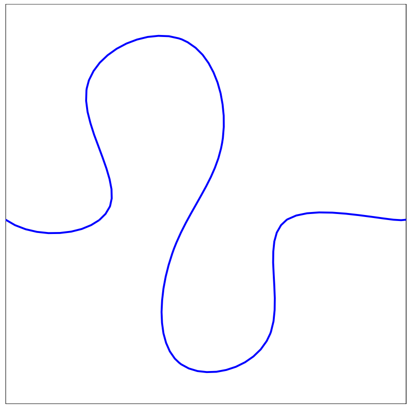
color lines



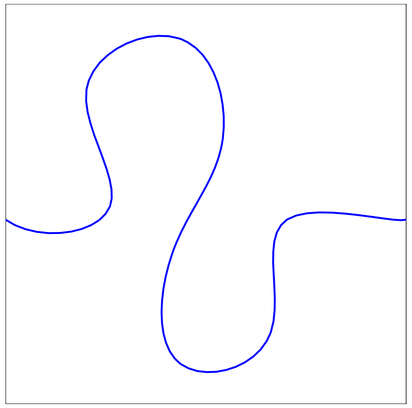
user curve

color lines

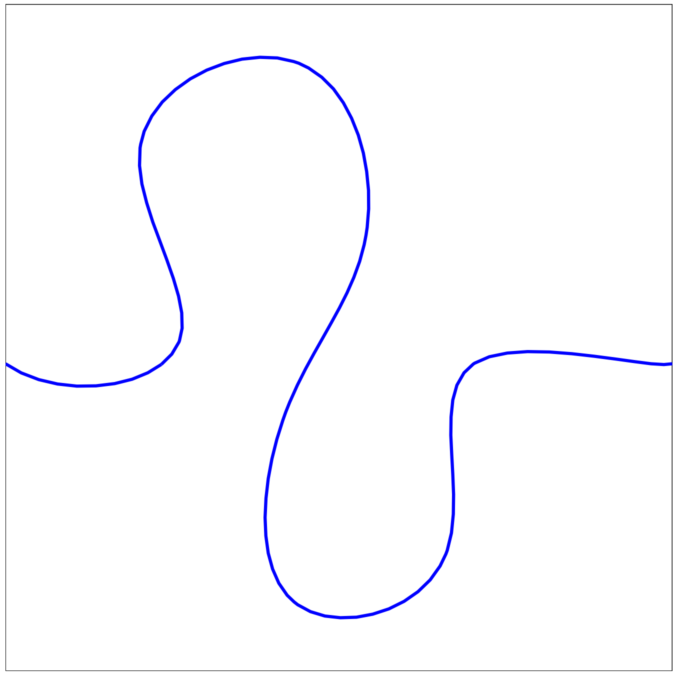
$$\text{minimize} \quad \text{(match user curve)} + \lambda \text{ (follow color lines)}$$



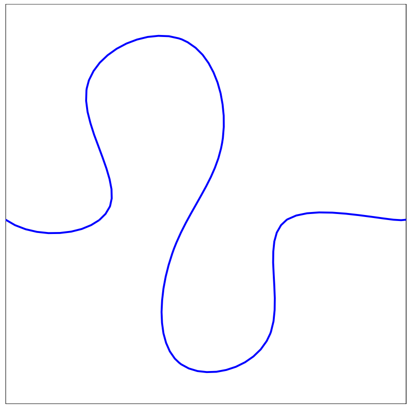
$$\text{minimize} \quad \text{(match user curve)} + \lambda \; \text{(follow color lines)}$$



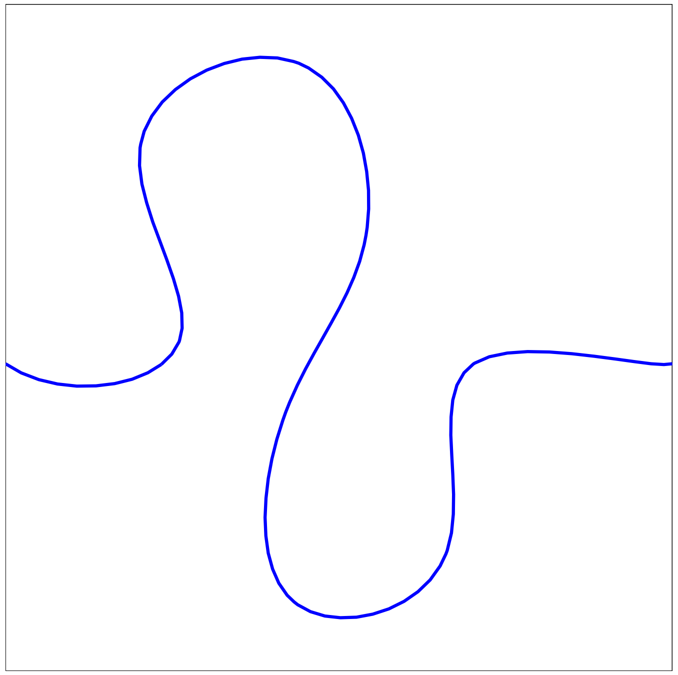
minimize (match user curve) $+\lambda$ (follow color lines)



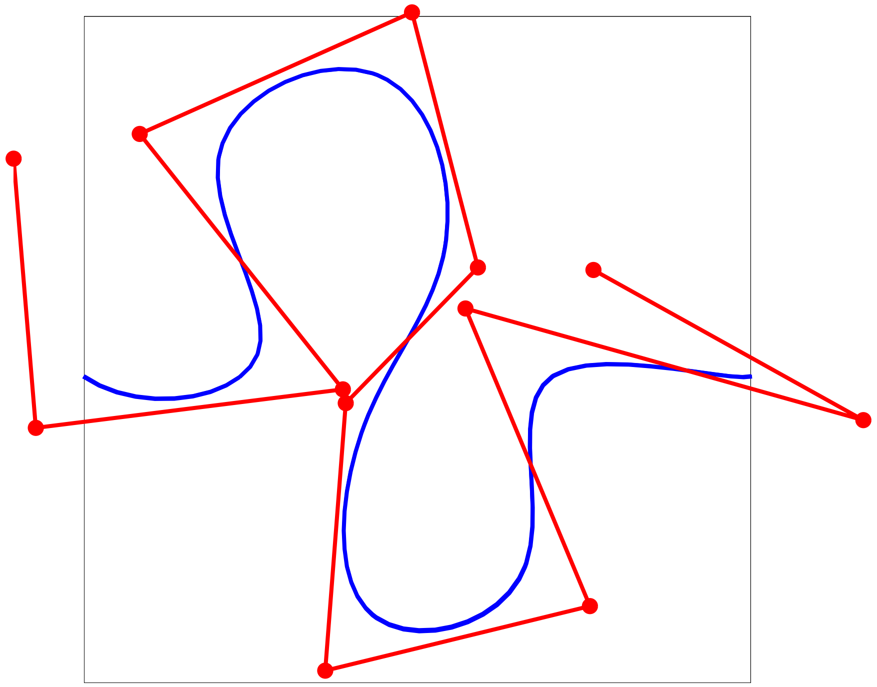
B-spline



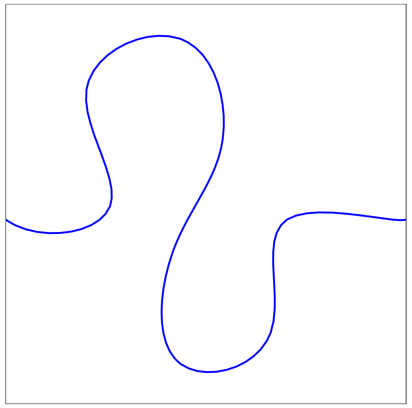
$\mathrm{minimize}$ (match user curve) $+\lambda$ (follow color lines)



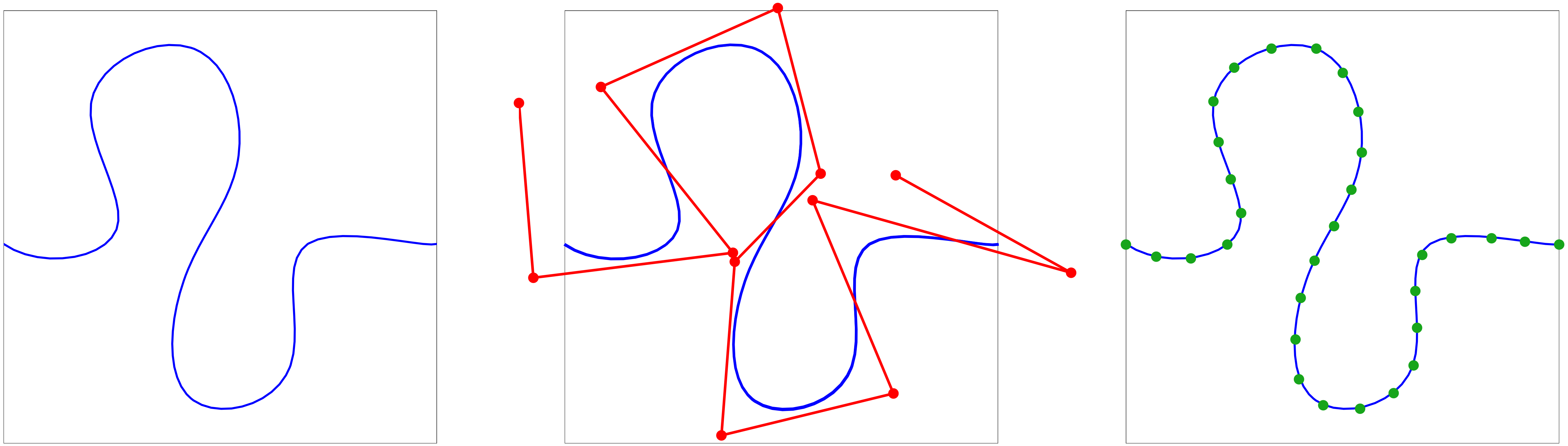
B-spline



control points $\mathbf{x}$



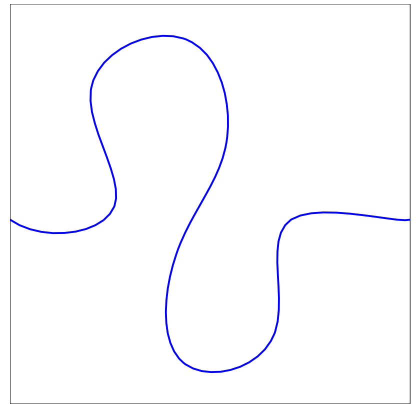
$$\text{minimize} \quad \text{(match user curve)} + \lambda \text{ (follow color lines)}$$



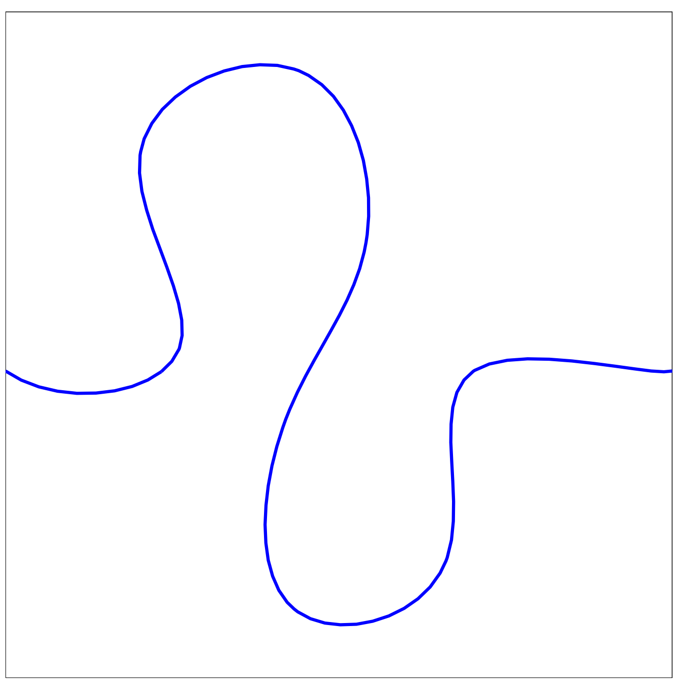
B-spline

control points $\mathbf{x}$

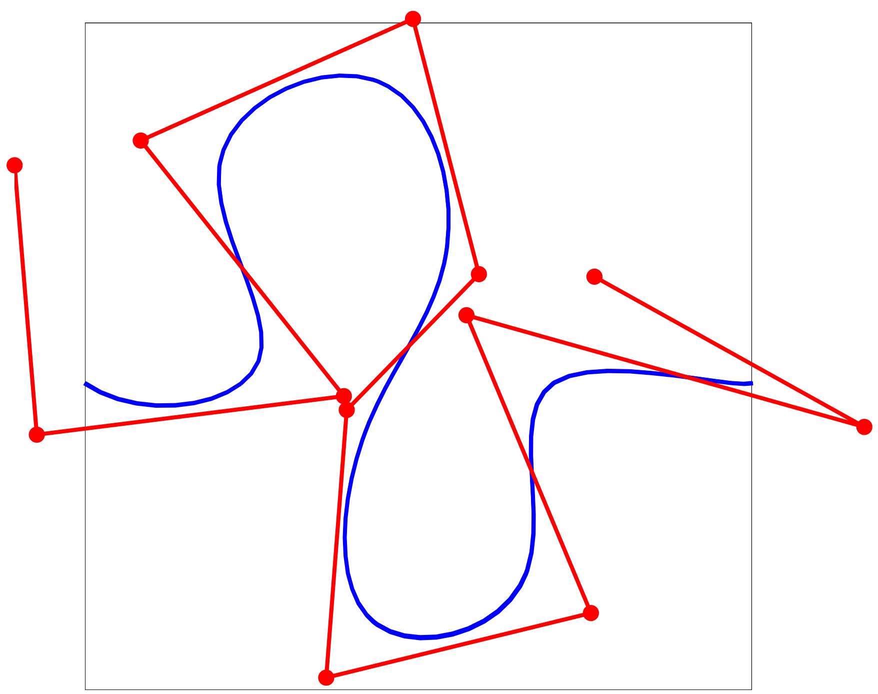
sample points $\mathbf{Bx}$



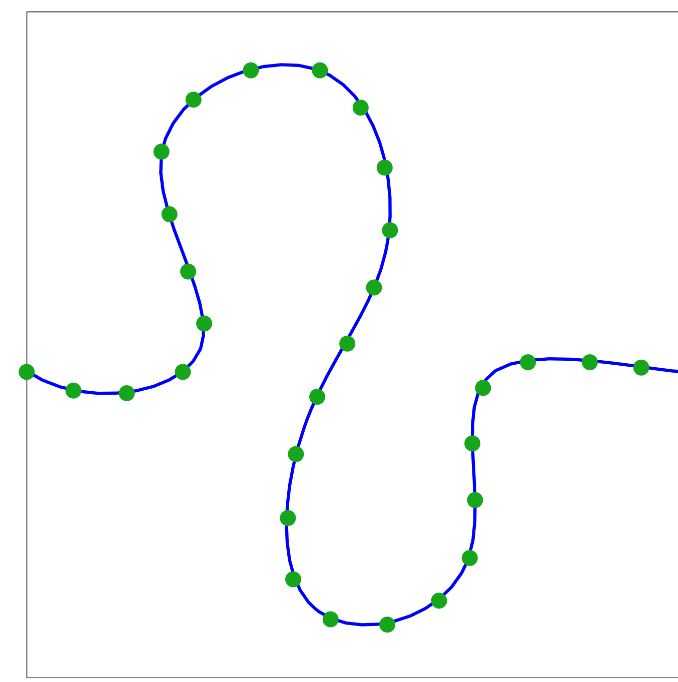
$\min$ (match user curve) $+\lambda$ (follow color lines)



B-spline

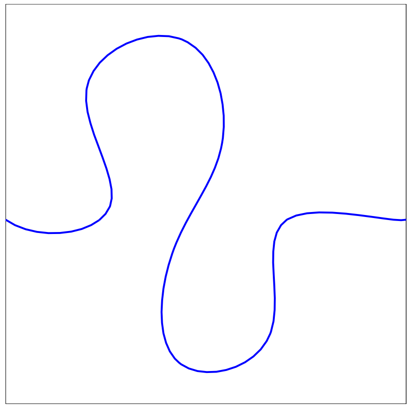


control points $\mathbf{x}$

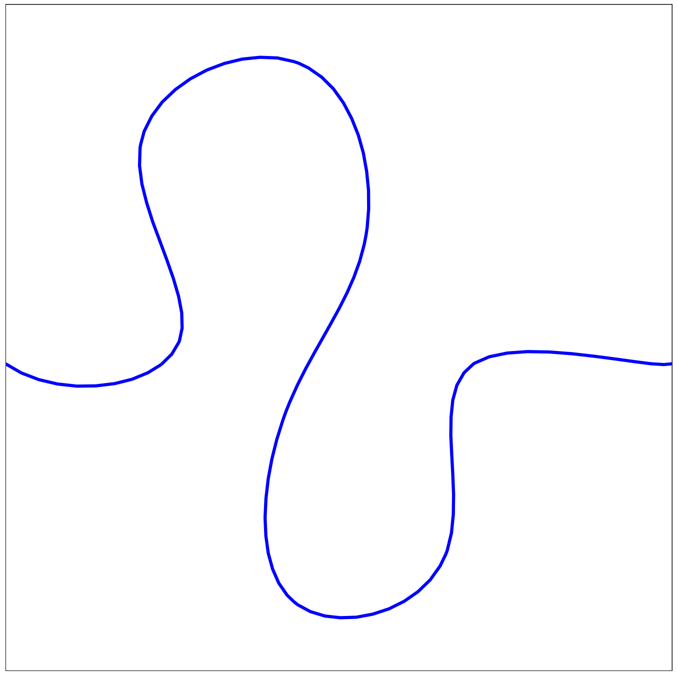


sample points $\mathbf{Bx}$

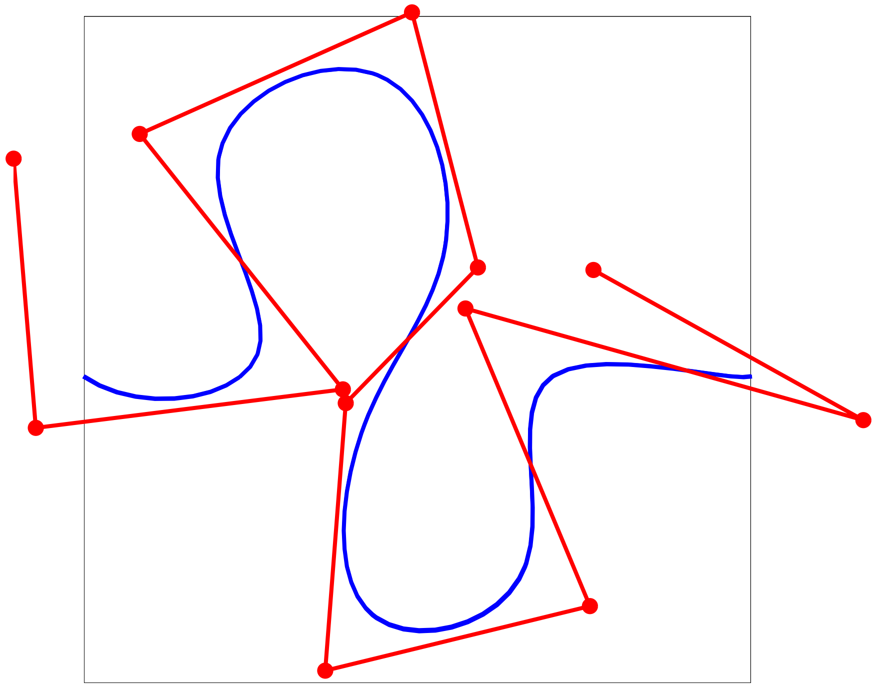
$\mathbf{B}'\mathbf{x} =$ sample points along 1st derivative



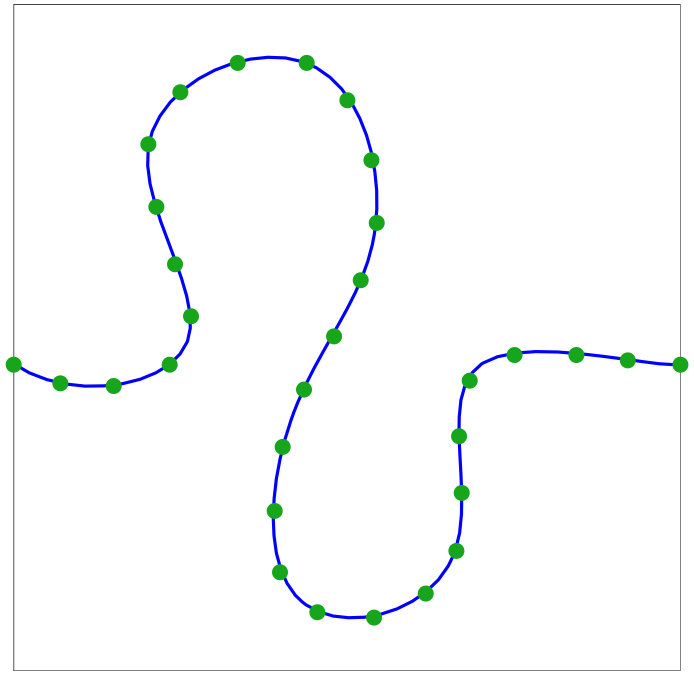
$$\underset{\mathbf{x}}{\text{minimize}} \quad \left\|\mathbf{B}'\mathbf{x} - \mathbf{B}'\mathbf{x_u}\right\|^2 \quad +\lambda \text{ (follow color lines)}$$



B-spline

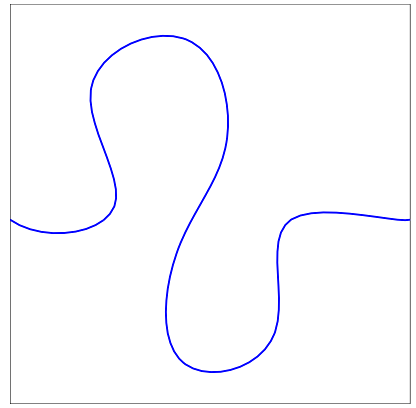


control points $\mathbf{x}$



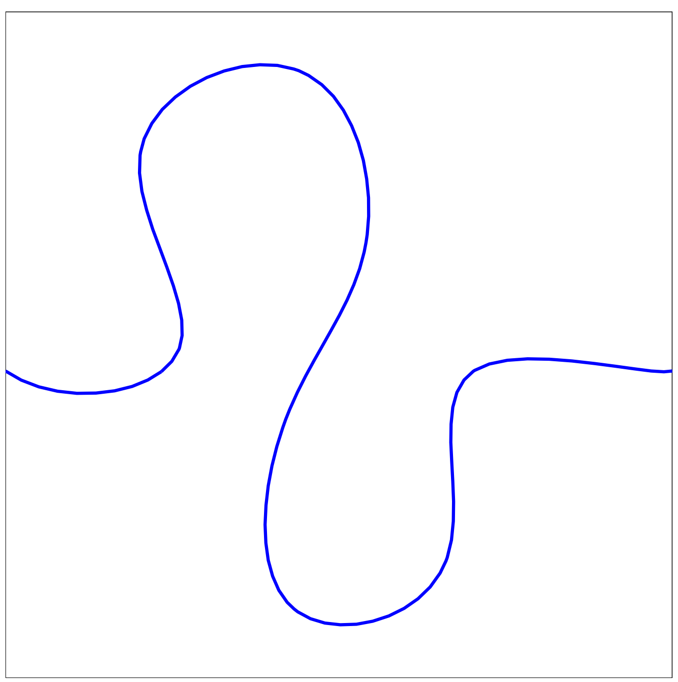
sample points $\mathbf{Bx}$

$\mathbf{B}'\mathbf{x} =$ sample points along 1st derivative

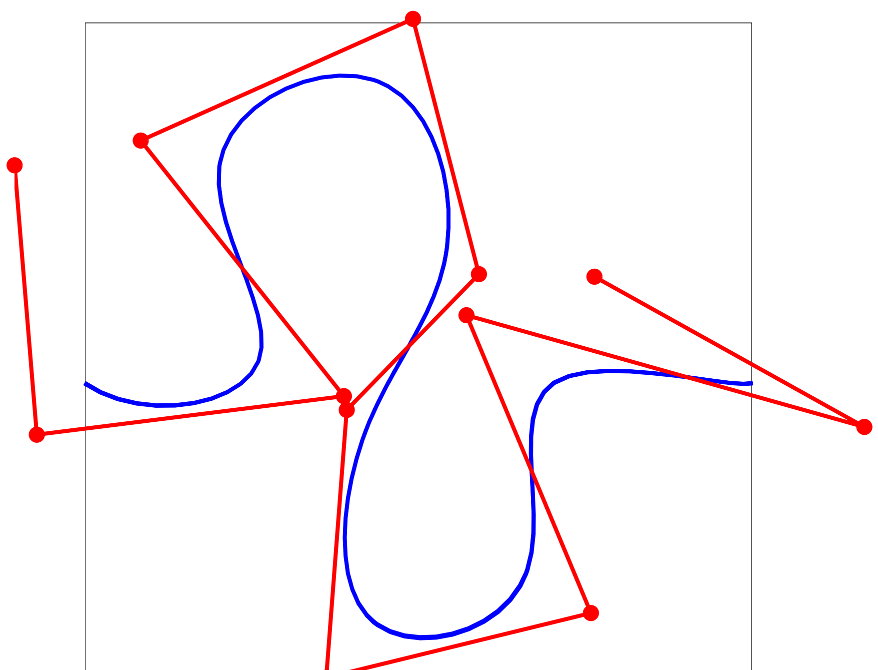


$$\underset{\mathbf{x}}{\text{minimize}} \quad \left\| \mathbf{B}'\mathbf{x} - \mathbf{B}'\mathbf{x_u} \right\|^2 \quad + \lambda \text{ (follow color lines)}$$

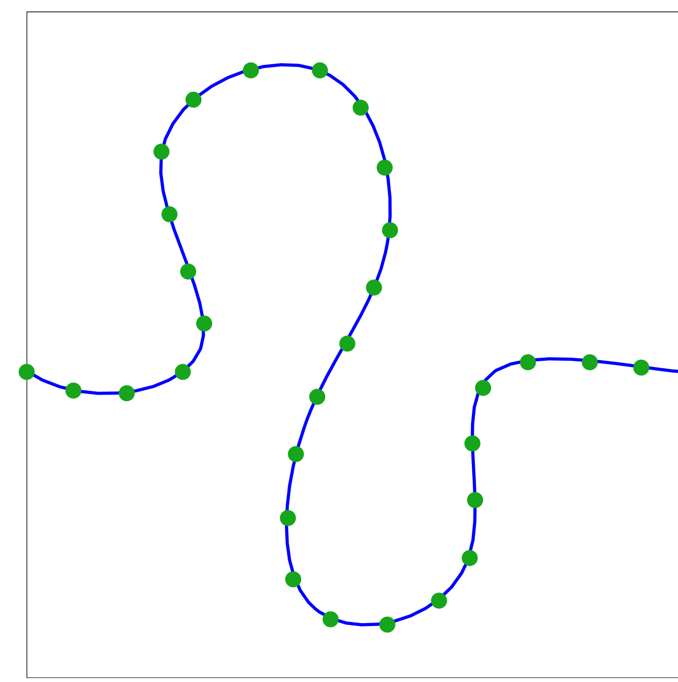
user curve
(1st derivative)



B-spline

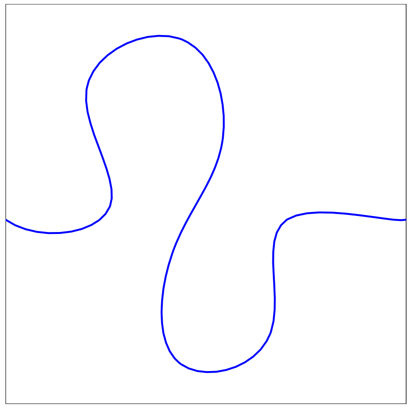


control points $\mathbf{x}$

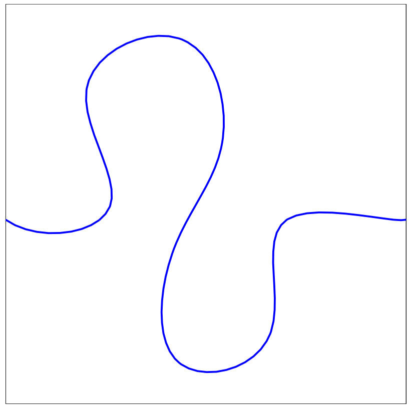


sample points $\mathbf{Bx}$

$\mathbf{B}'\mathbf{x} =$ sample points along 1st derivative

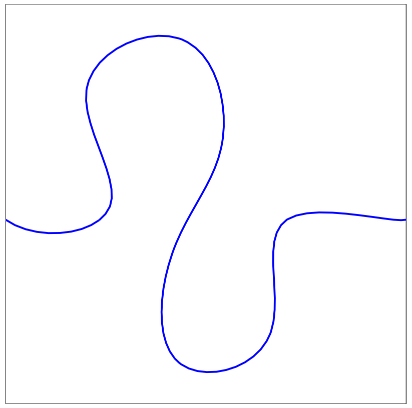


$$\underset{\mathbf{x}}{\text{minimize}} \quad \left\|\mathbf{B}'\mathbf{x} - \mathbf{B}'\mathbf{x_u}\right\|^2 \quad + \lambda \text{ (follow color lines)}$$



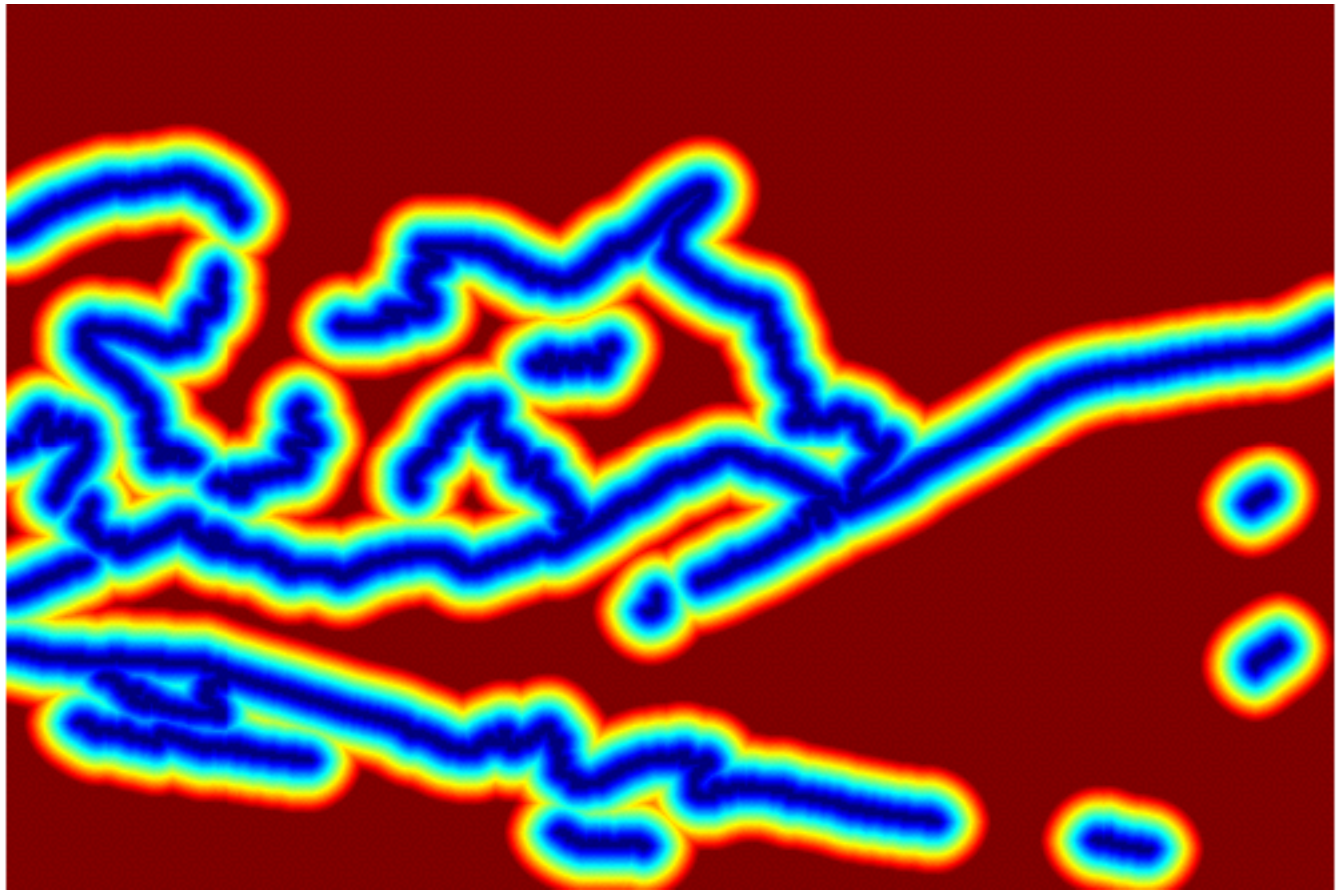
$$\underset{\mathbf{x}}{\text{minimize}} \quad \left\|\mathbf{B}'\mathbf{x} - \mathbf{B}'\mathbf{x_u}\right\|^2 \quad +\lambda \text{ (follow color lines)}$$

color lines

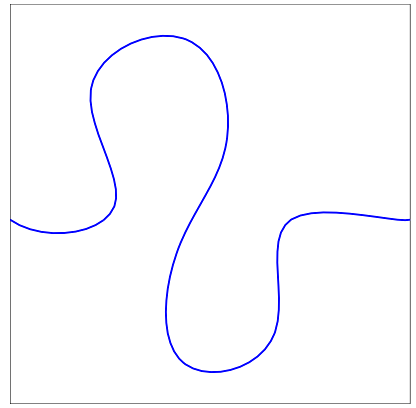


$$\underset{\mathbf{x}}{\text{minimize}} \quad \left\|\mathbf{B}'\mathbf{x} - \mathbf{B}'\mathbf{x_u}\right\|^2 \quad + \lambda \text{ (follow color lines)}$$

color lines

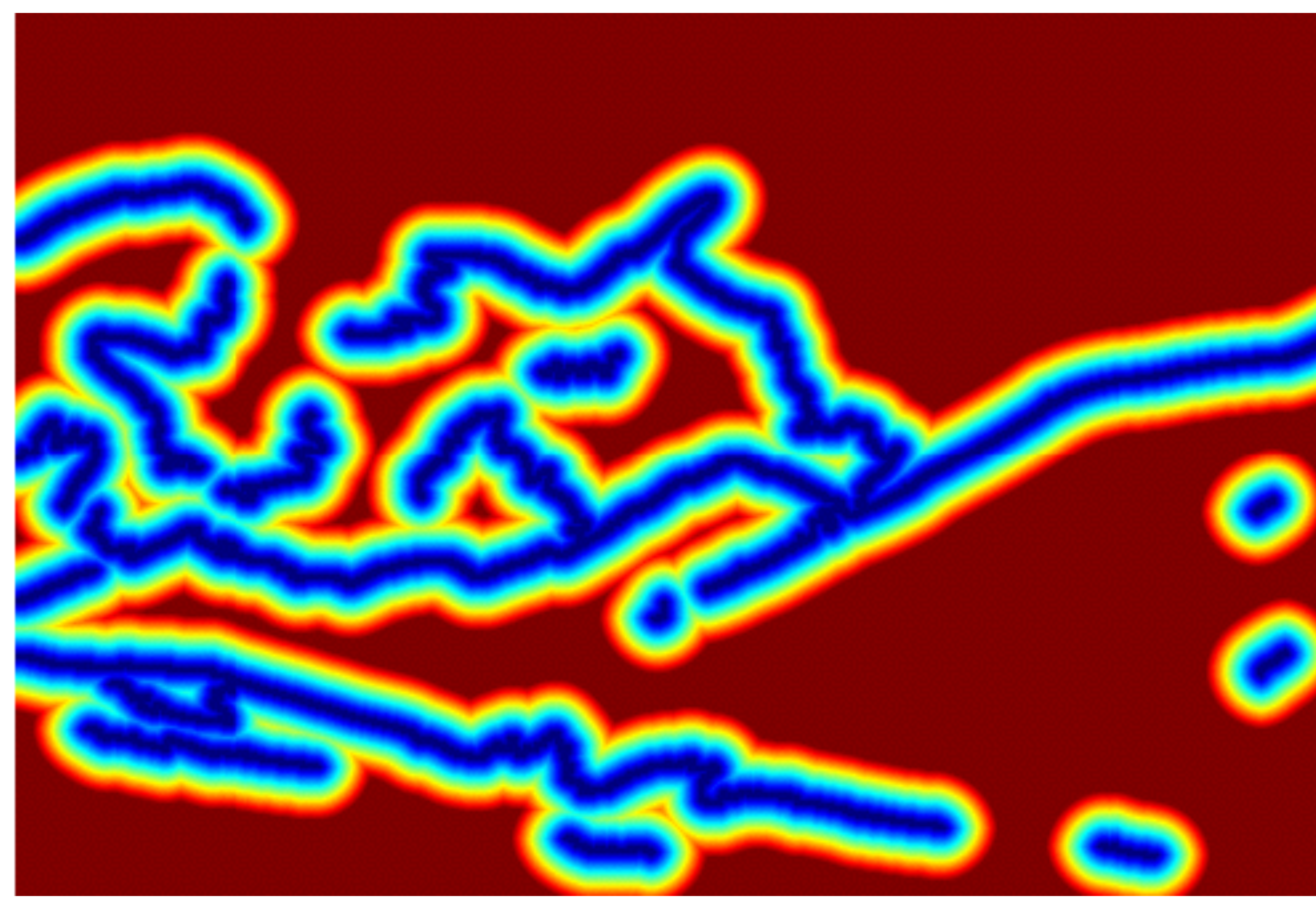


clipped distance field $\mathbf{I}$

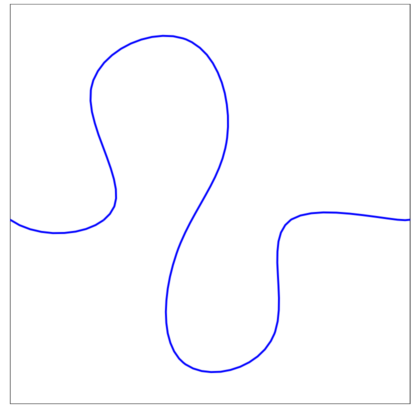


$$\underset{\mathbf{x}}{\text{minimize}} \quad \left\|\mathbf{B}'\mathbf{x} - \mathbf{B}'\mathbf{x}_{\mathbf{u}}\right\|^2 \quad + \lambda \sum_{i=1}^{n_s} \mathbf{I}(\mathbf{B}_i\mathbf{x})$$

color lines

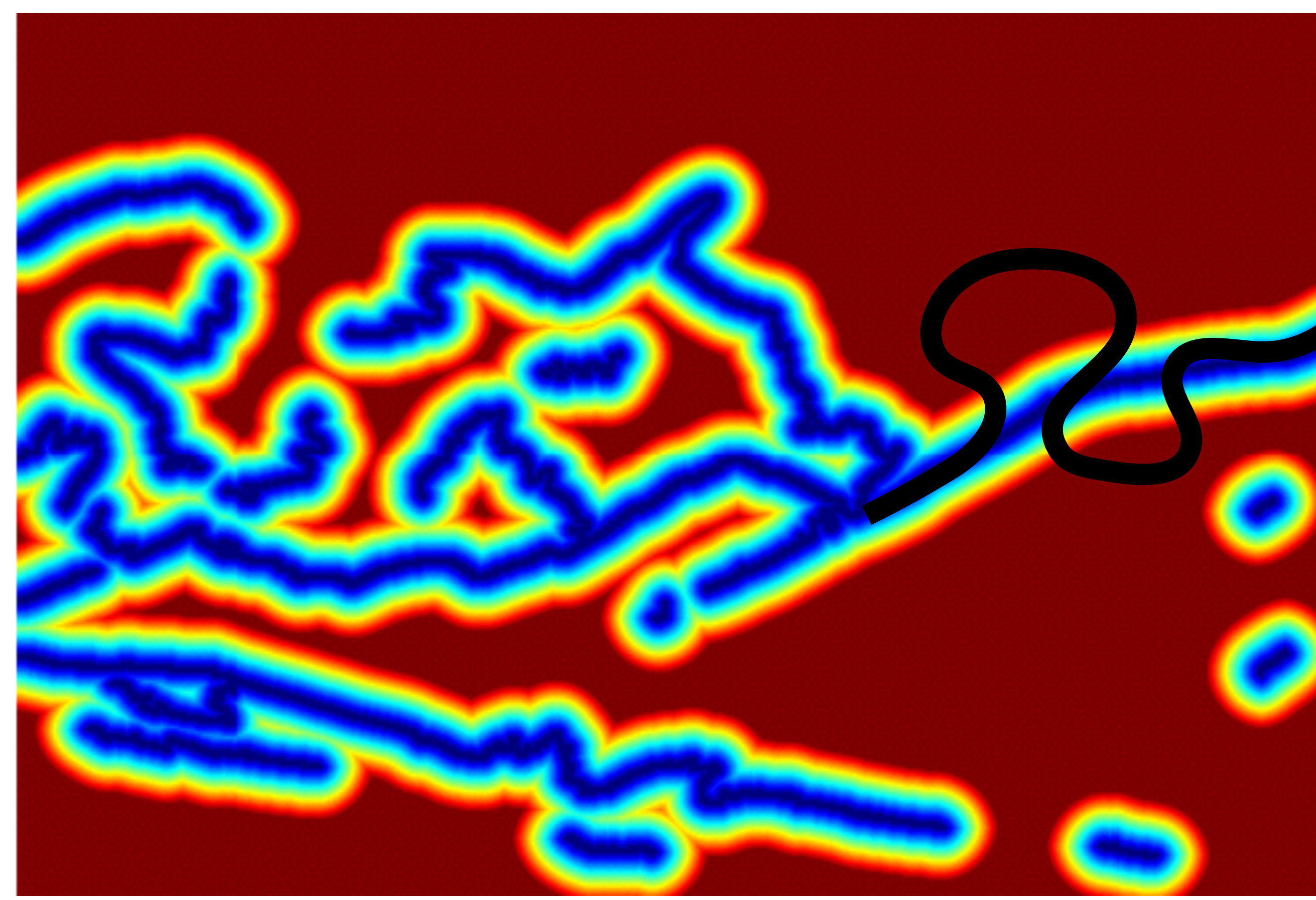


clipped distance field $\mathbf{I}$

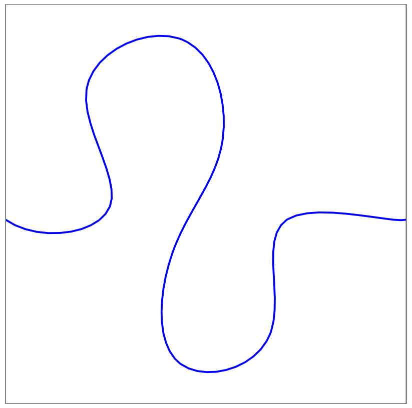


$$\underset{\mathbf{x}}{\text{minimize}} \quad \left\|\mathbf{B}'\mathbf{x} - \mathbf{B}'\mathbf{x}_{\mathbf{u}}\right\|^2 \quad + \lambda \sum_{i=1}^{n_s} \mathbf{I}(\mathbf{B}_i \mathbf{x})$$

color lines



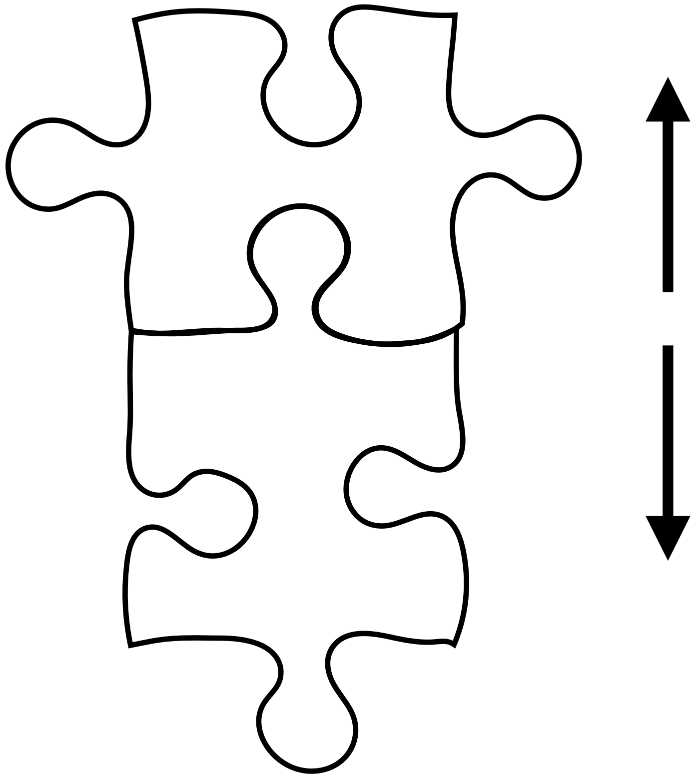
clipped distance field $\mathbf{I}$

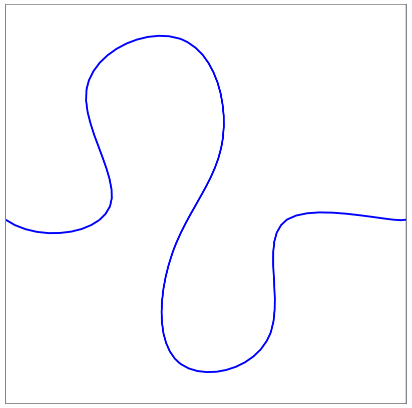


$$\underset{\mathbf{x}}{\text{minimize}} \quad \left\|\mathbf{B}'\mathbf{x} - \mathbf{B}'\mathbf{x}_{\mathbf{u}}\right\|^2 \quad + \lambda \sum_{i=1}^{n_s} \mathbf{I}(\mathbf{B}_i \mathbf{x})$$

Constraints:

interlocking



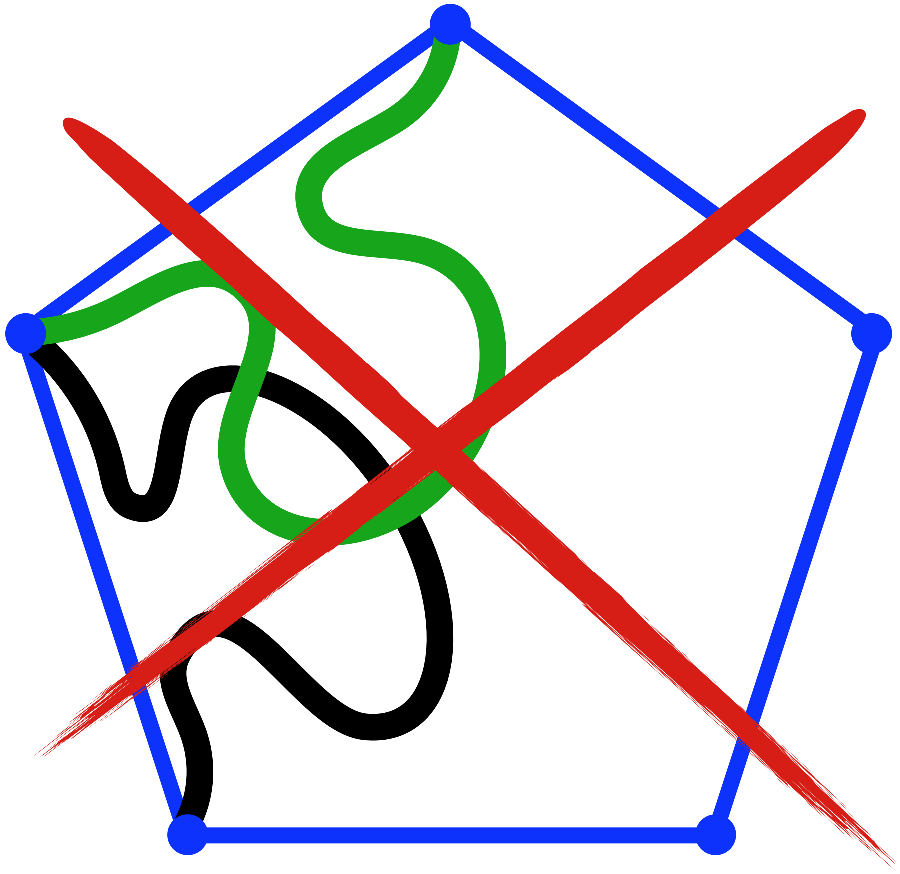


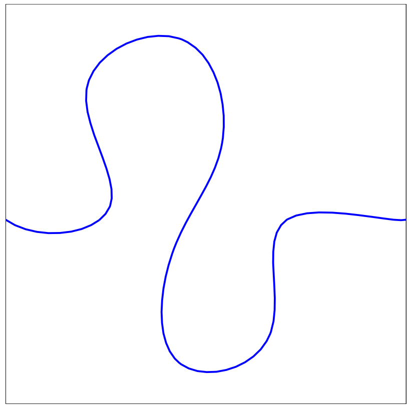
$$\underset{\mathbf{x}}{\text{minimize}} \quad \left\|\mathbf{B}'\mathbf{x} - \mathbf{B}'\mathbf{x_u}\right\|^2 \quad + \lambda \sum_{i=1}^{n_s} \mathbf{I}(\mathbf{B}_i \mathbf{x})$$

Constraints:

interlocking

intersection





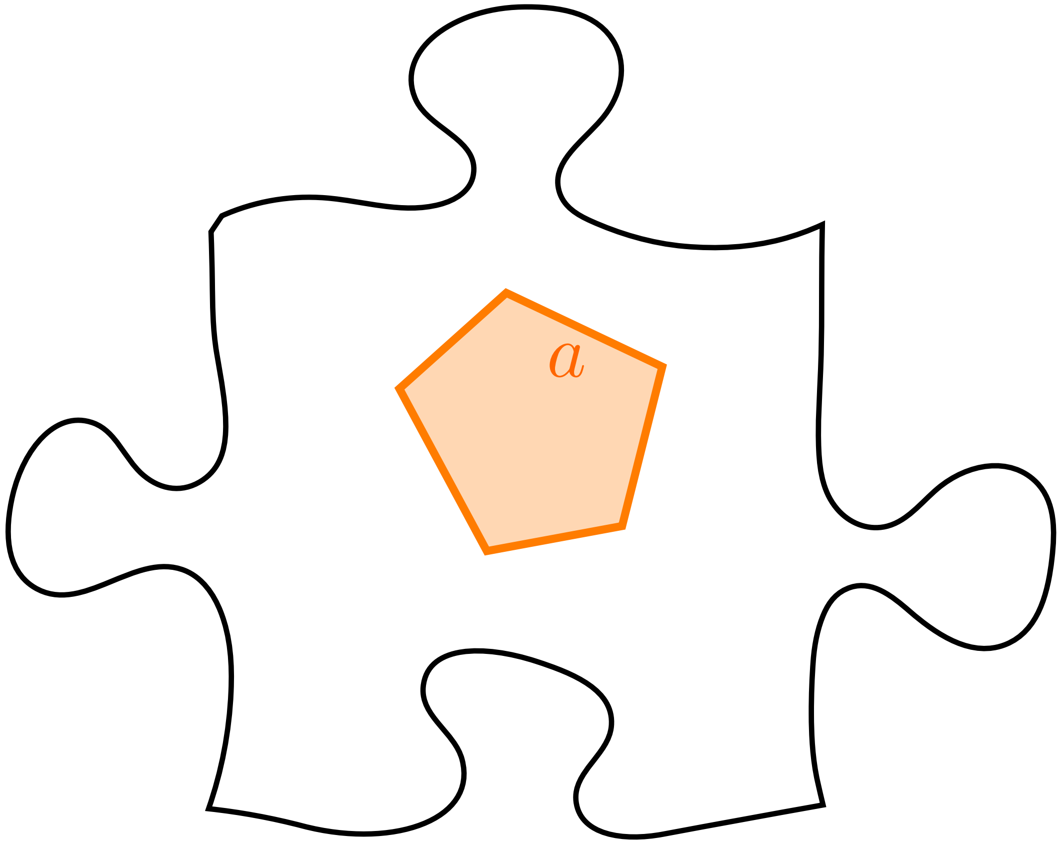
$$\underset{\mathbf{x}}{\text{minimize}} \quad \left\|\mathbf{B}'\mathbf{x} - \mathbf{B}'\mathbf{x_u}\right\|^2 \quad + \lambda \sum_{i=1}^{n_s} \mathbf{I}(\mathbf{B}_i\mathbf{x})$$

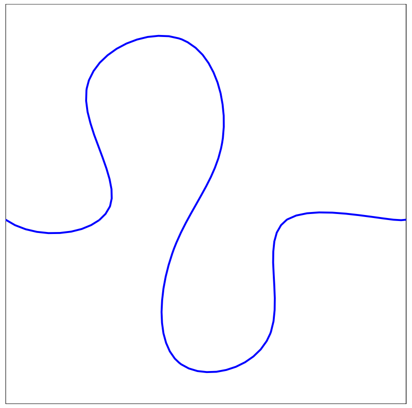
Constraints:

interlocking

intersection

minimum piece size





$$\underset{\mathbf{x}}{\text{minimize}} \quad \left\|\mathbf{B}'\mathbf{x} - \mathbf{B}'\mathbf{x_u}\right\|^2 \qquad + \lambda \sum_{i=1}^{n_s} \mathbf{I}(\mathbf{B}_i \mathbf{x})$$

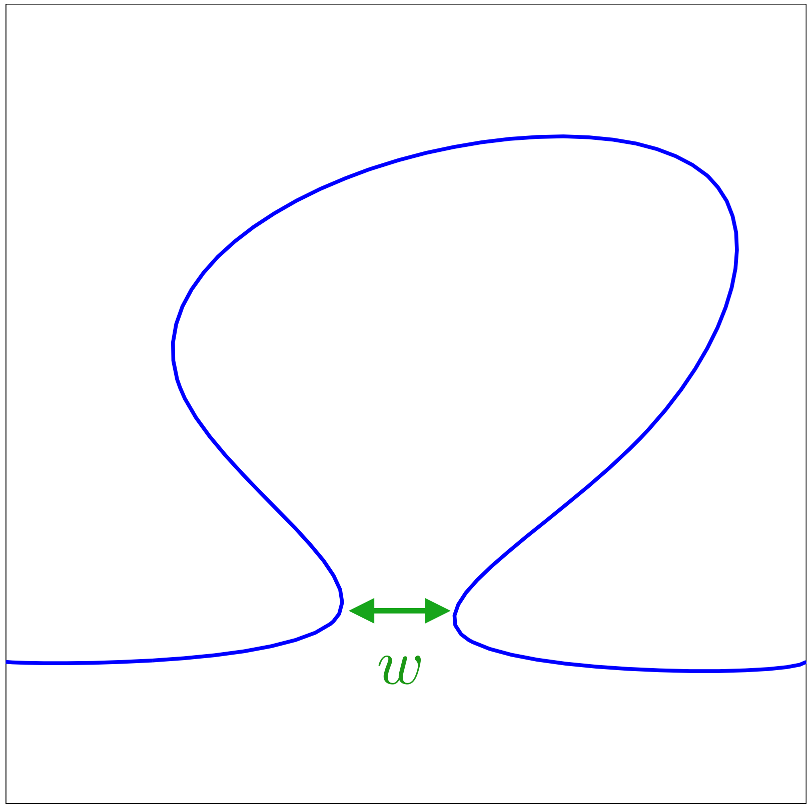
Constraints:

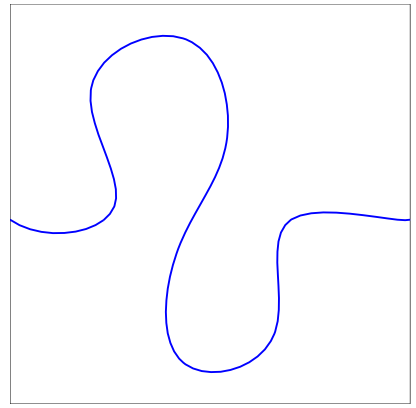
interlocking

intersection

minimum piece size

minimum width





$$\underset{\mathbf{x}}{\text{minimize}} \quad \left\|\mathbf{B}'\mathbf{x} - \mathbf{B}'\mathbf{x_u}\right\|^2 \qquad + \lambda \sum_{i=1}^{n_s} \mathbf{I}(\mathbf{B}_i\mathbf{x})$$

Constraints:

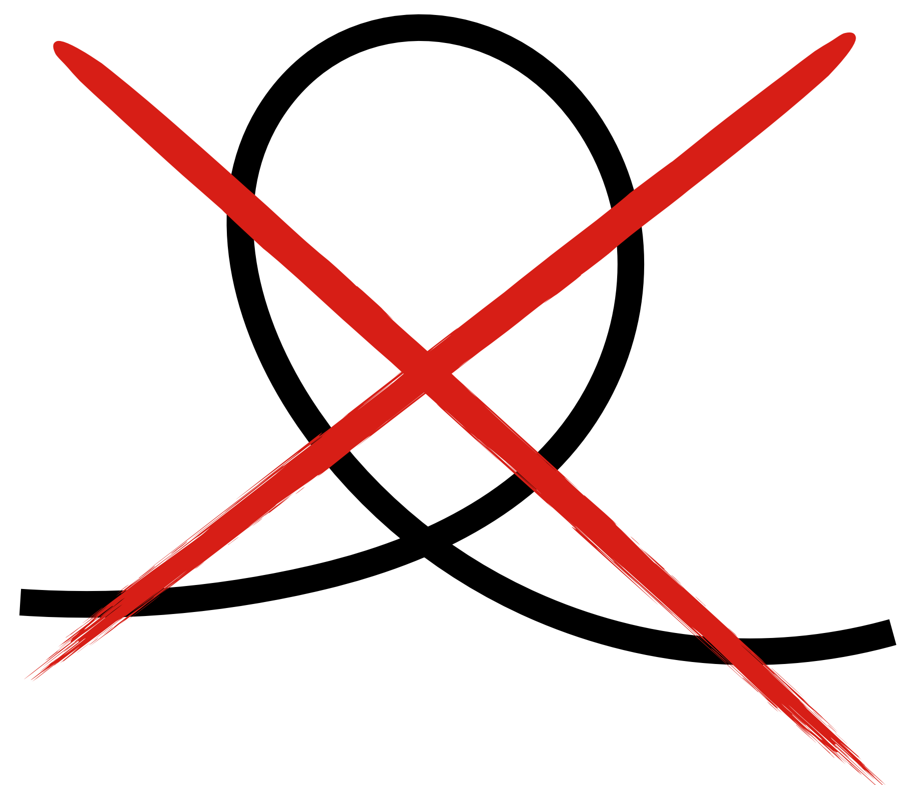
interlocking

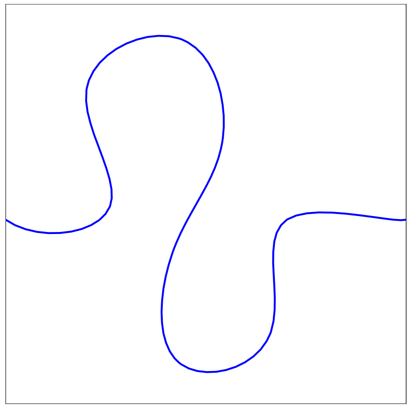
intersection

minimum piece size

minimum width

self intersection





$$\underset{\mathbf{x}}{\text{minimize}} \quad \left\|\mathbf{B}'\mathbf{x} - \mathbf{B}'\mathbf{x_u}\right\|^2 \quad + \lambda \sum_{i=1}^{n_s} \mathbf{I}(\mathbf{B}_i\mathbf{x})$$

Constraints:

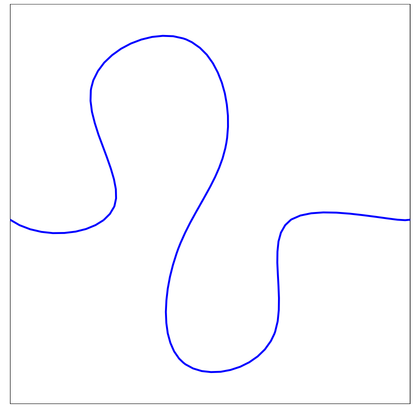
interlocking

intersection

minimum piece size

minimum width

self intersection



$$\underset{\mathbf{x}}{\text{minimize}} \quad \left\|\mathbf{B}'\mathbf{x} - \mathbf{B}'\mathbf{x_u}\right\|^2 \quad + \lambda \sum_{i=1}^{n_s} \mathbf{I}(\mathbf{B}_i\mathbf{x})$$

$$\text{subject to} \quad \mathbf{A}\mathbf{x} < \mathbf{b}$$

interlocking → $\mathbf{A}_1\mathbf{x} < \mathbf{b}_1$

intersection

minimum piece size

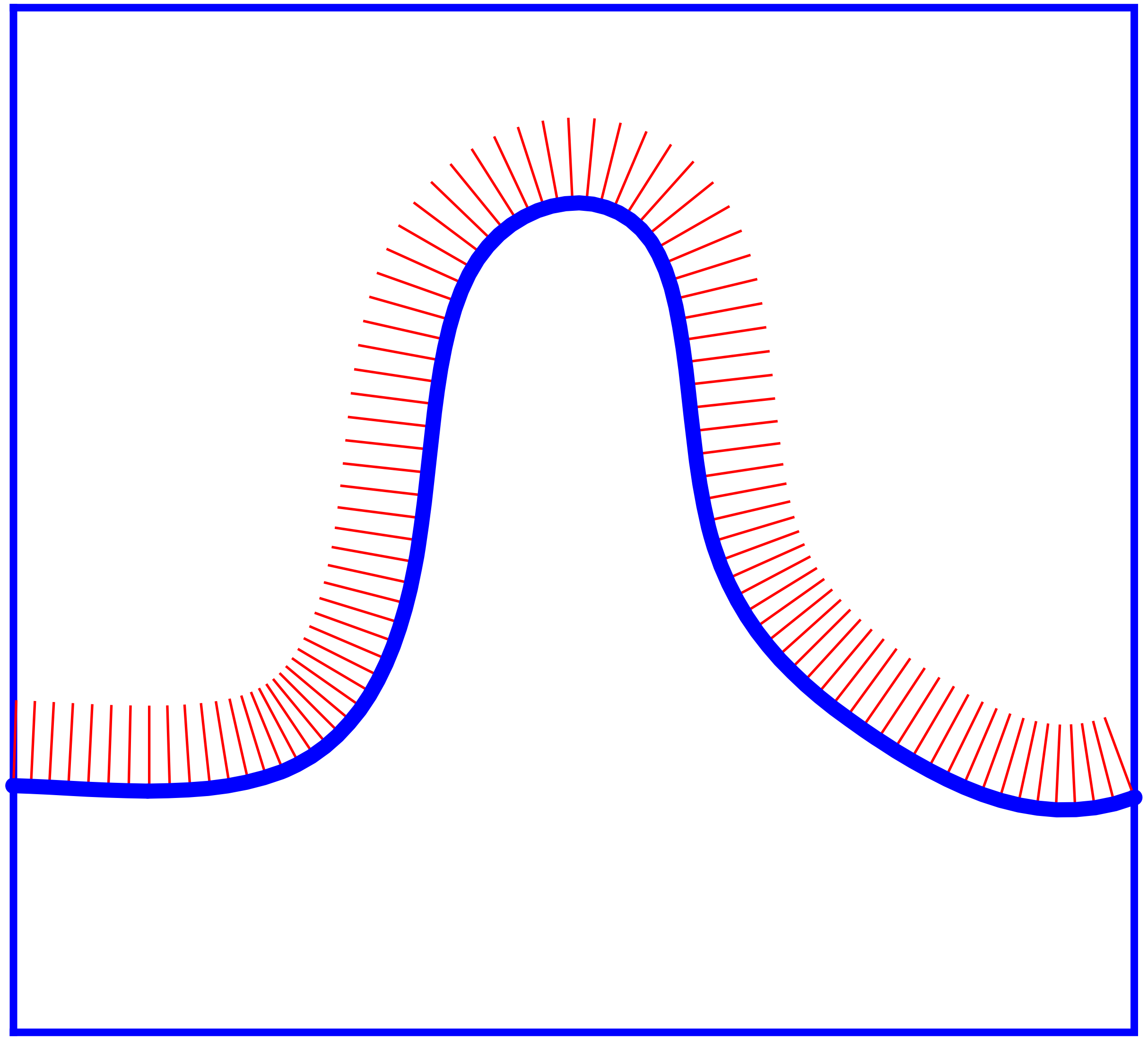
minimum width (inter-curve)

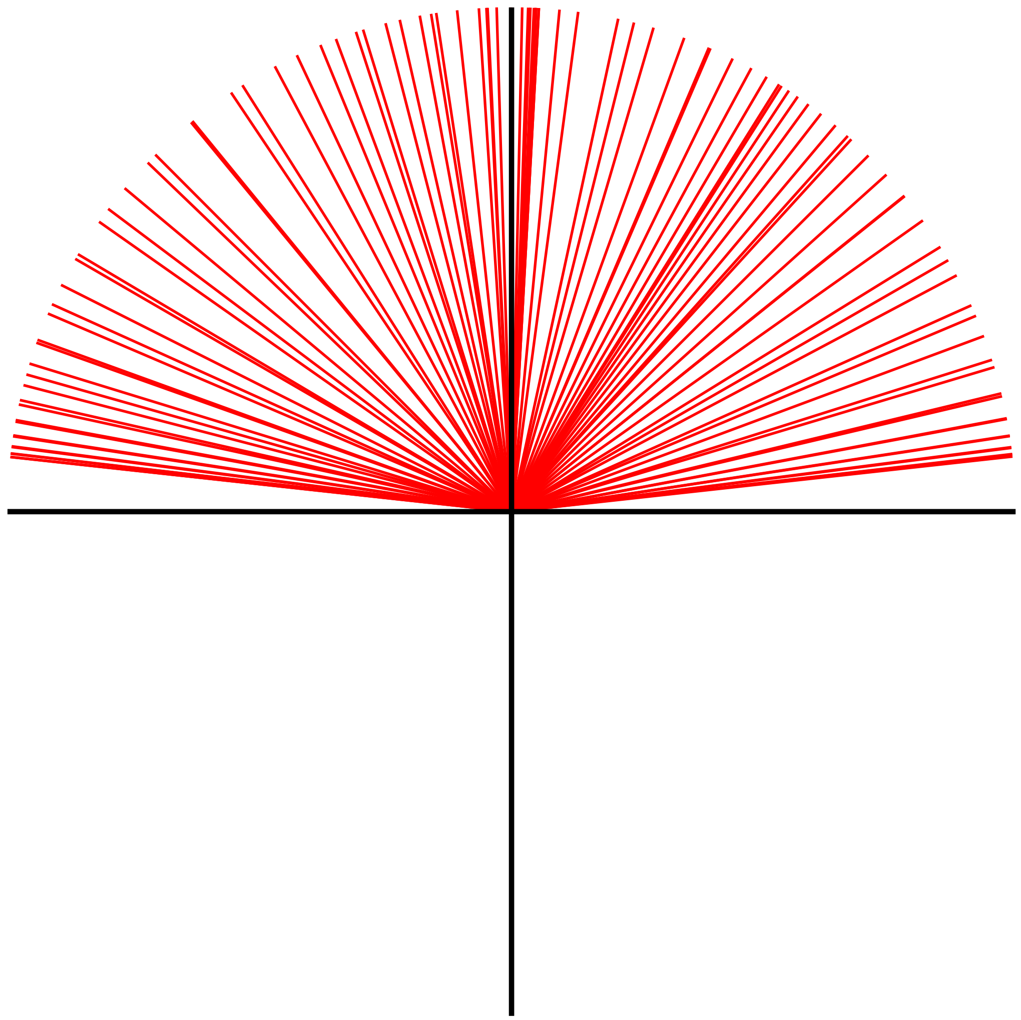
→ $\mathbf{A}_2\mathbf{x} < \mathbf{b}_2$

Post Processing:

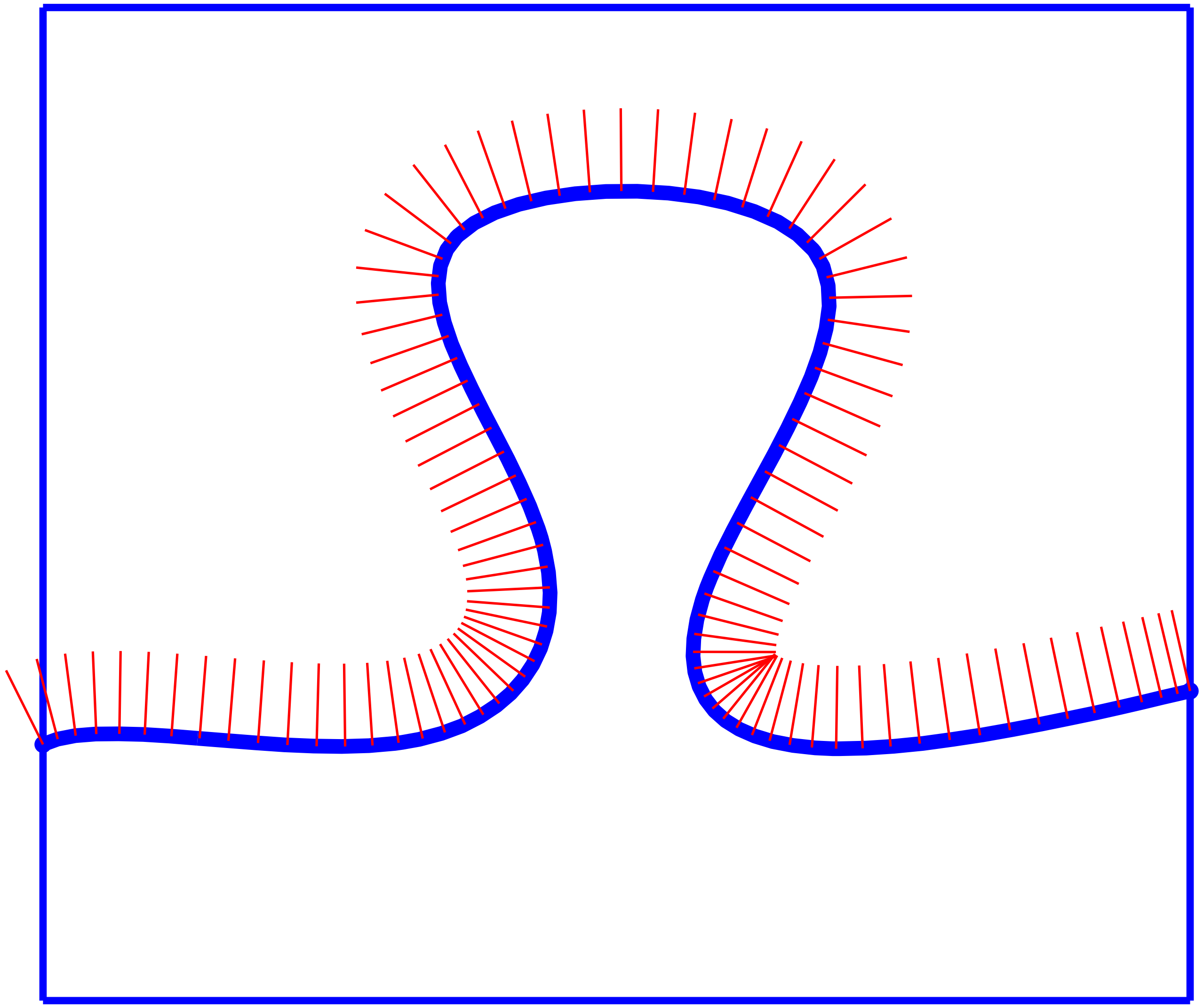
minimum width (intra-curve)

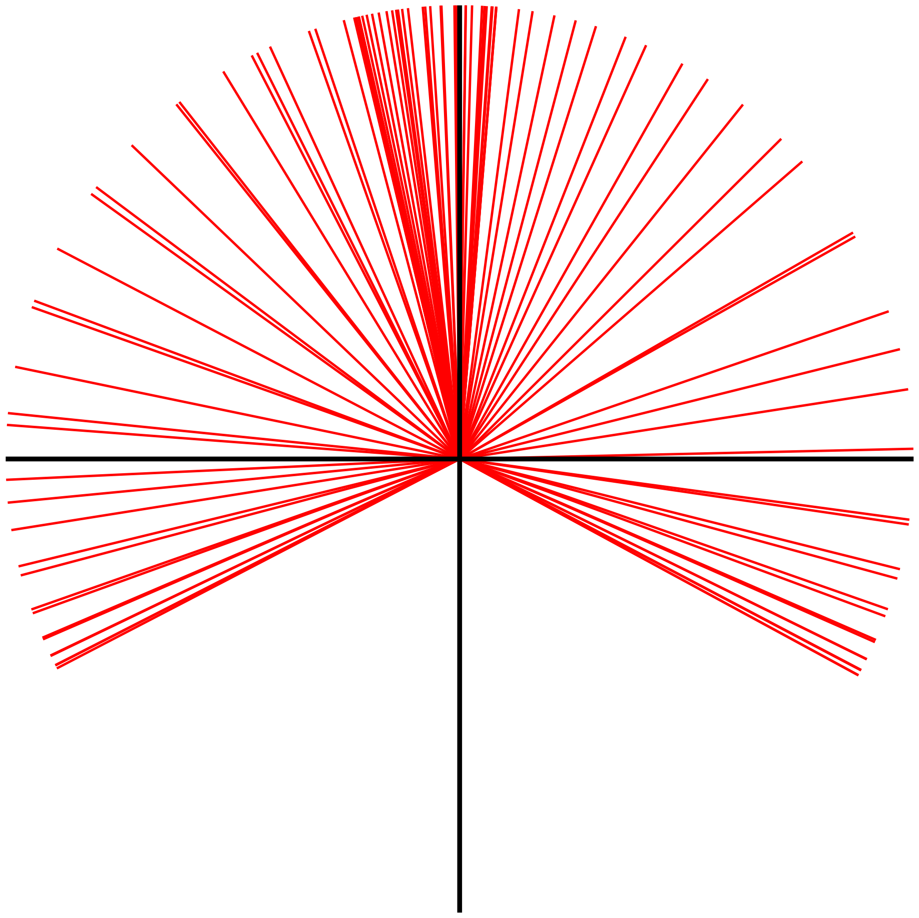
self intersection



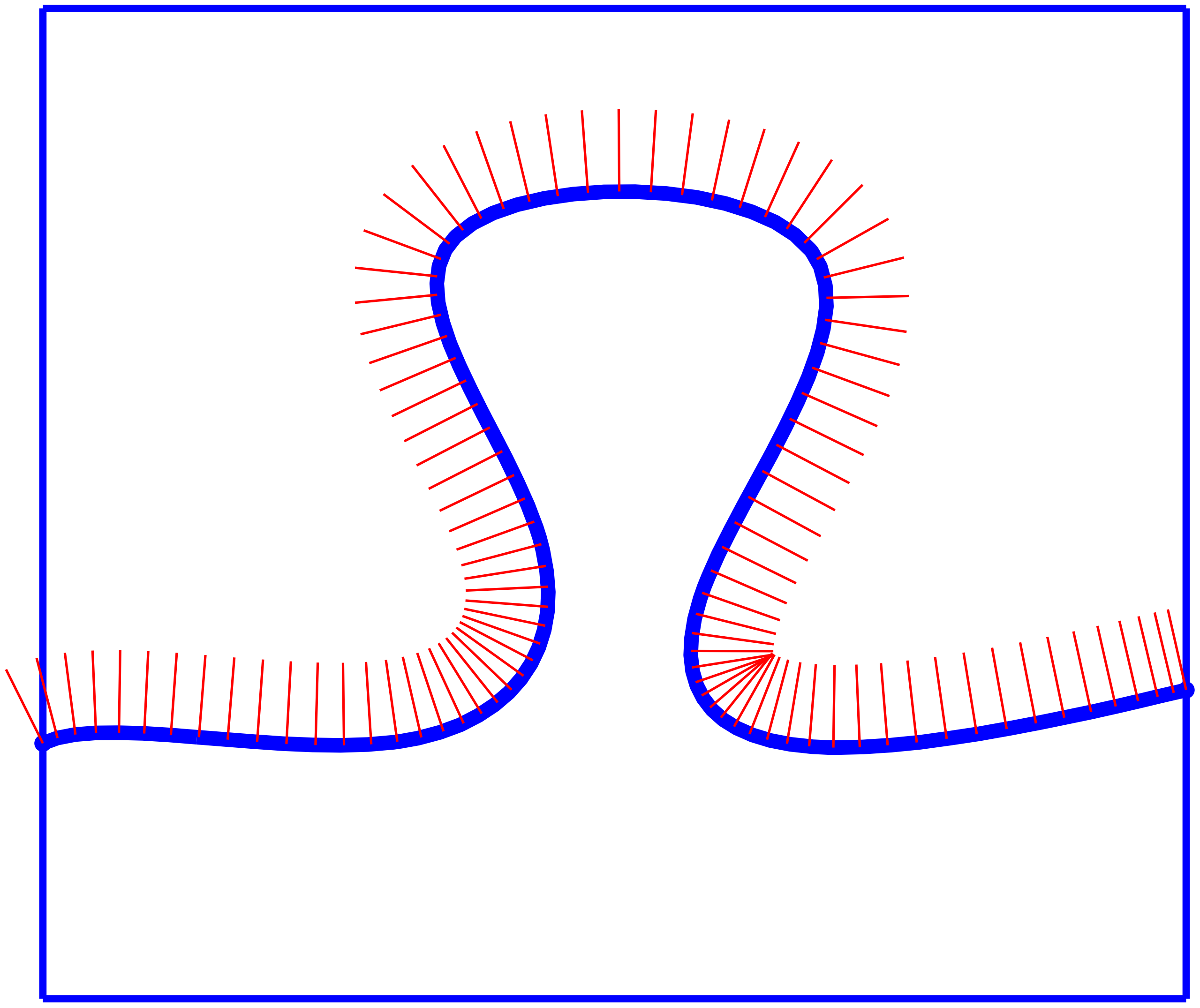


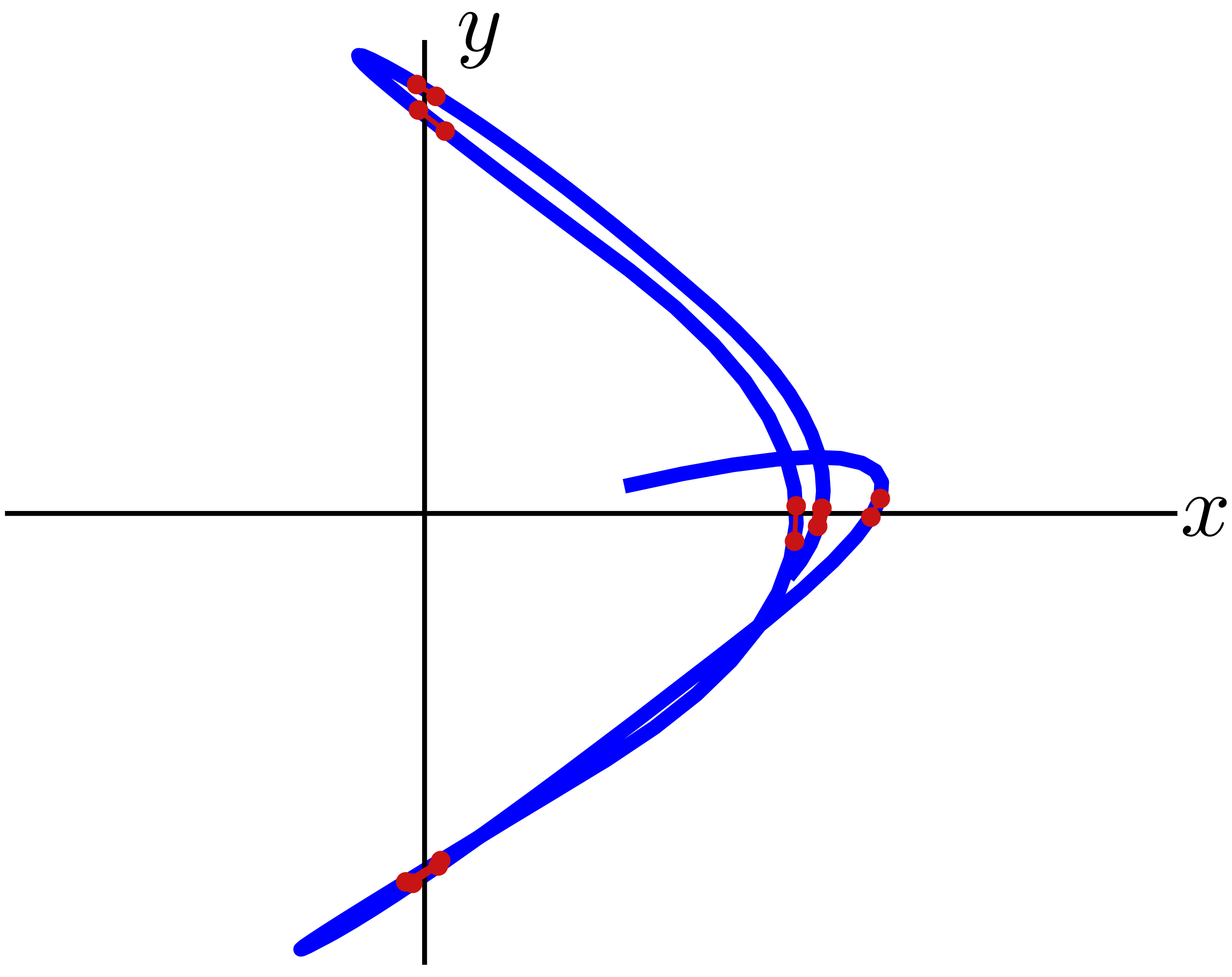
not interlocking





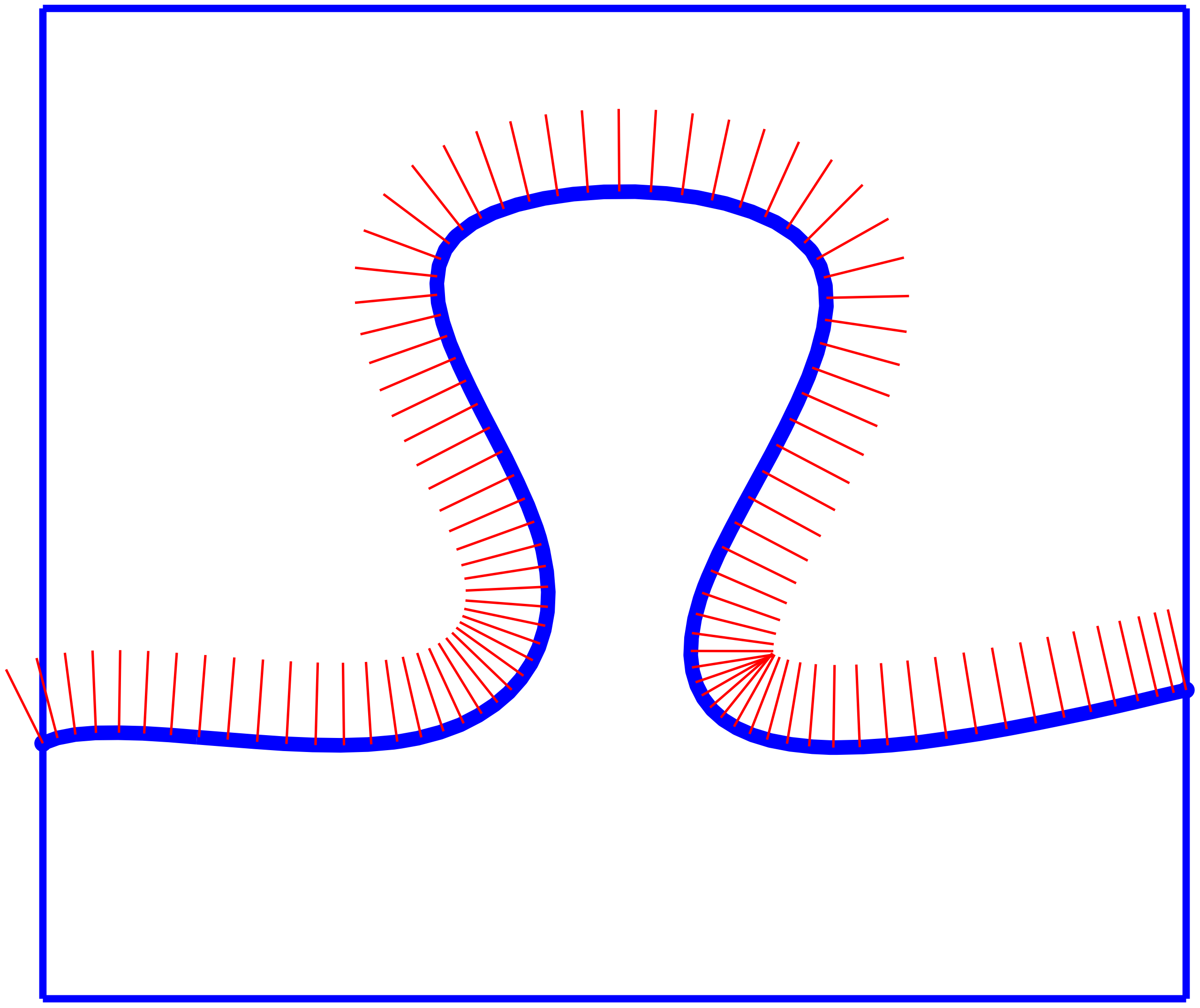
interlocking

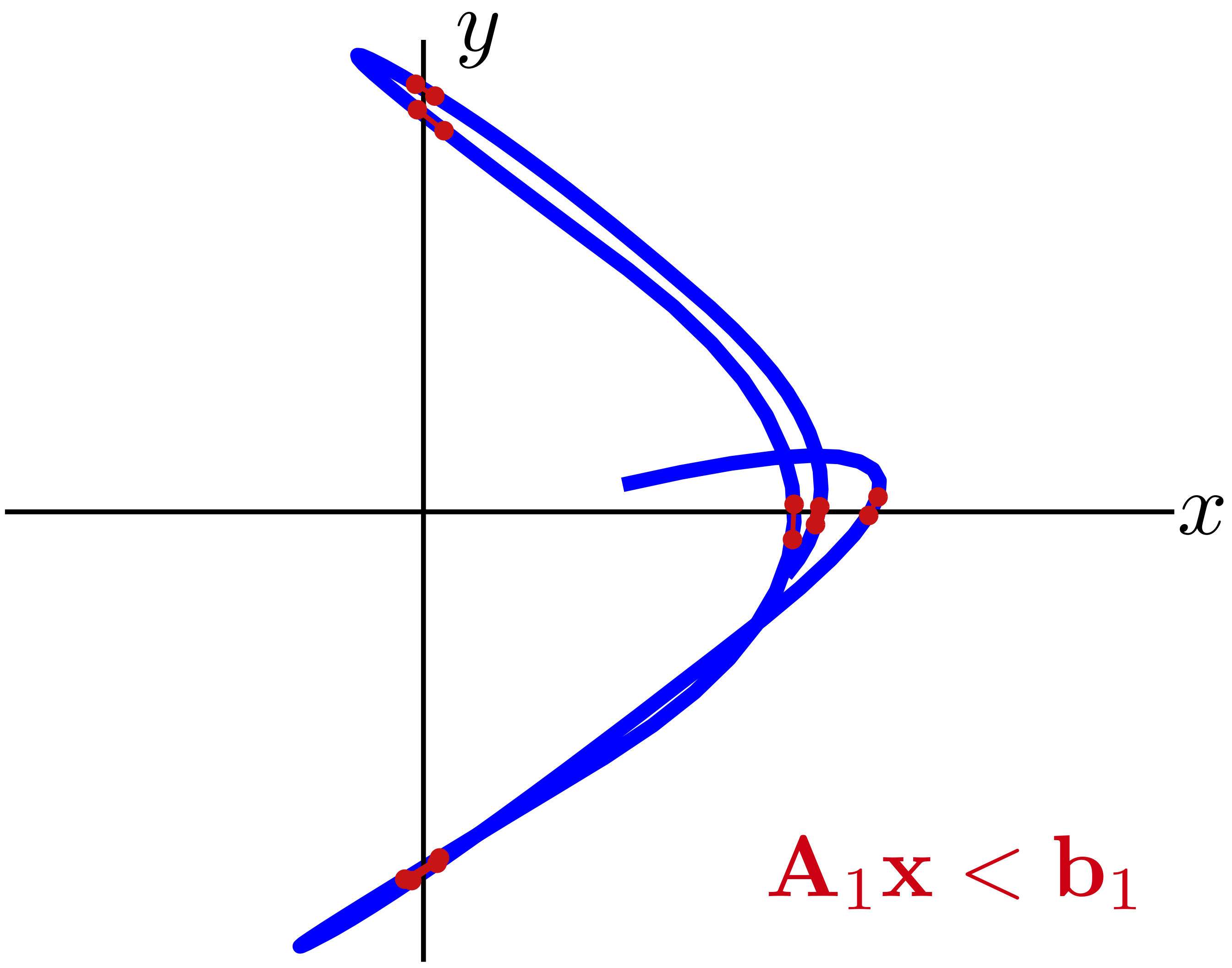




1st derivative

linear interlocking constraint





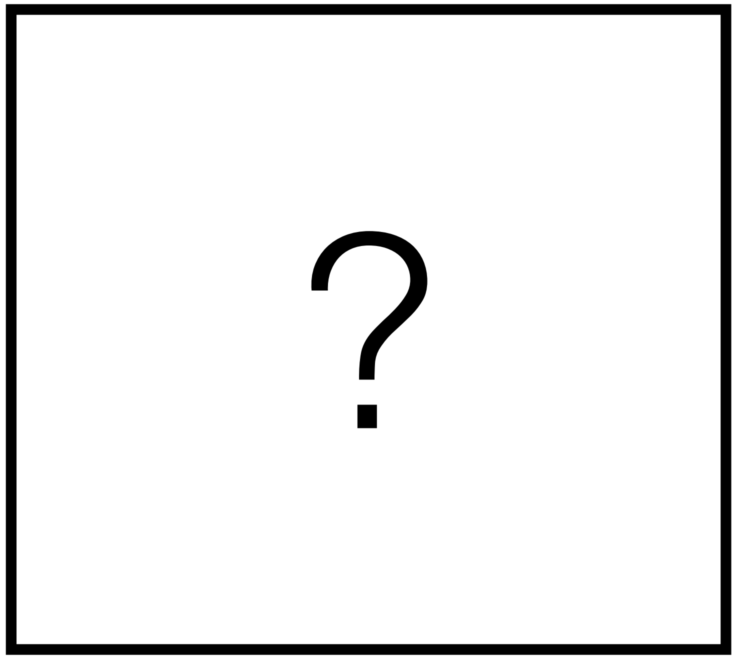
1st derivative

linear interlocking constraint

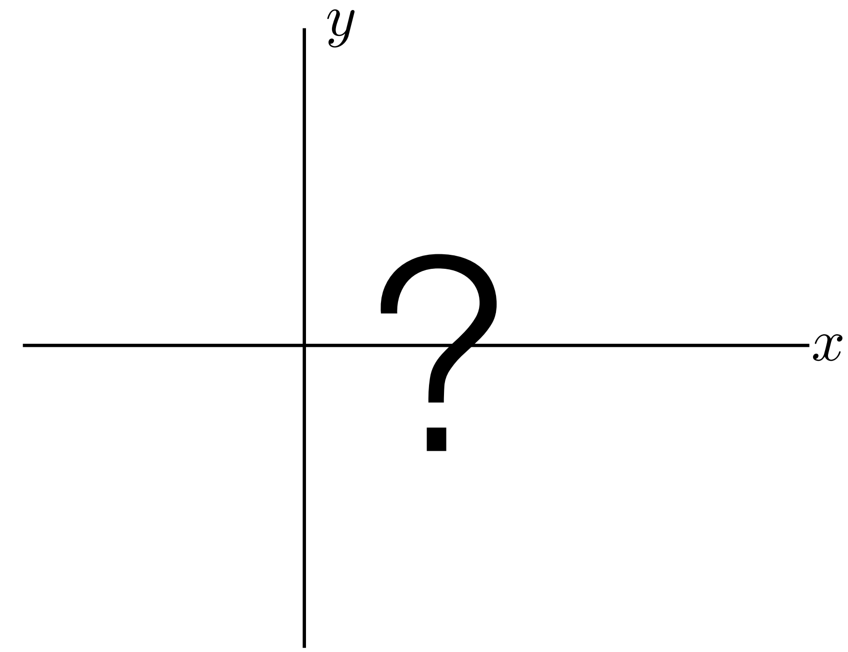
?

optimized curve

linear interlocking constraint

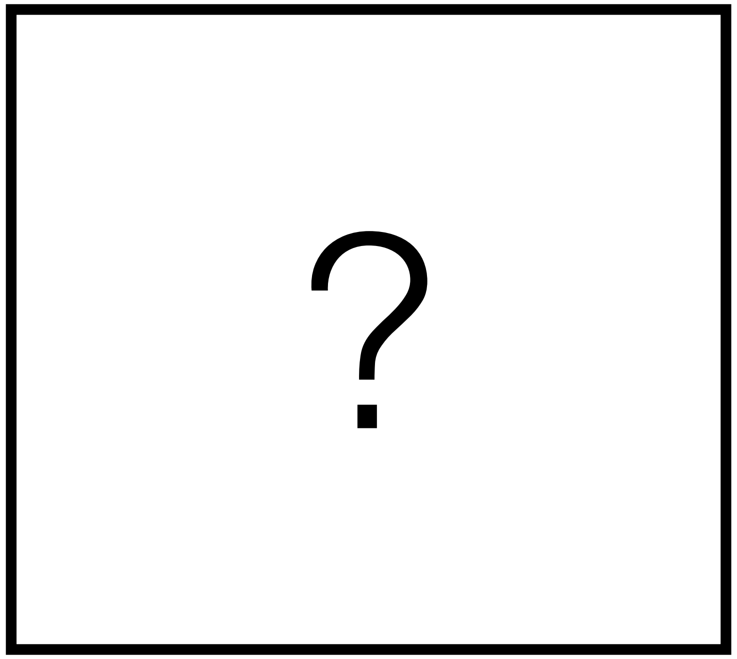


optimized curve

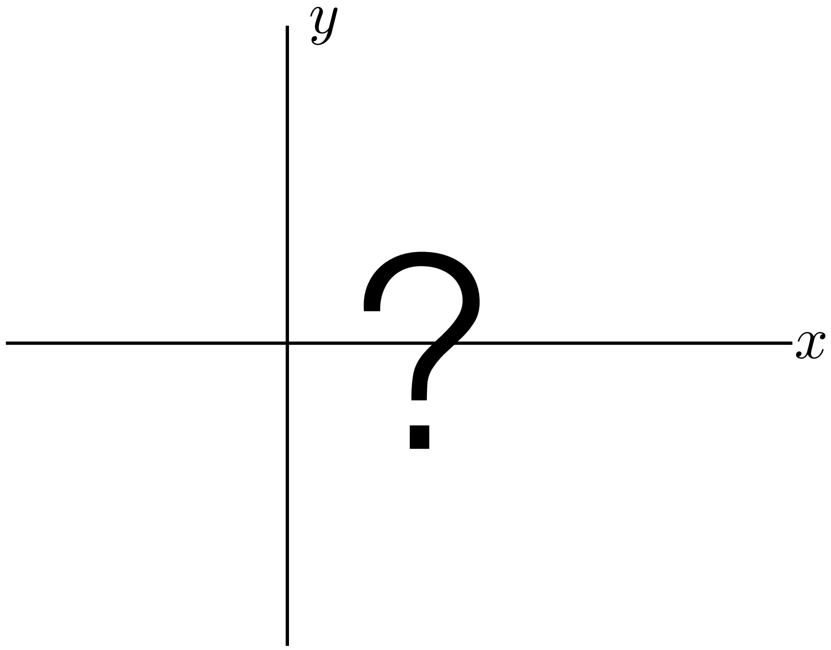


axis crossings

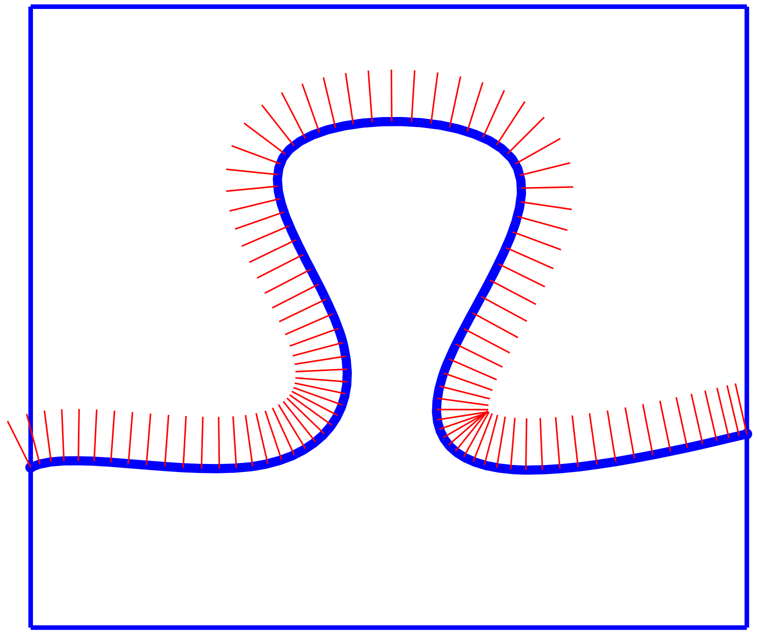
linear interlocking constraint



optimized curve

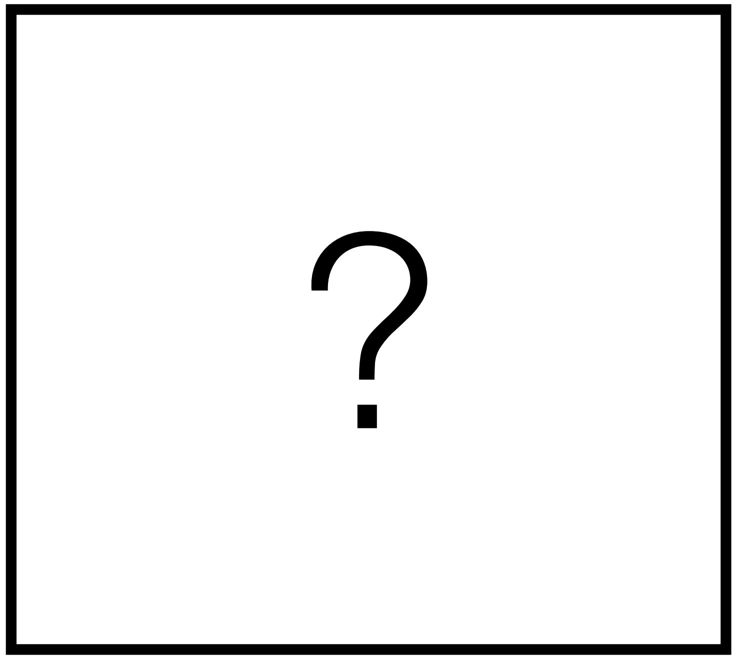


axis crossings

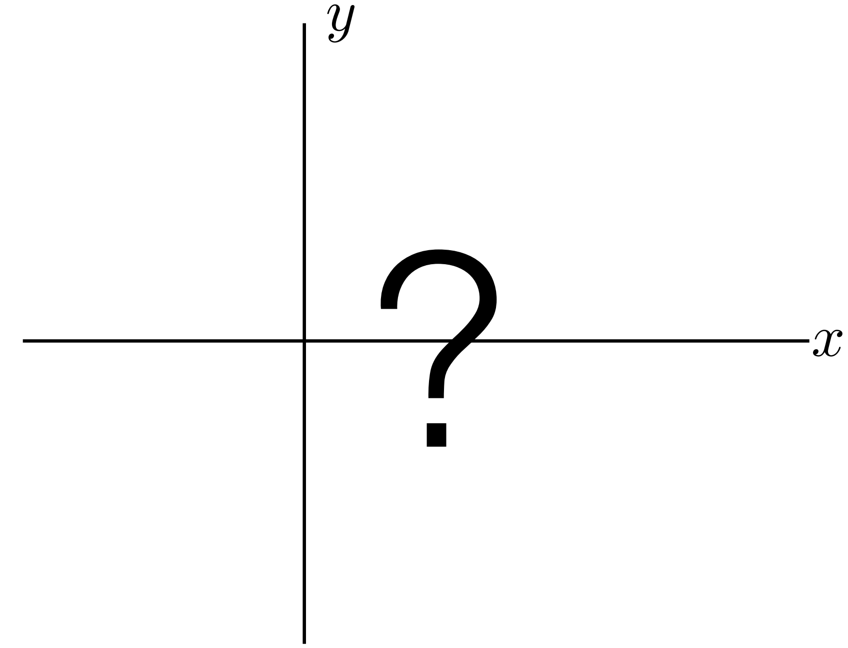


user curve

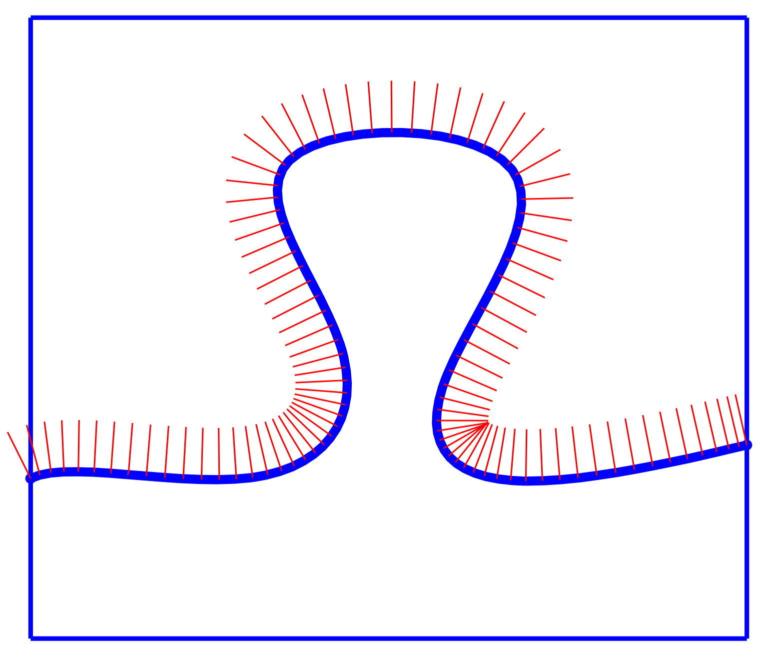
linear interlocking constraint



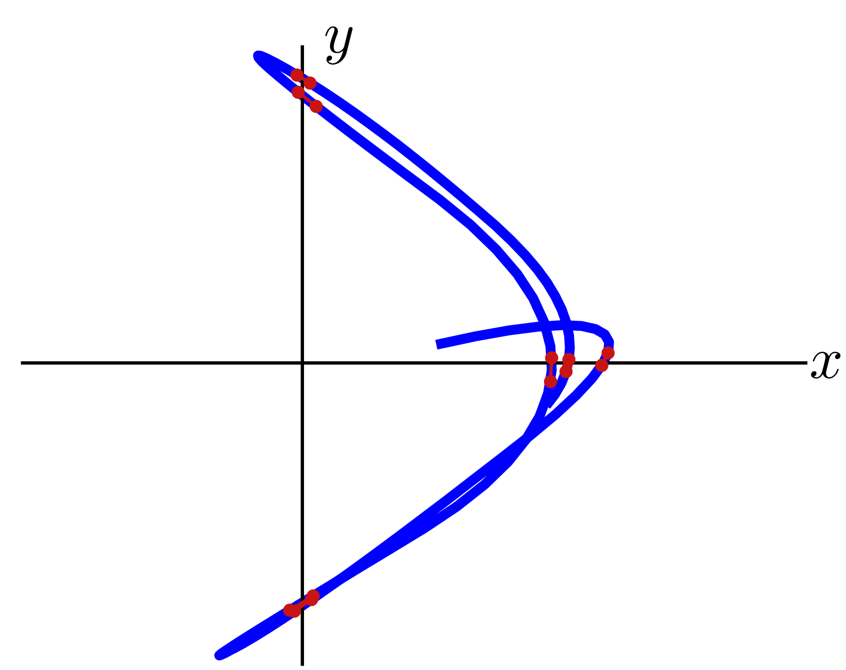
optimized curve



axis crossings

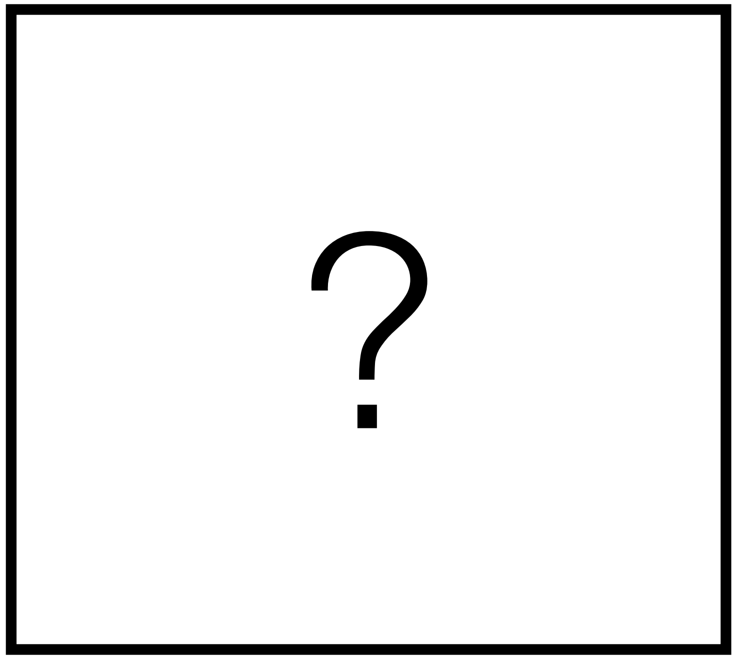


user curve

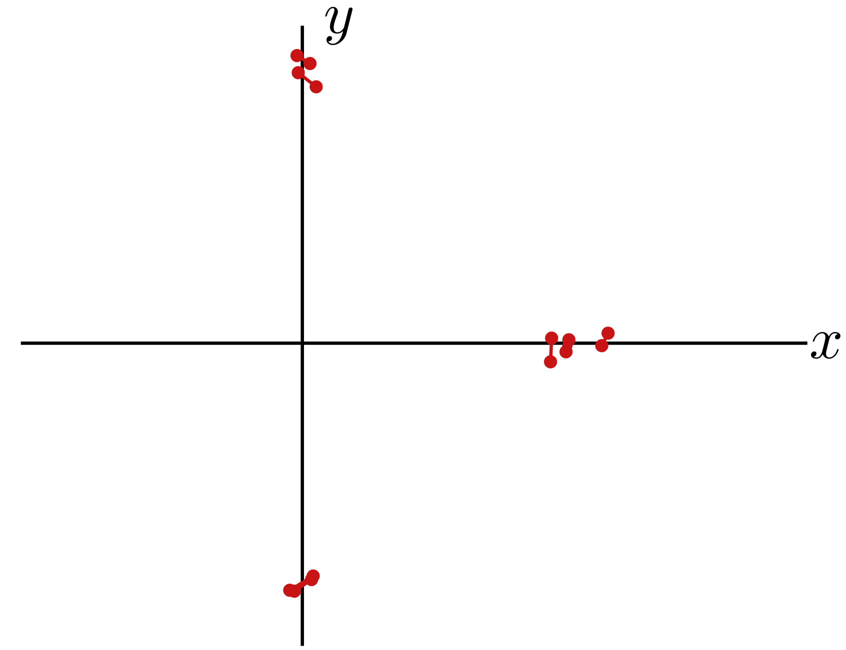


1st derivative

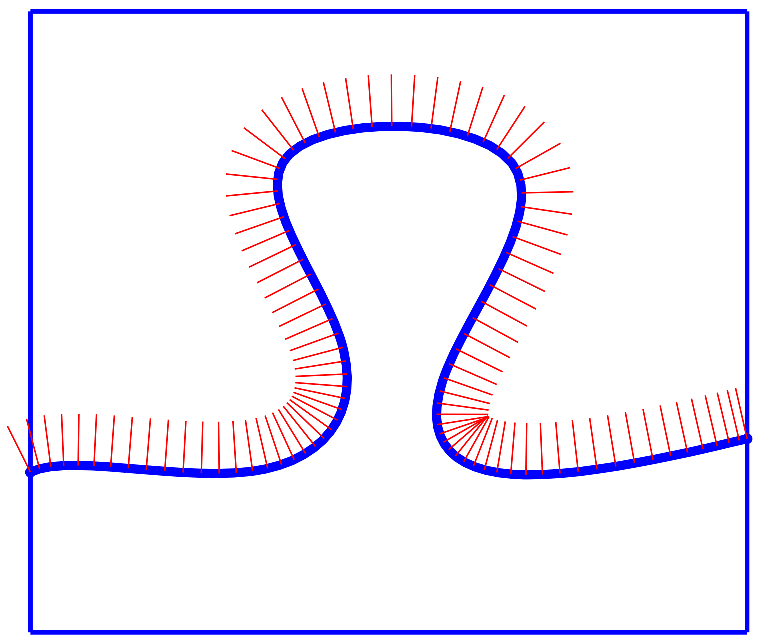
linear interlocking constraint



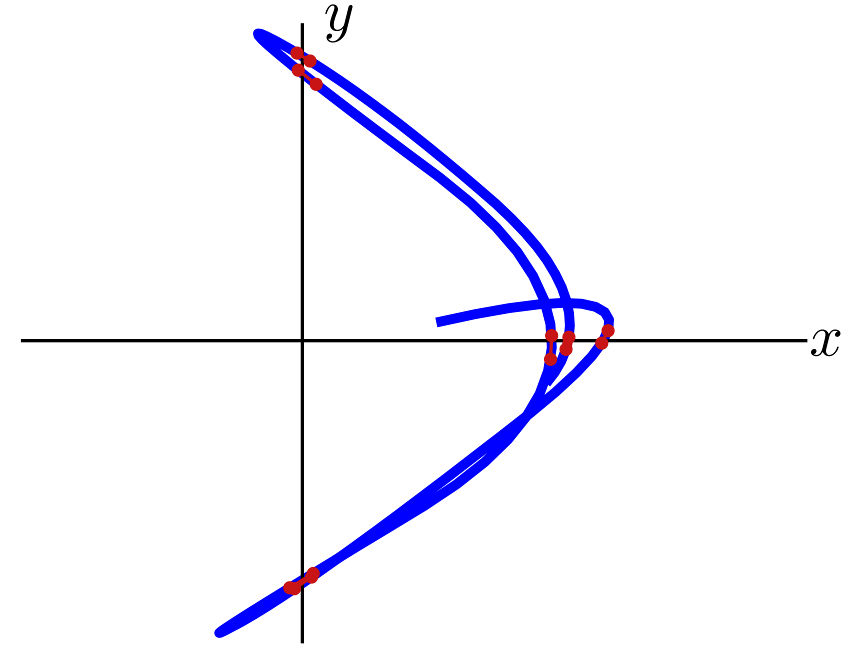
optimized curve



axis crossings

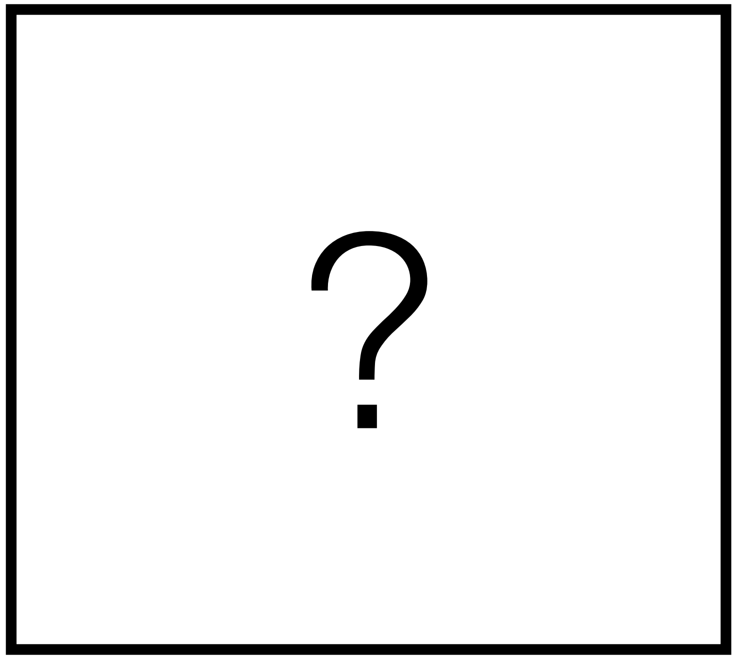


user curve

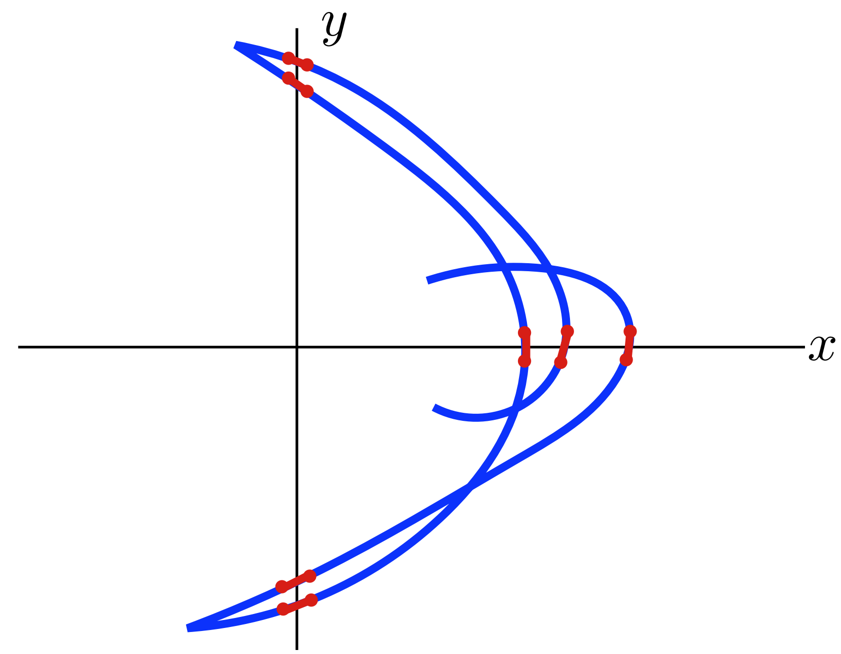


1st derivative

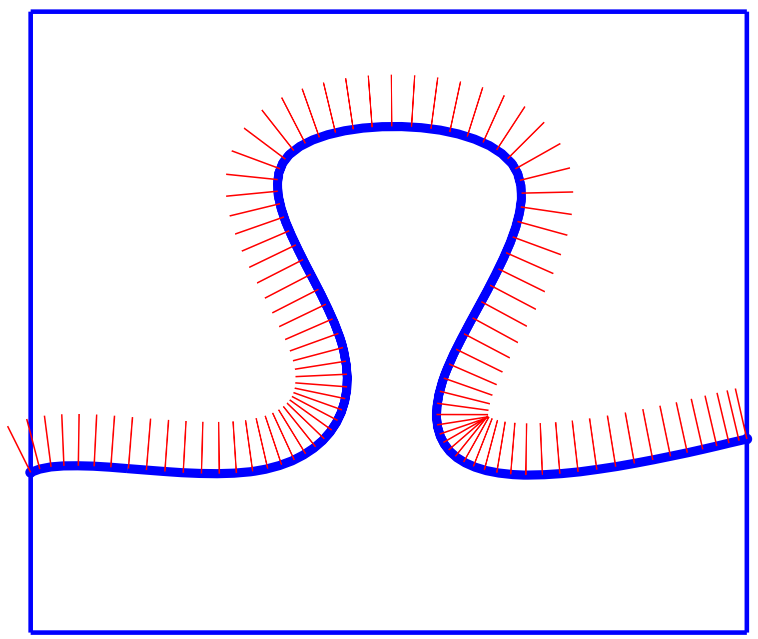
linear interlocking constraint



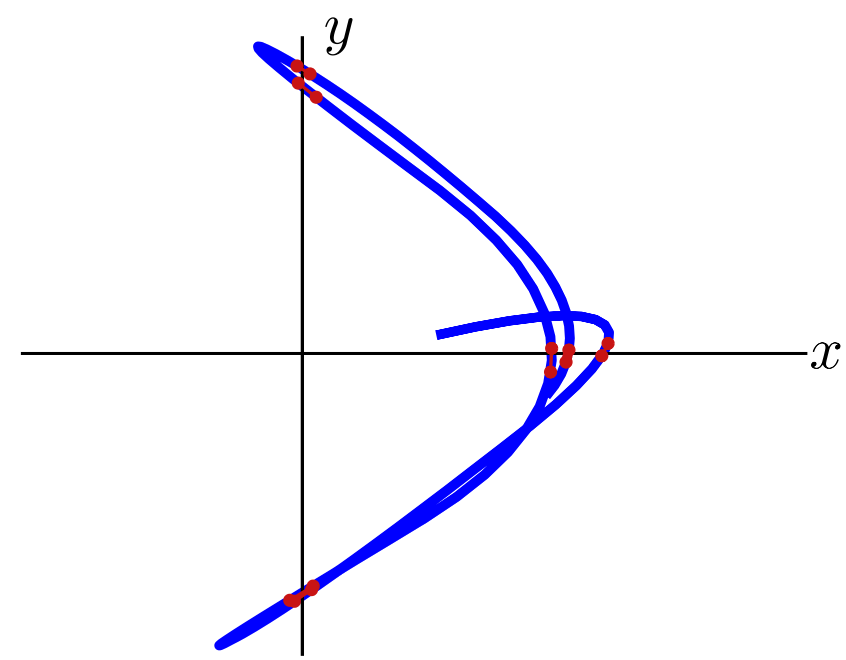
optimized curve



axis crossings

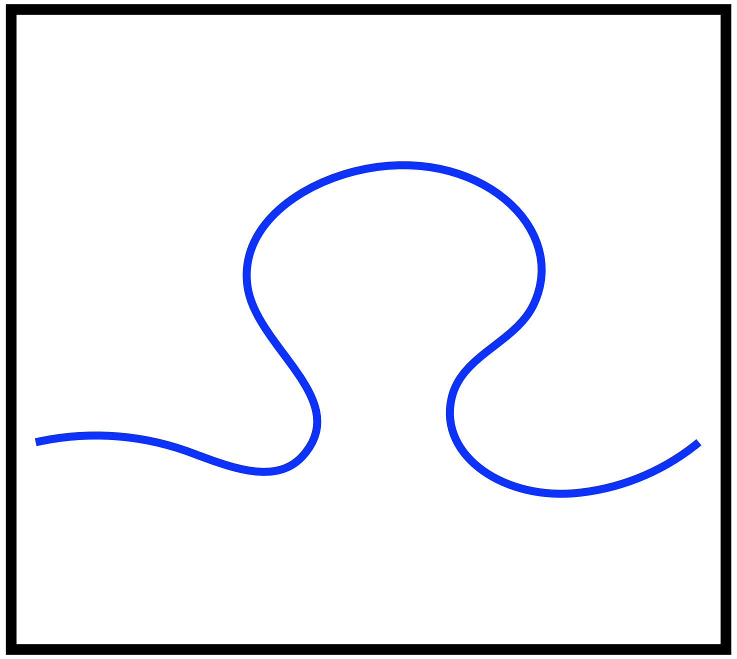


user curve

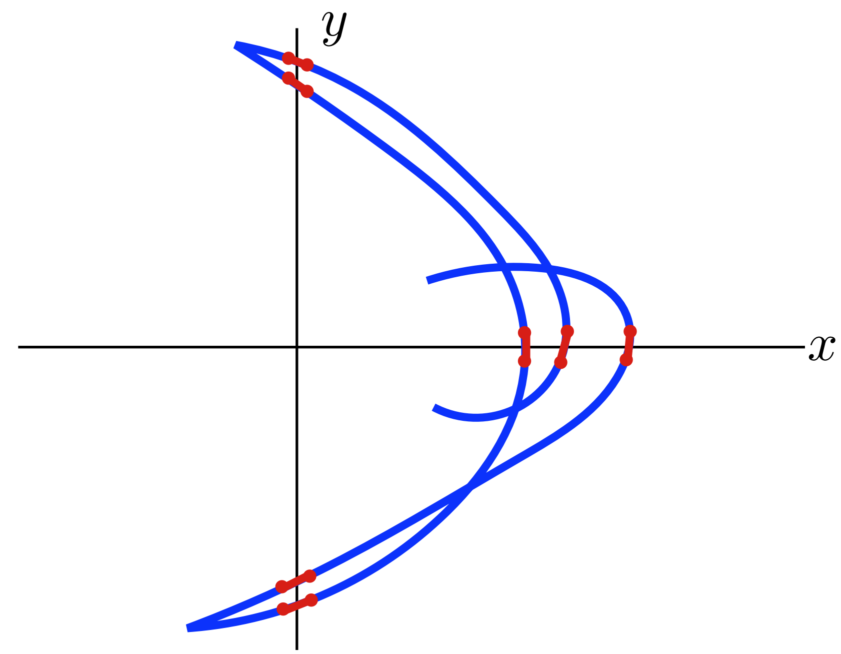


1st derivative

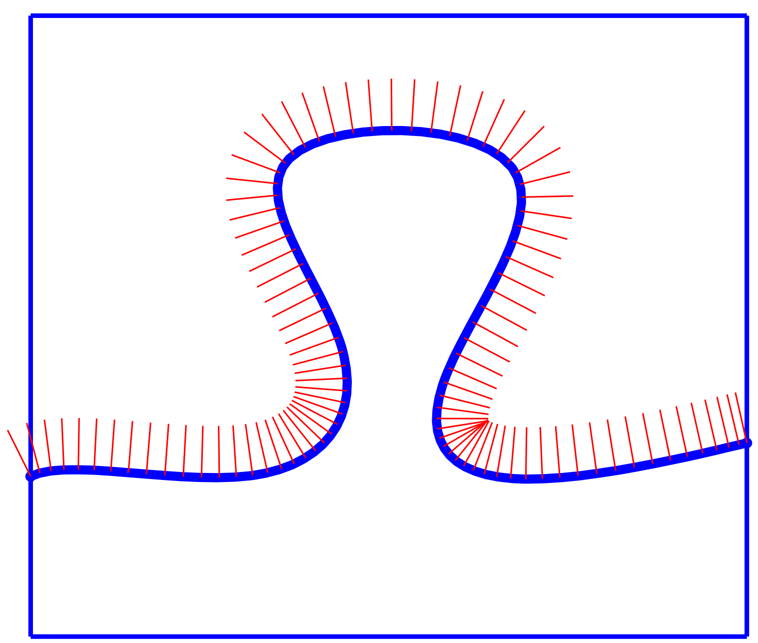
linear interlocking constraint



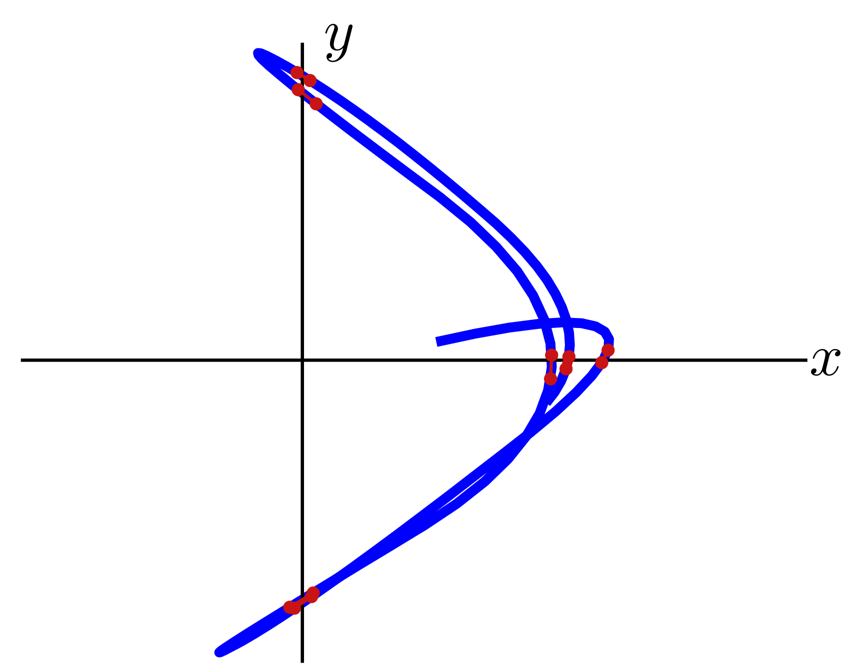
optimized curve



axis crossings

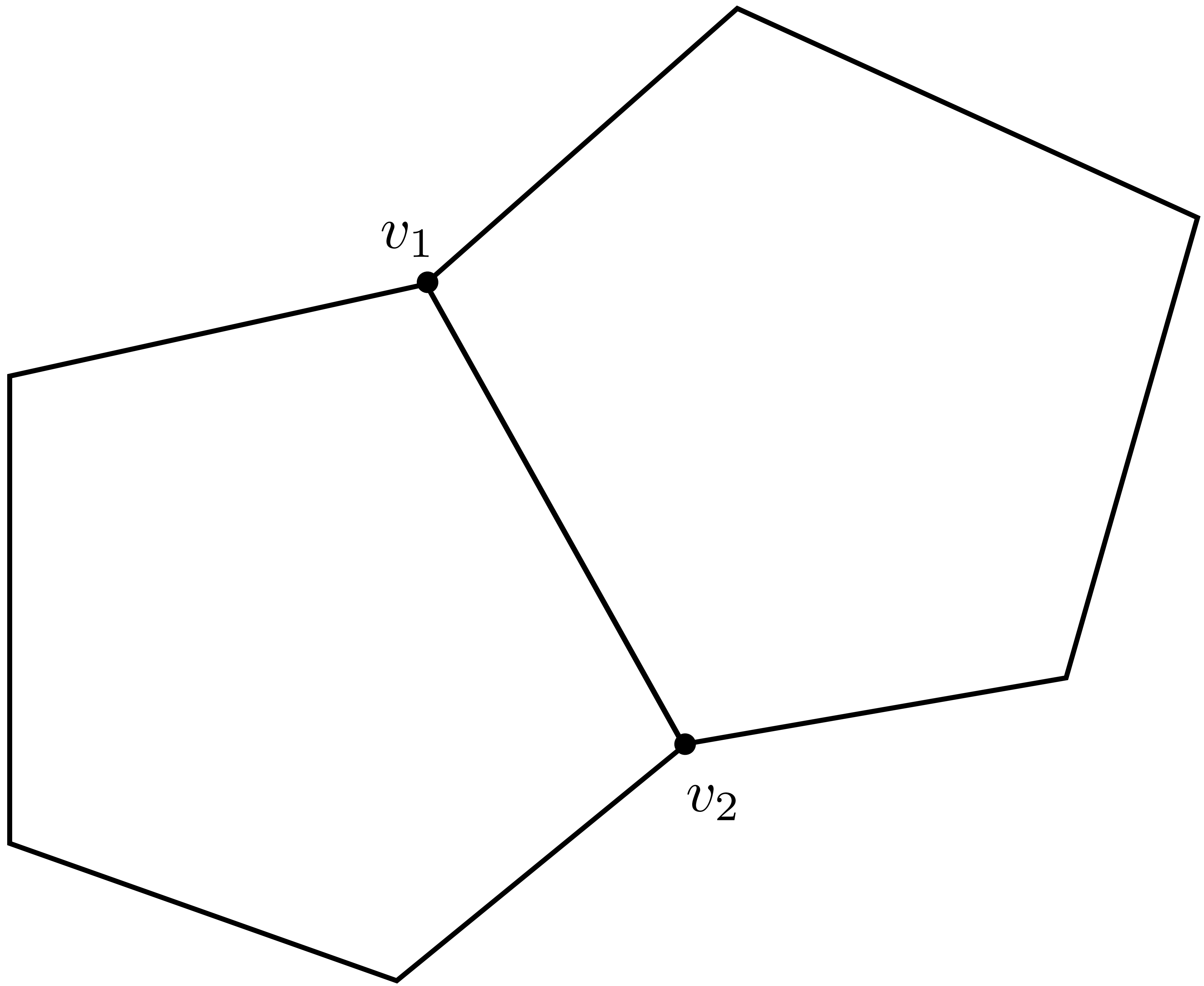


user curve

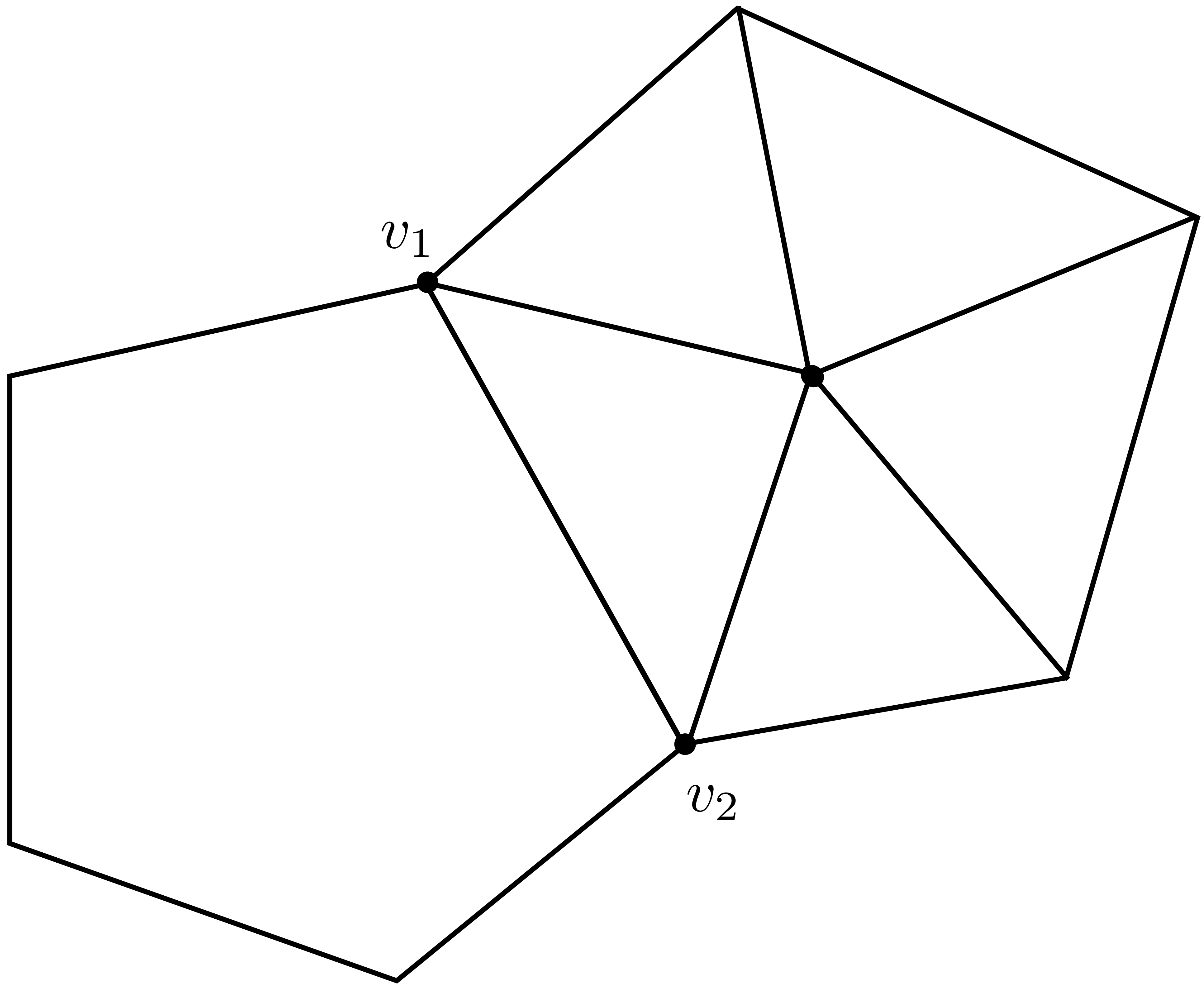


1st derivative

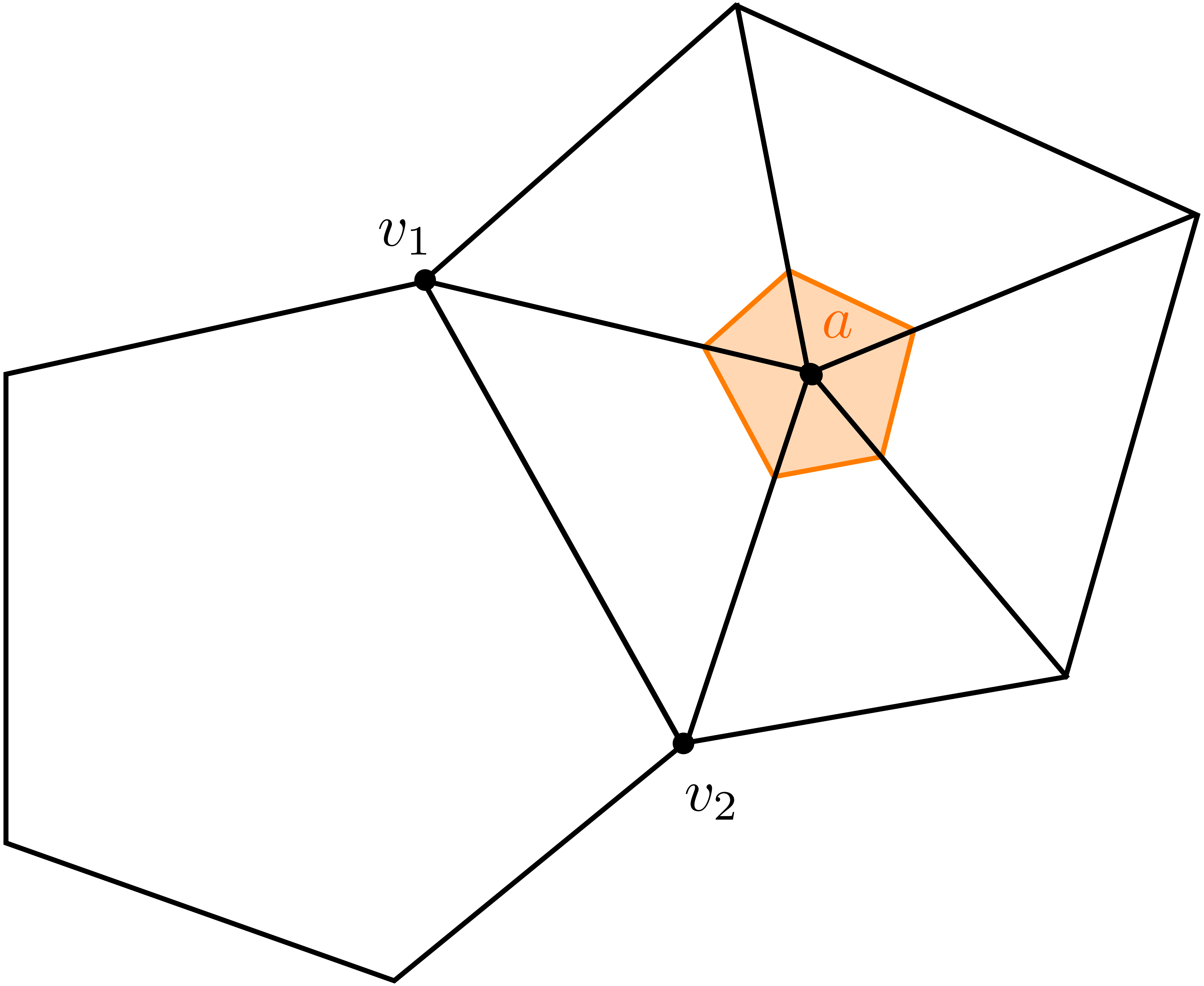
linear interlocking constraint



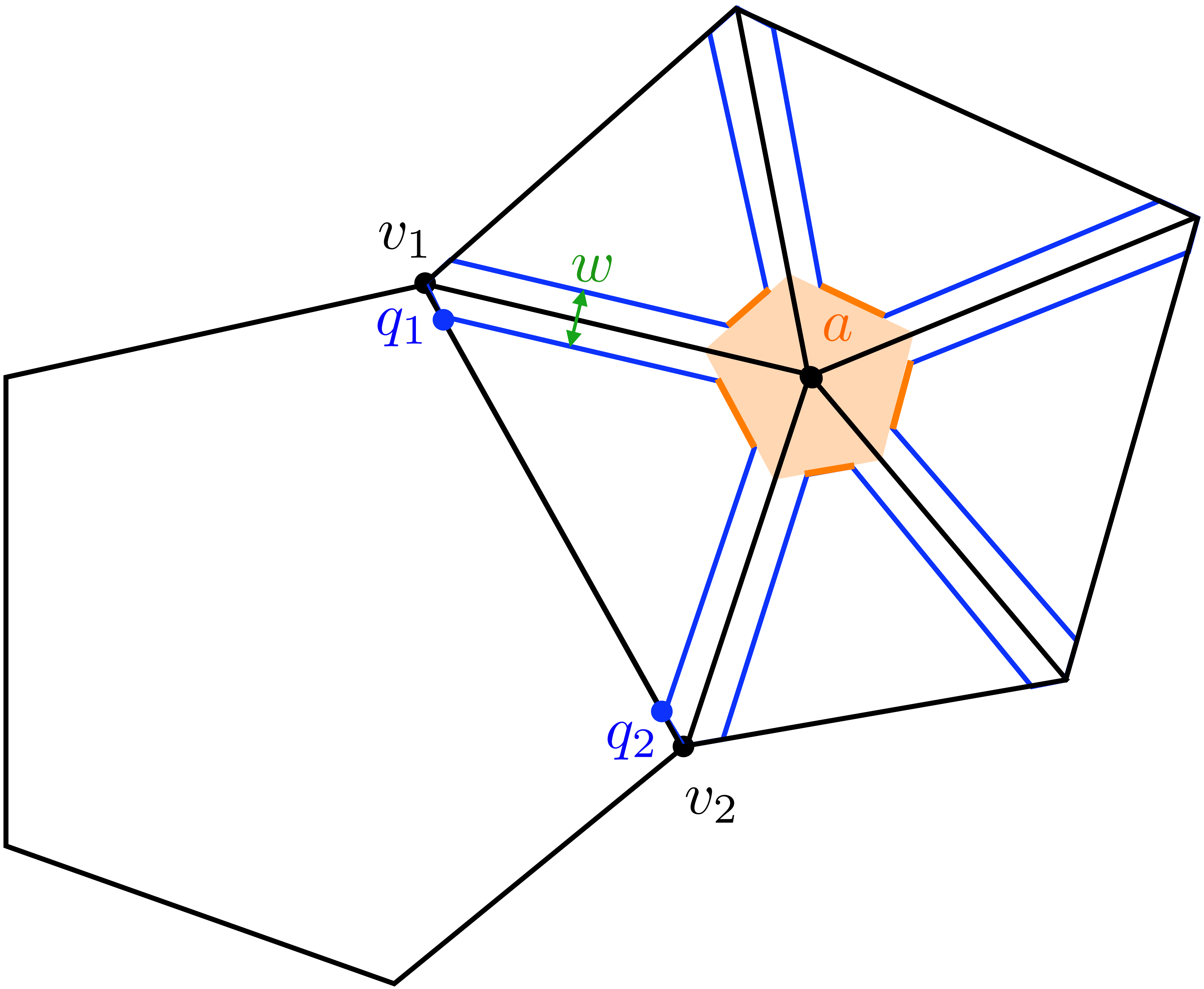
v_1
v_2



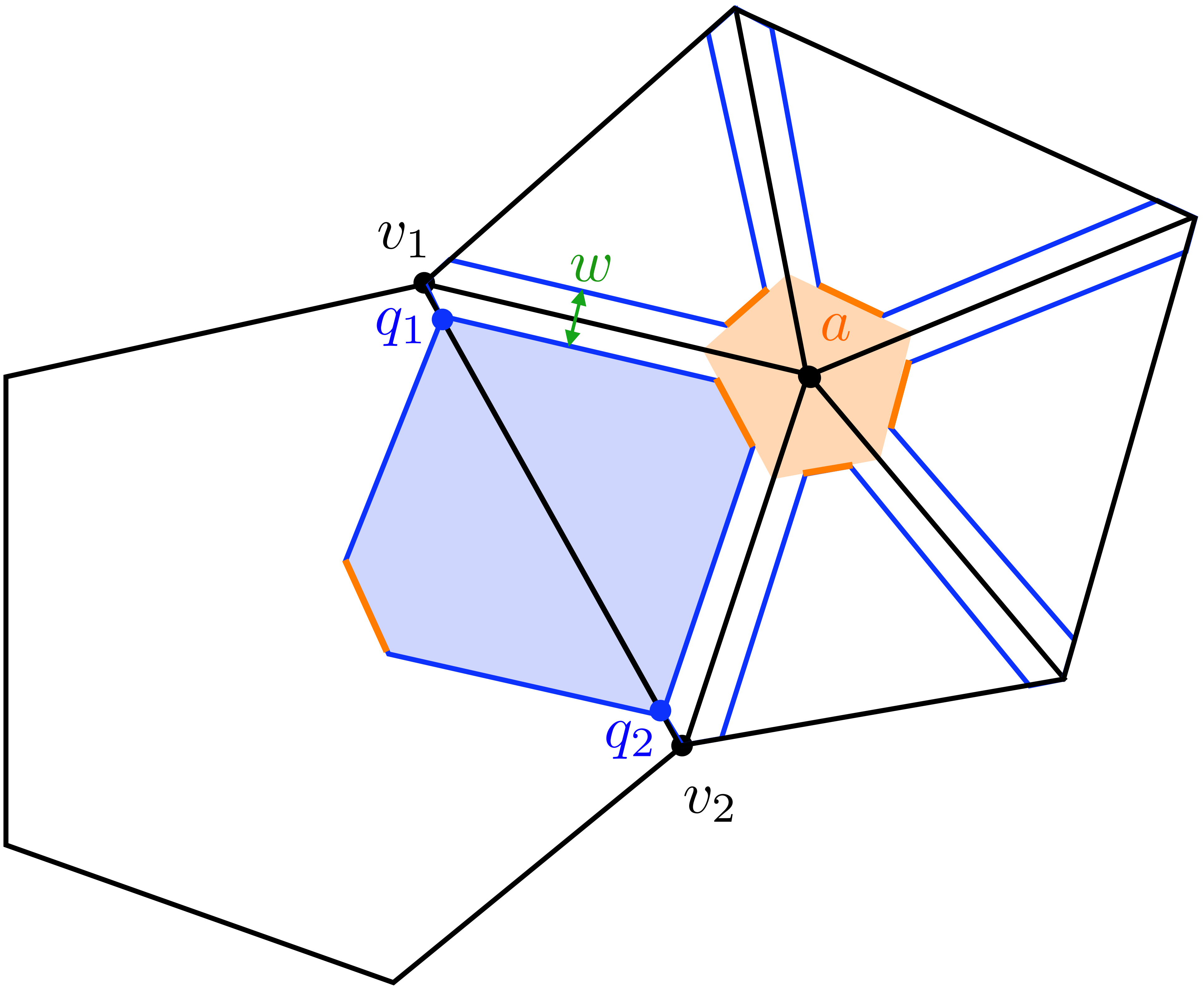
intersection constraint



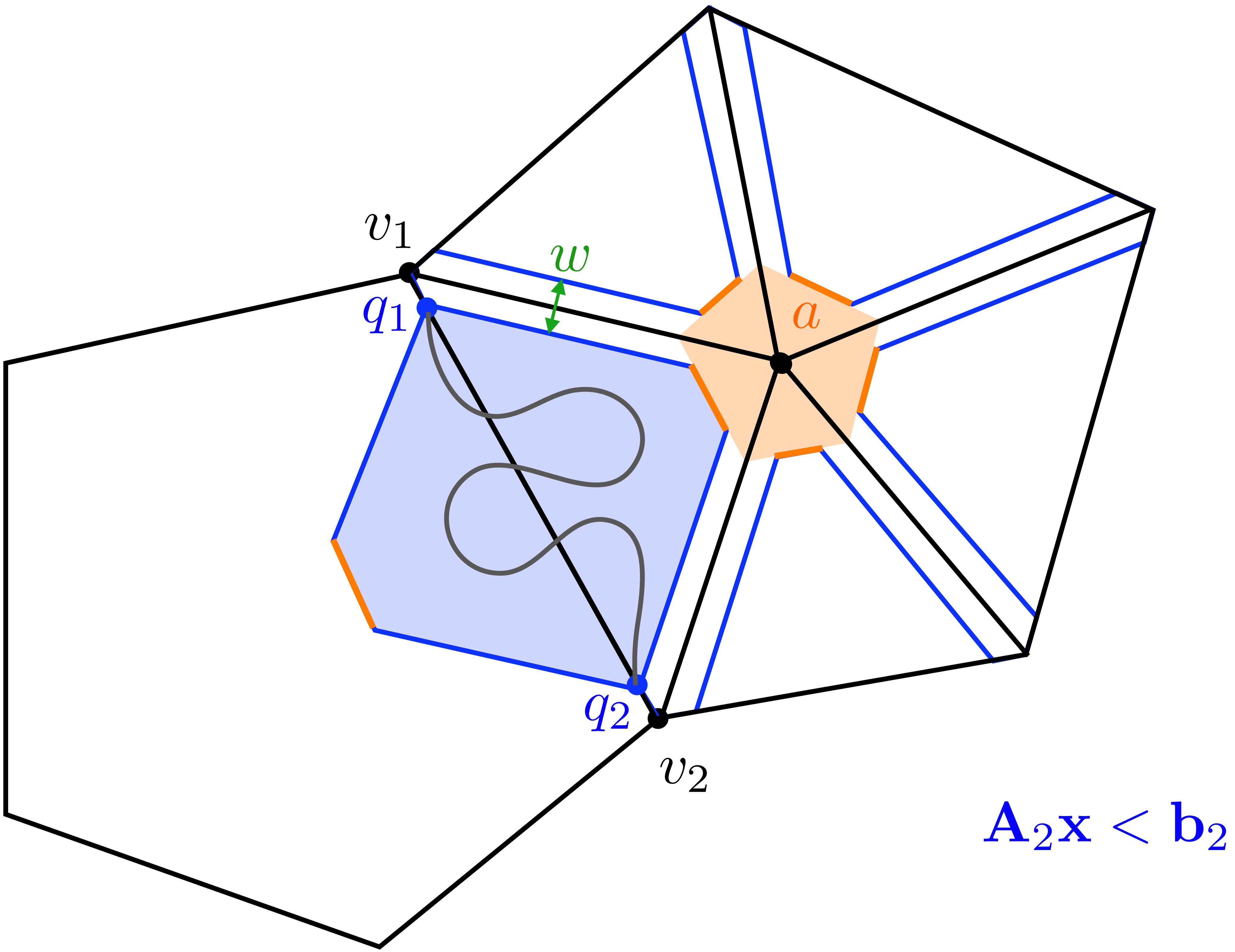
minimum piece size constraint



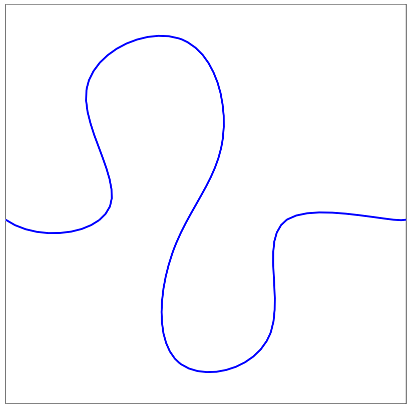
minimum width constraint (between curves)



intersection, min piece size, min width constraints



intersection, min piece size, min width constraints



$$\underset{\mathbf{x}}{\text{minimize}} \quad \left\|\mathbf{B}'\mathbf{x} - \mathbf{B}'\mathbf{x_u}\right\|^2 \quad + \lambda \sum_{i=1}^{n_s} \mathbf{I}(\mathbf{B}_i \mathbf{x})$$

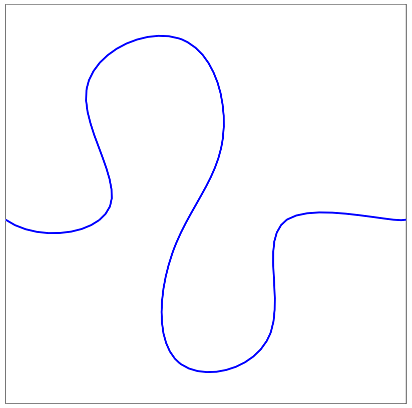
$$\text{subject to} \quad \mathbf{A}\mathbf{x} < \mathbf{b}$$

interlocking

minimum piece size

intersection

minimum width



$$\underset{\mathbf{x}}{\text{minimize}} \quad \left\|\mathbf{B}'\mathbf{x} - \mathbf{B}'\mathbf{x}_{\mathbf{u}}\right\|^2 \quad + \lambda \sum_{i=1}^{n_s} \mathbf{I}(\mathbf{B}_i \mathbf{x})$$

$$\text{subject to} \quad \mathbf{A}\mathbf{x} < \mathbf{b}$$

interlocking

minimum piece size

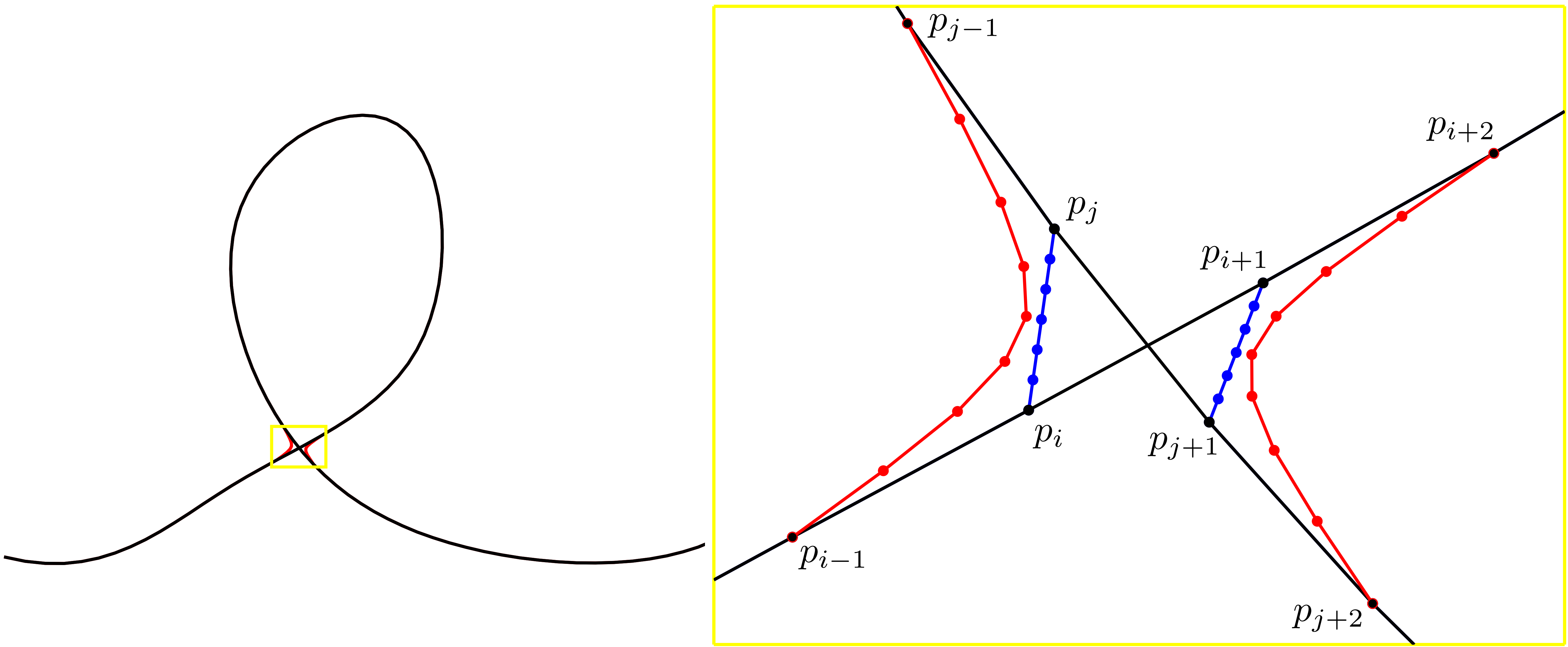
intersection

minimum width

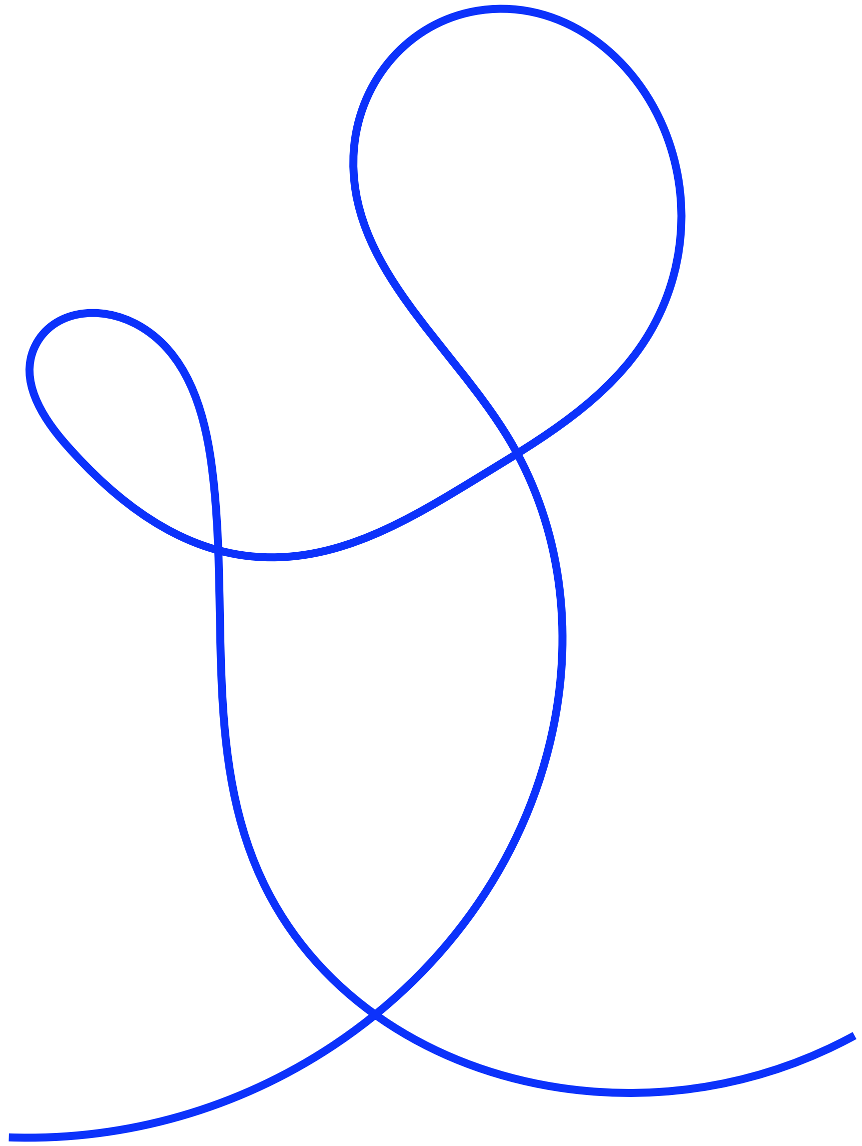
Post Processing:

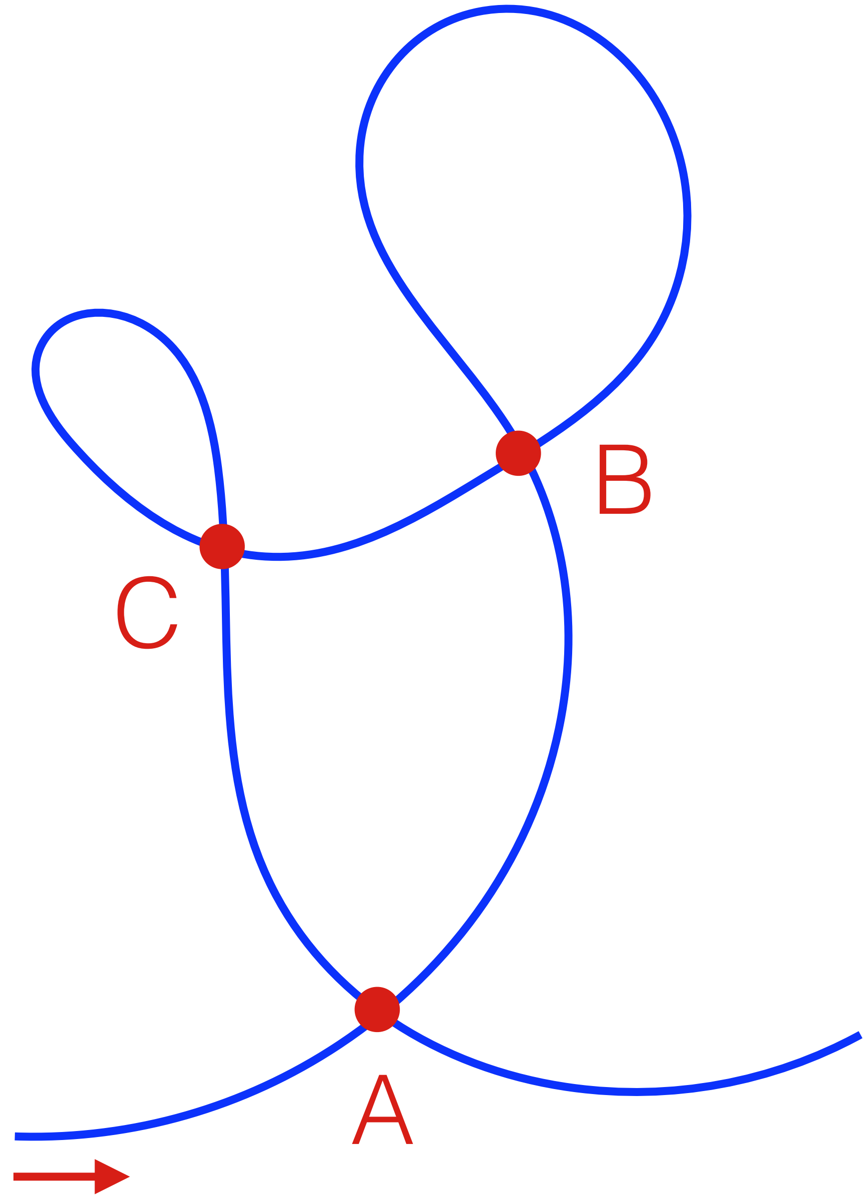
minimum width

self intersection

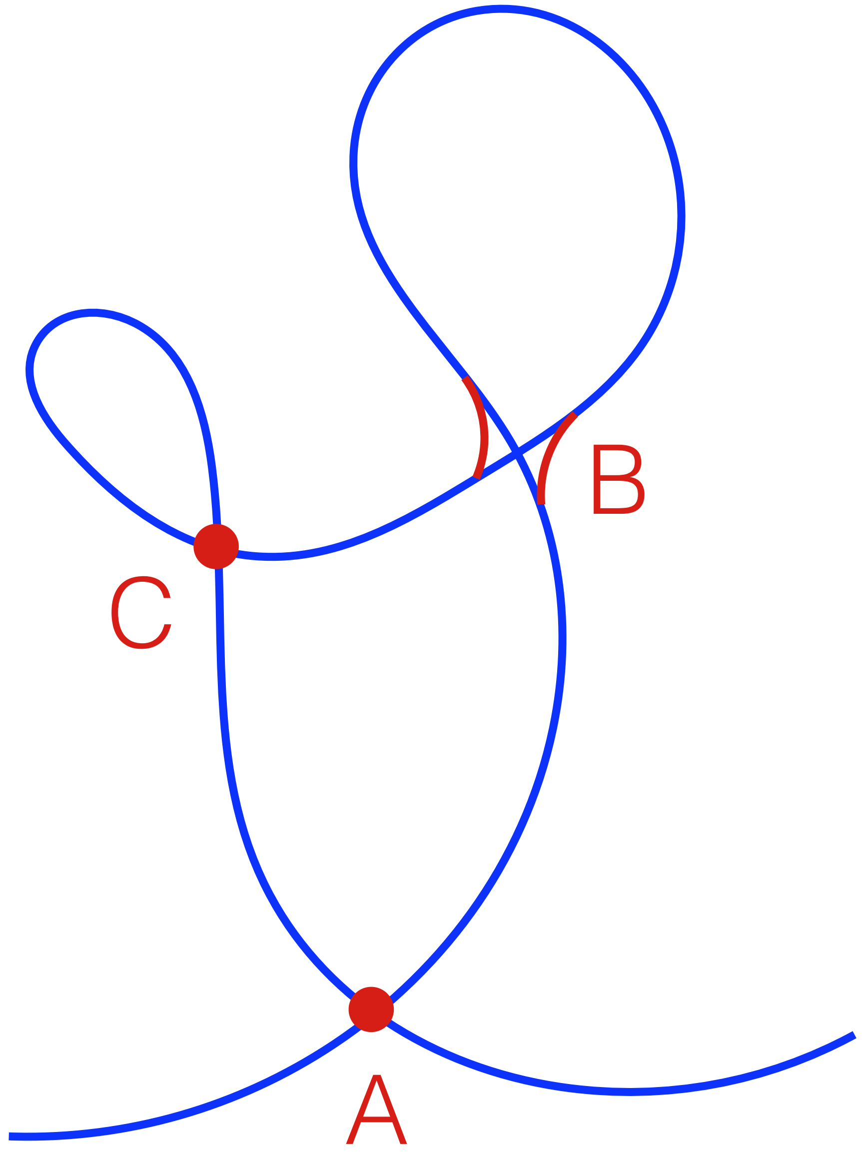


p_{j-1}
p_{i+2}
p_j
p_{i+1}
p_i
p_{j+1}
p_{i-1}
p_{j+2}

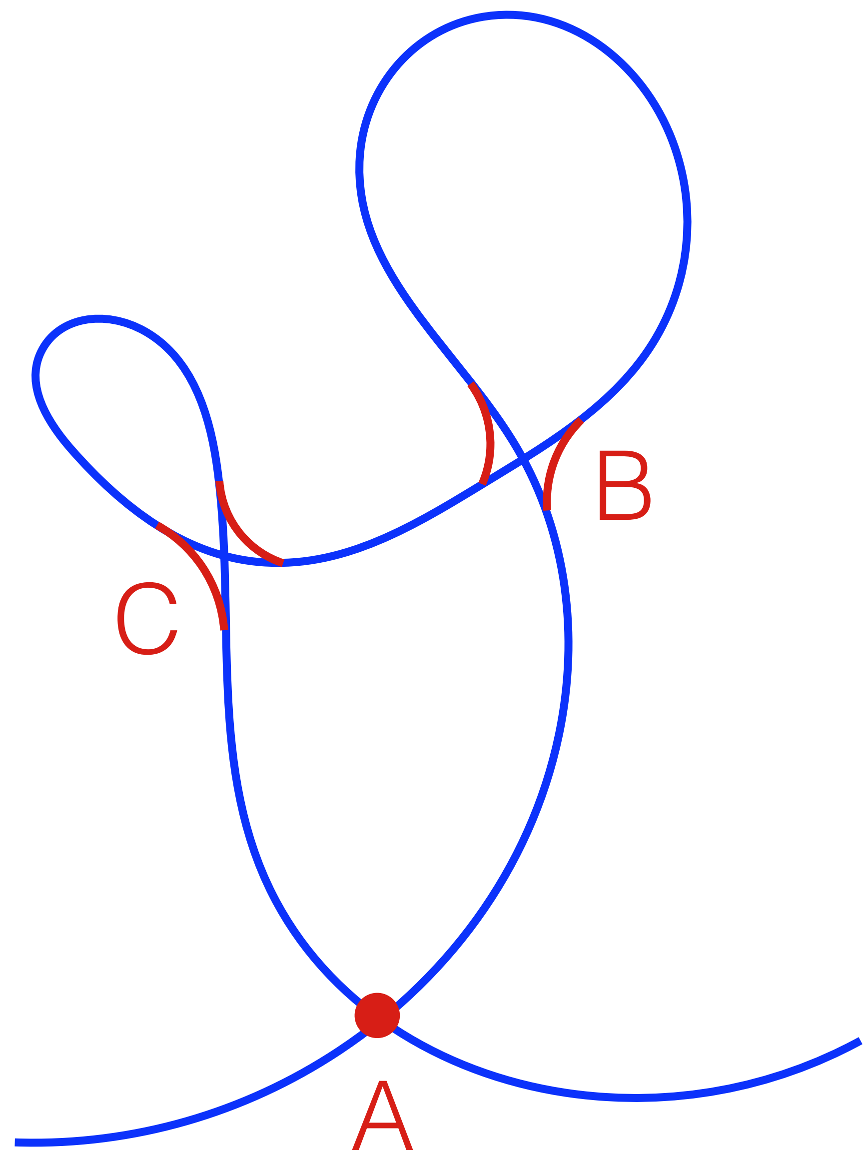




ABBCCA



ABBCCA



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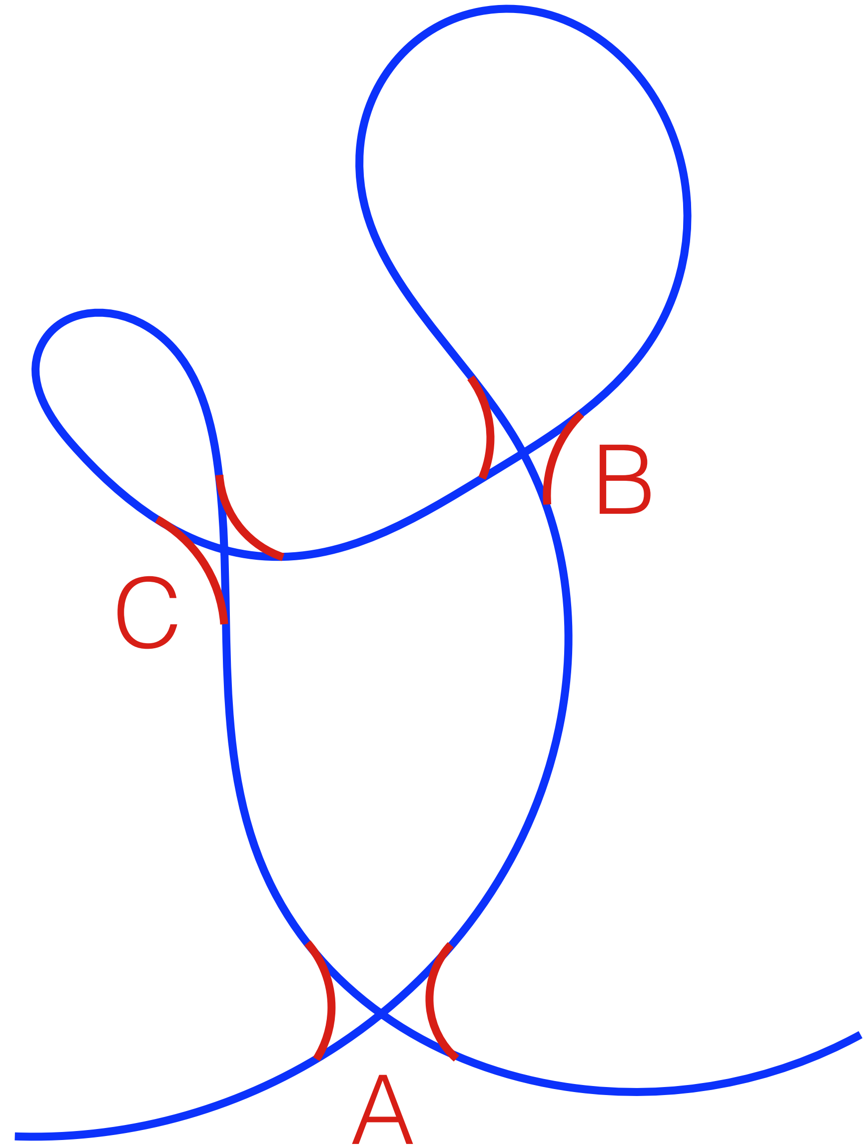

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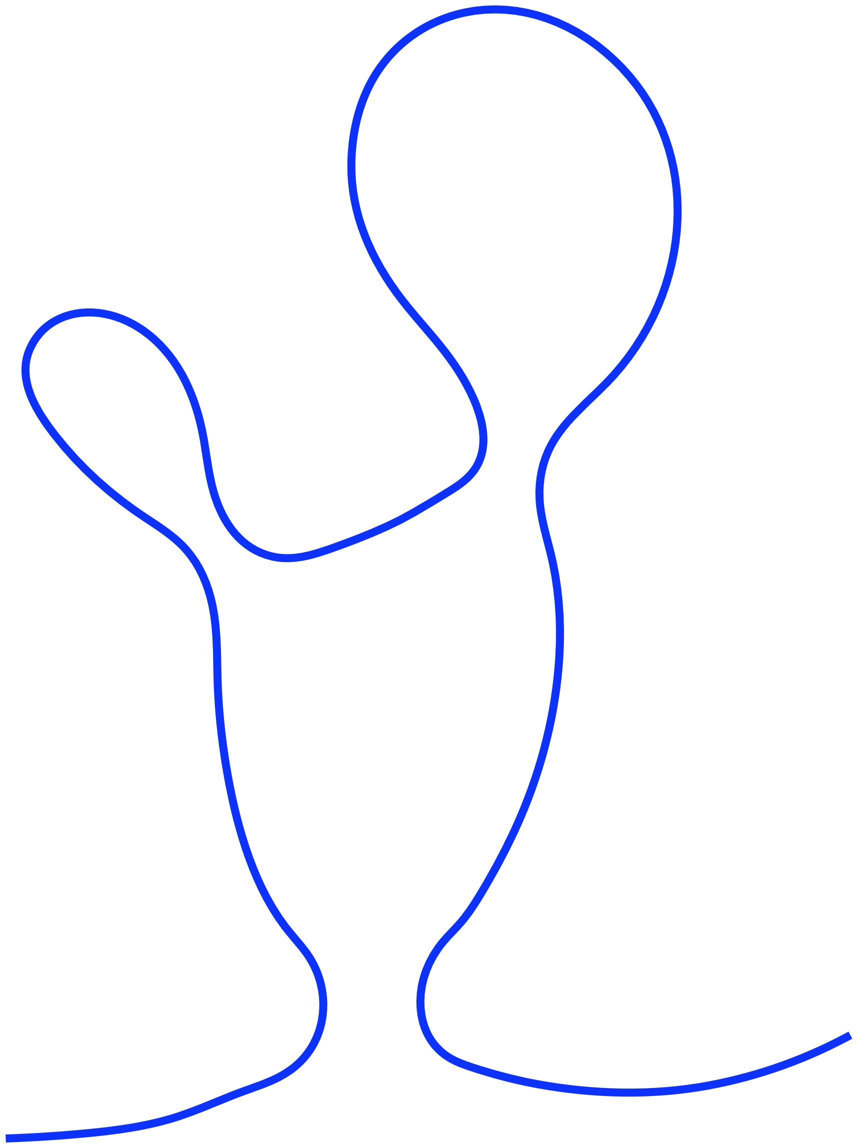
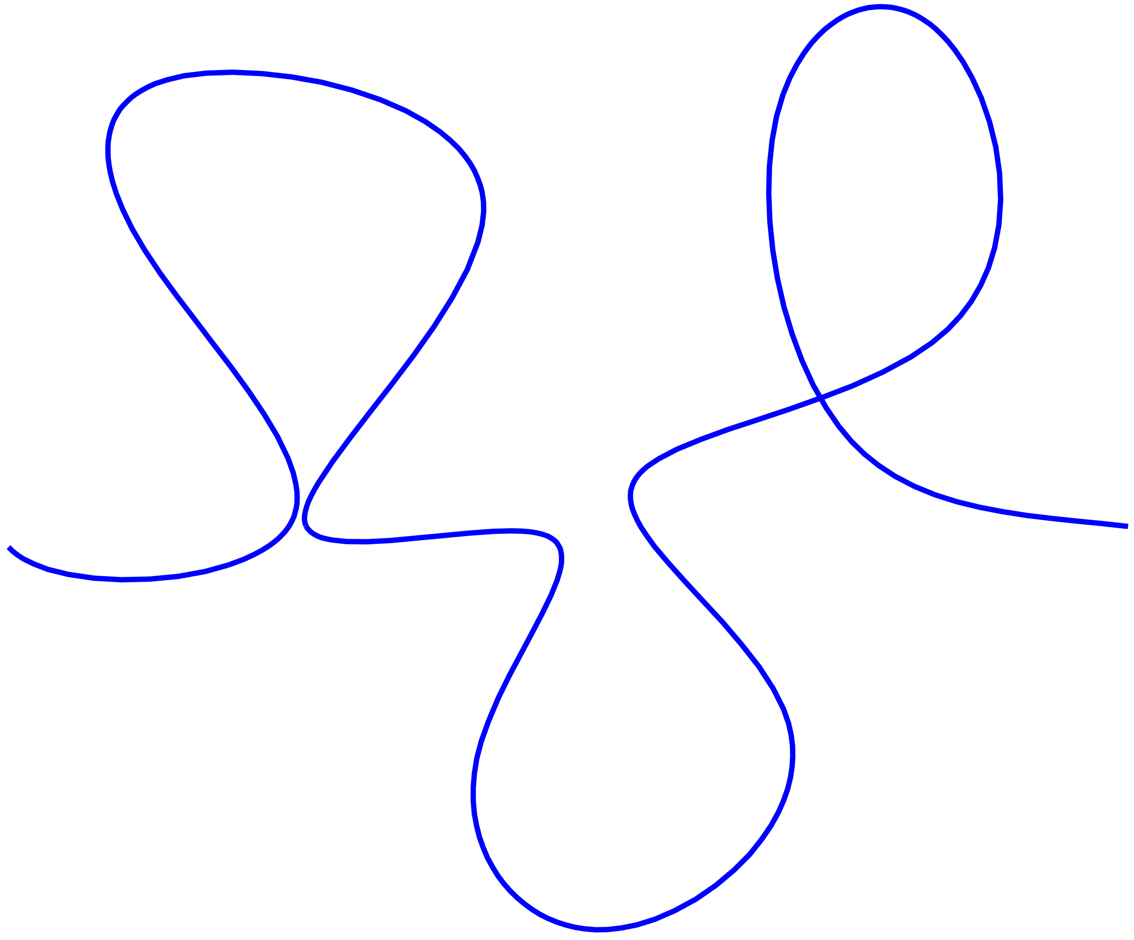
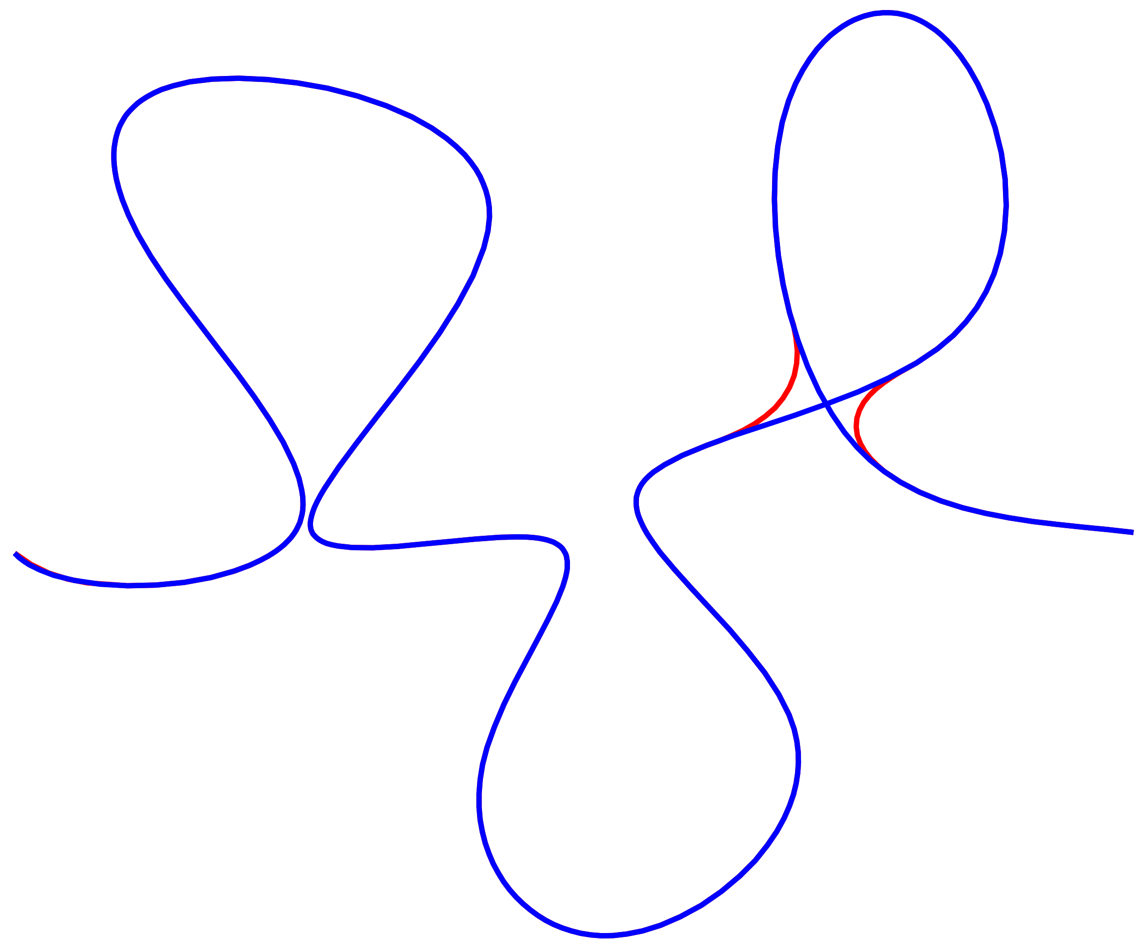
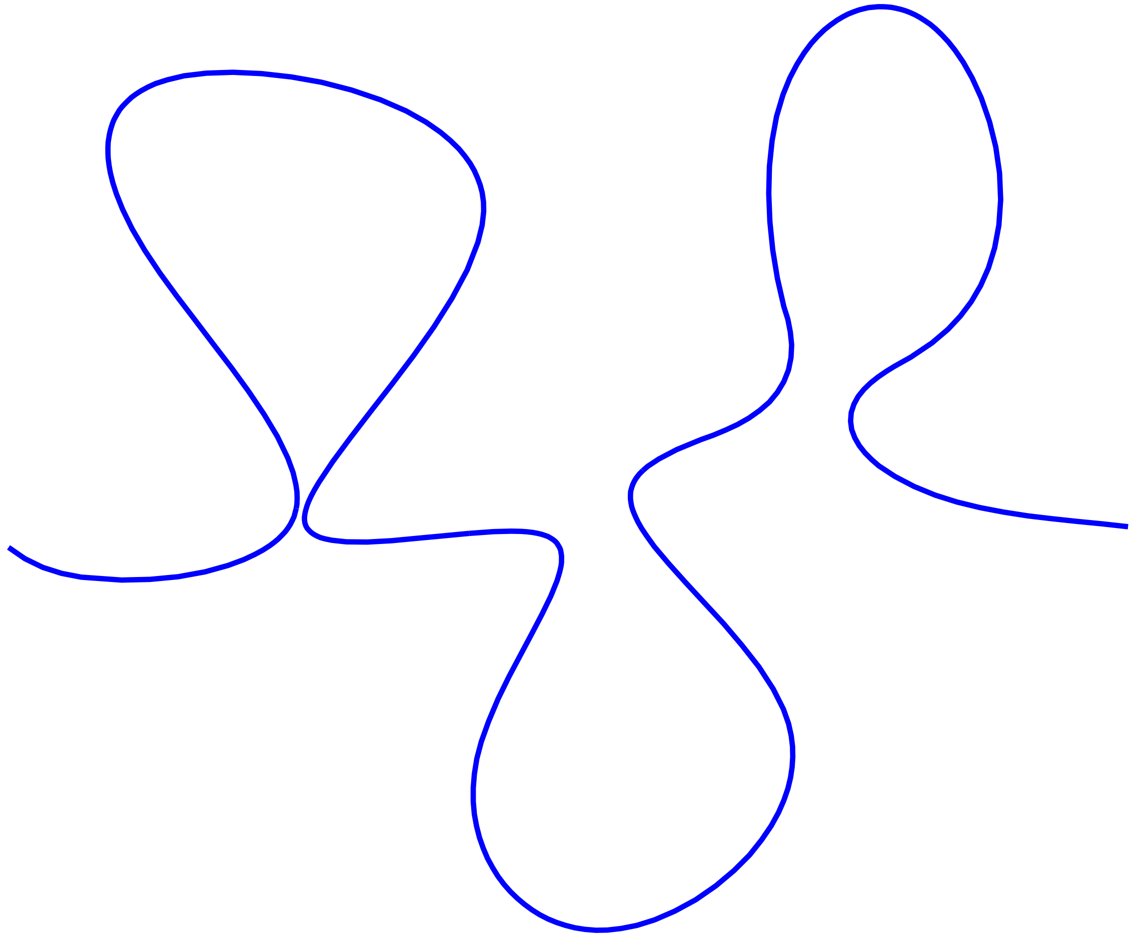
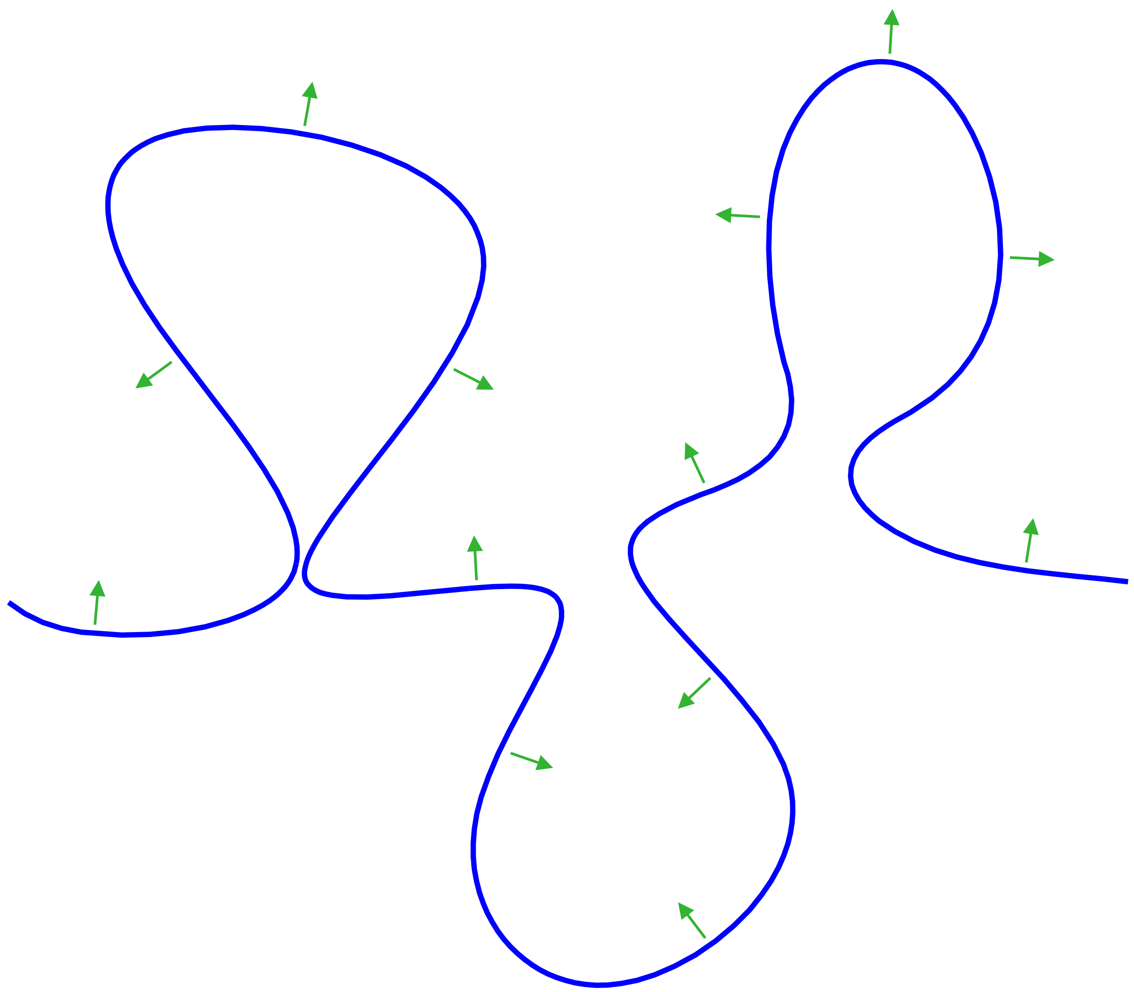
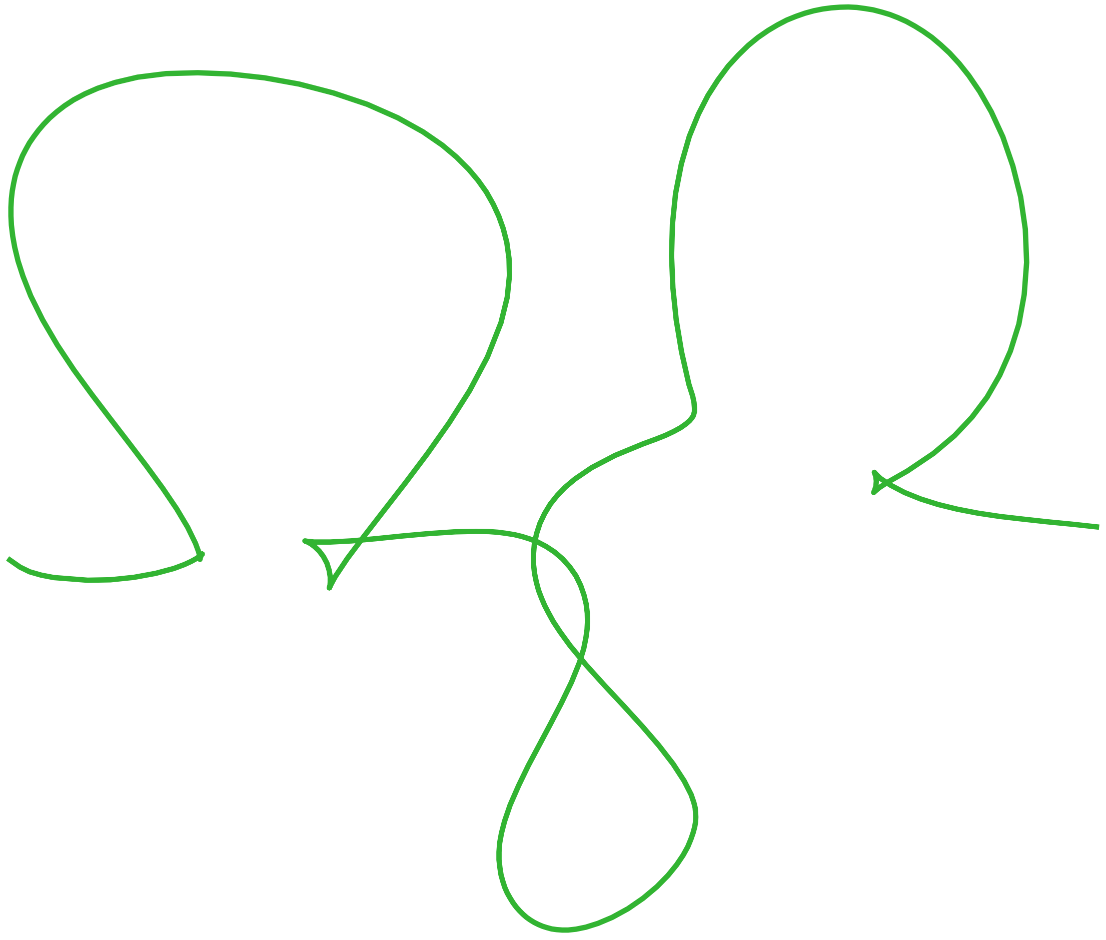


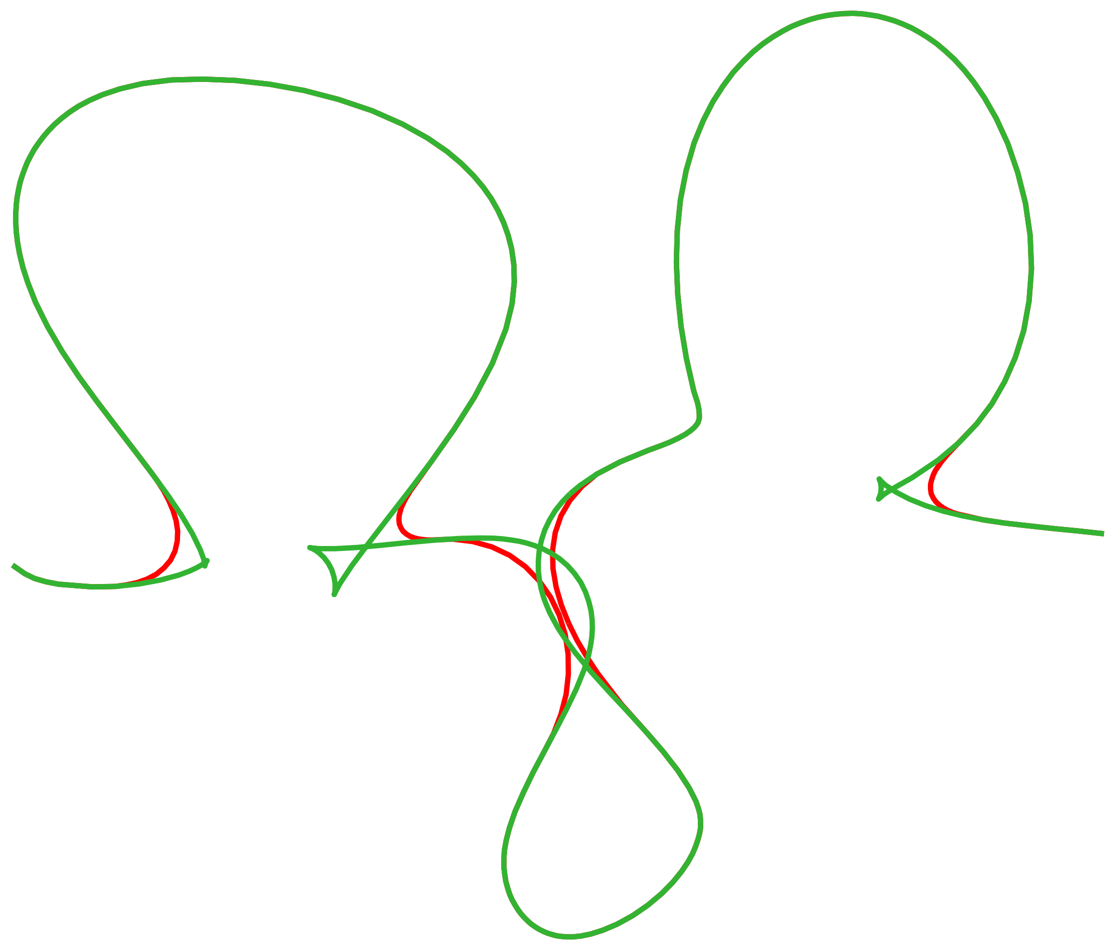


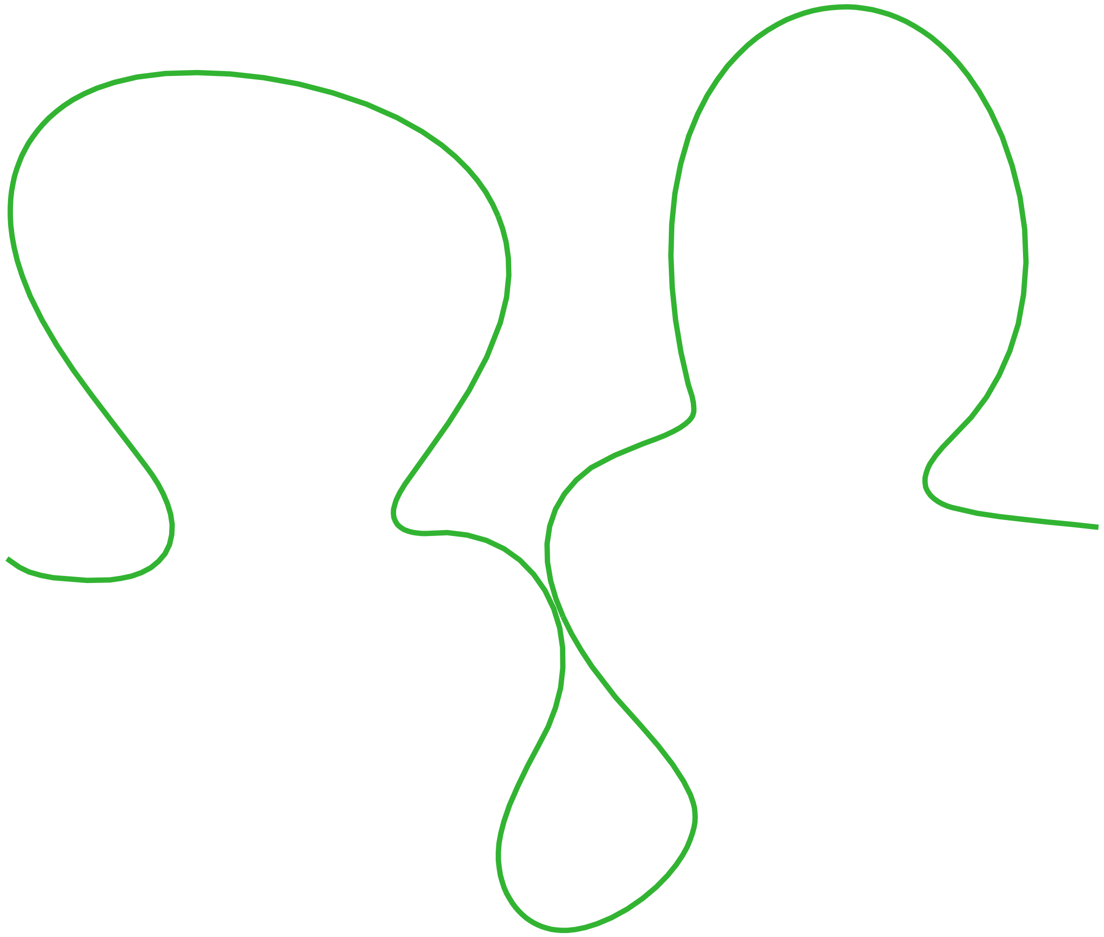


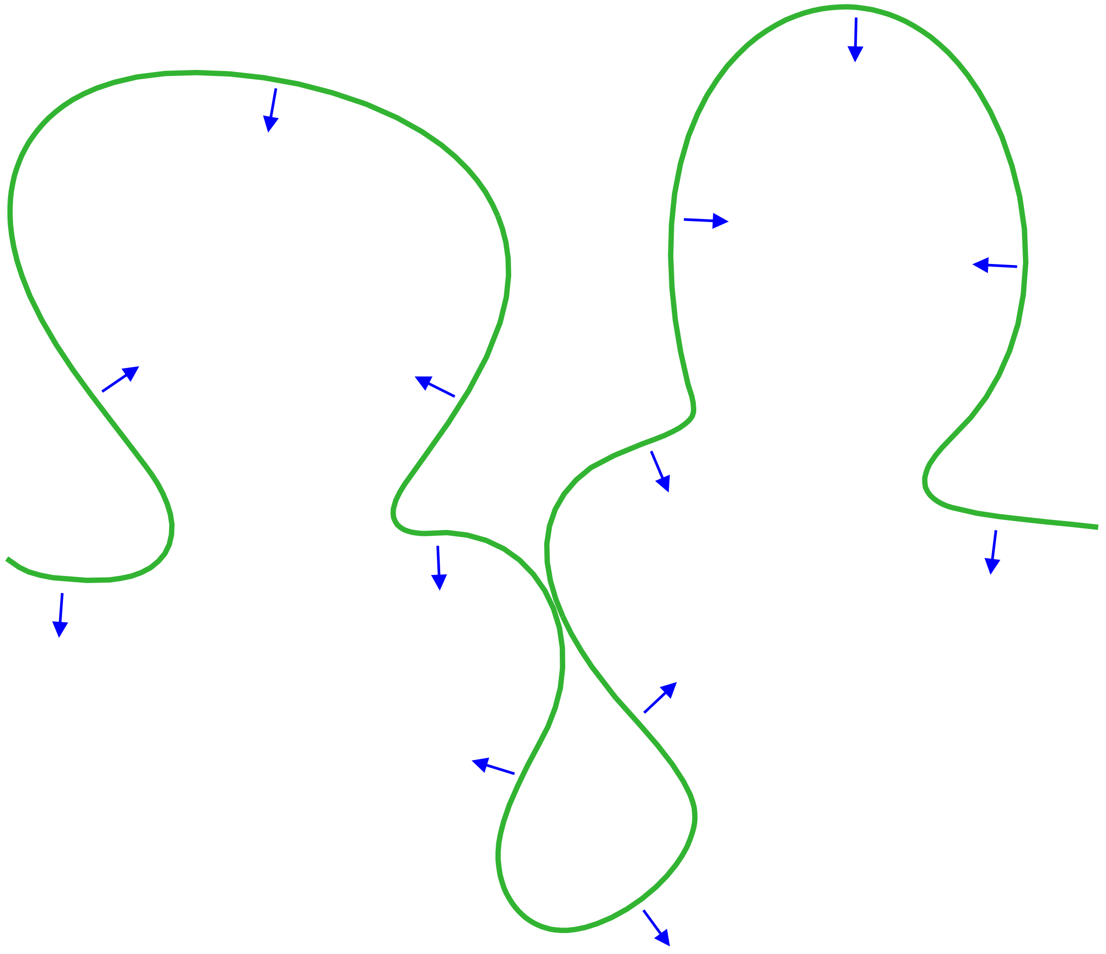


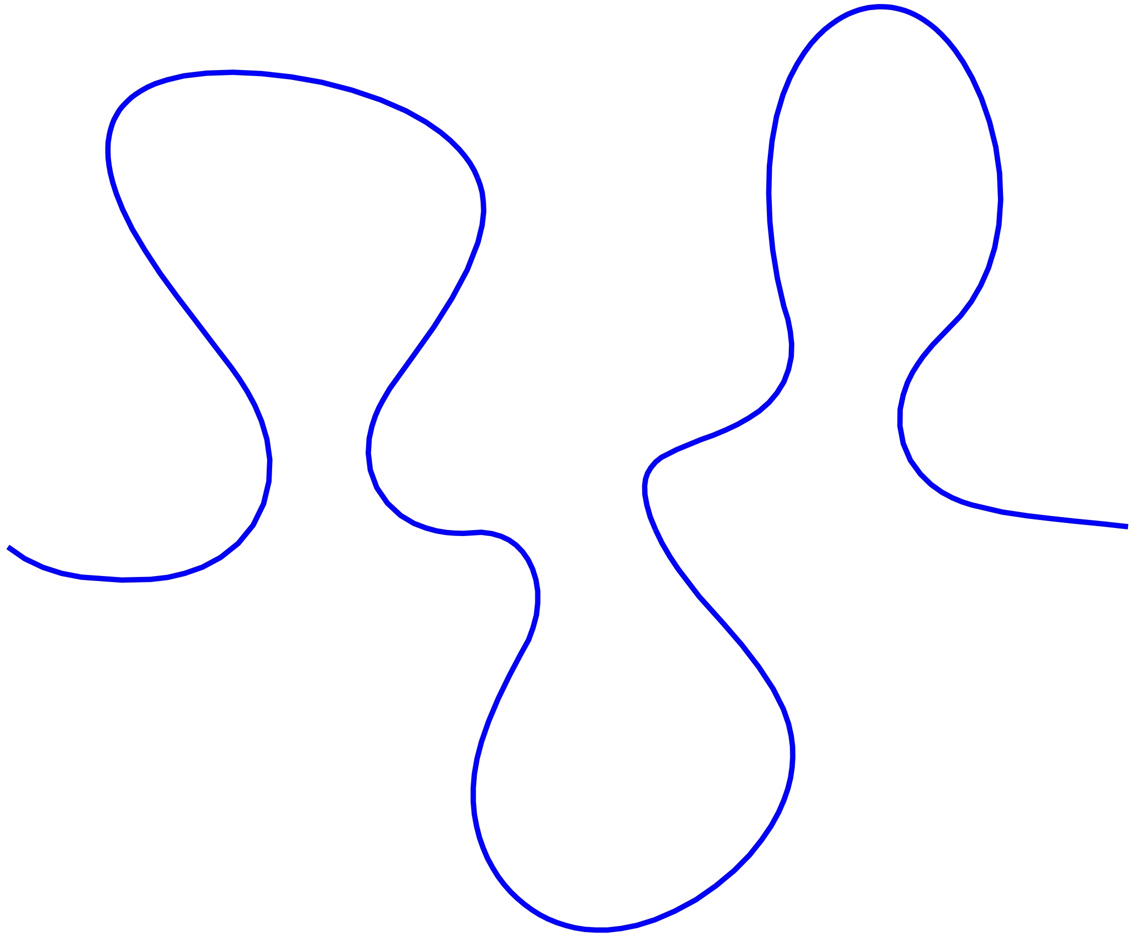


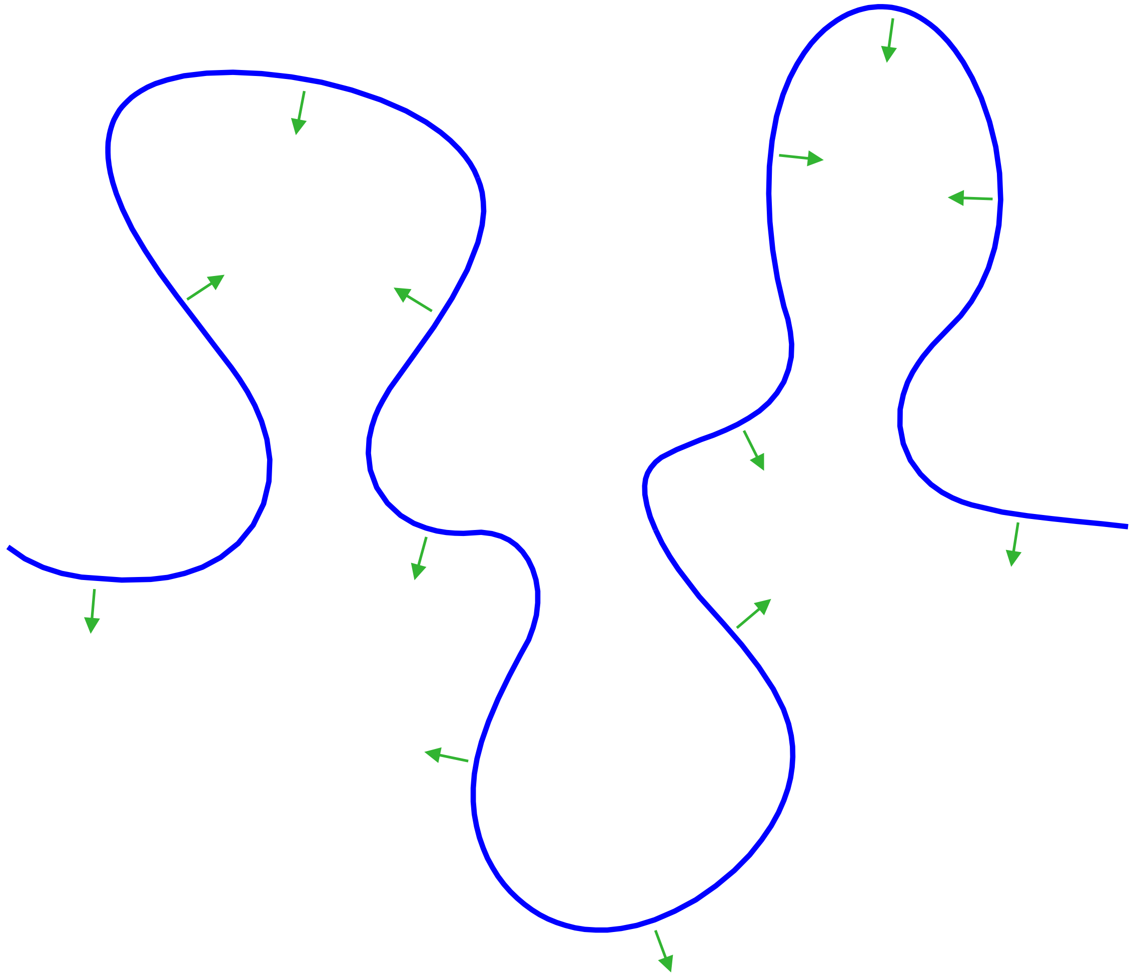


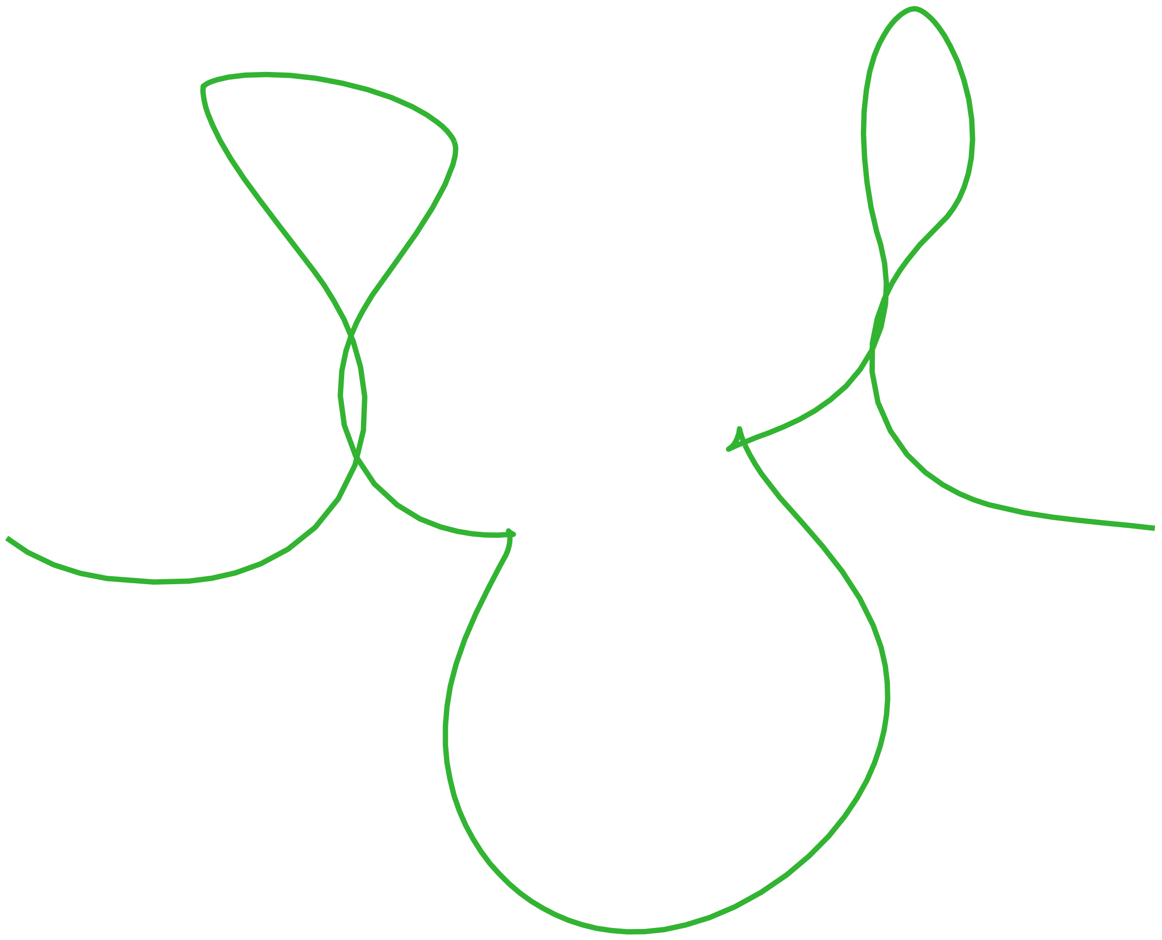


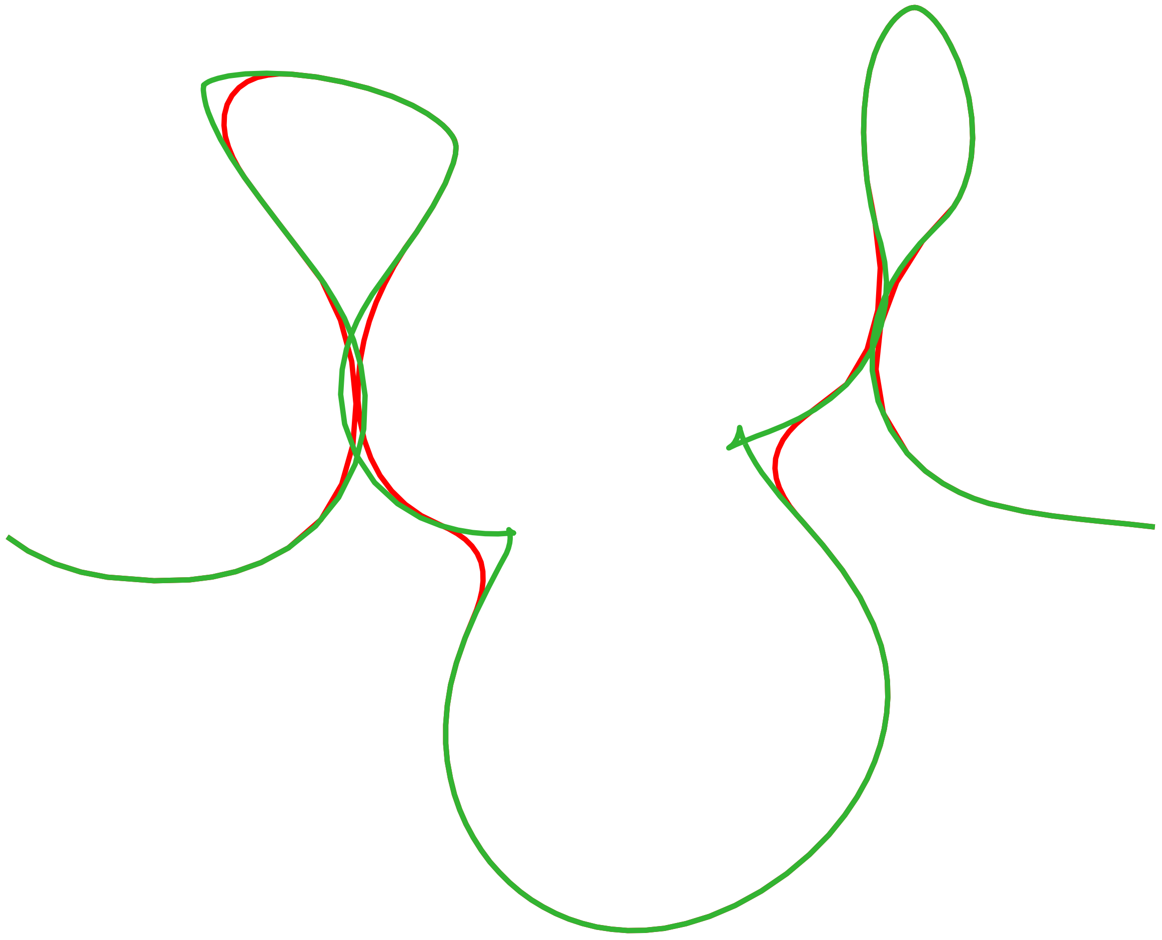


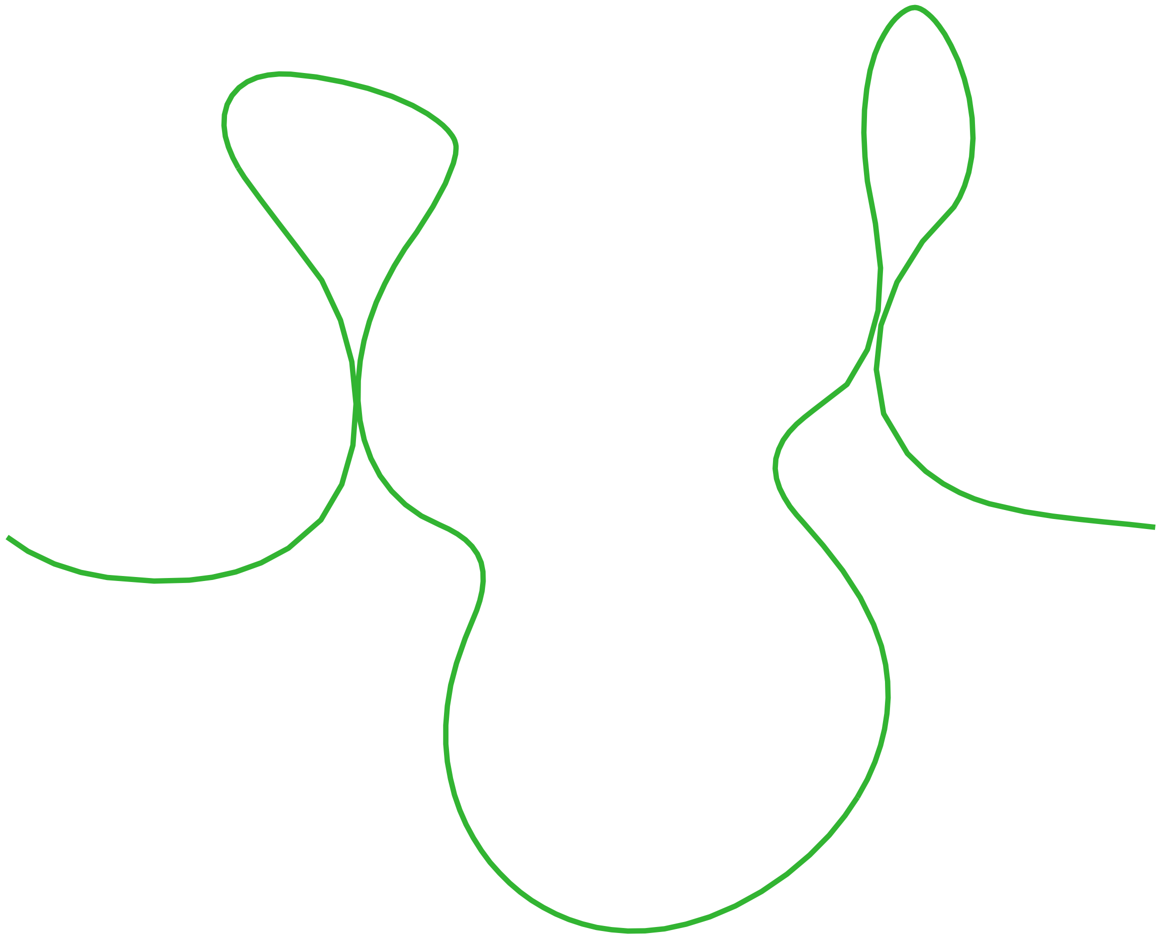


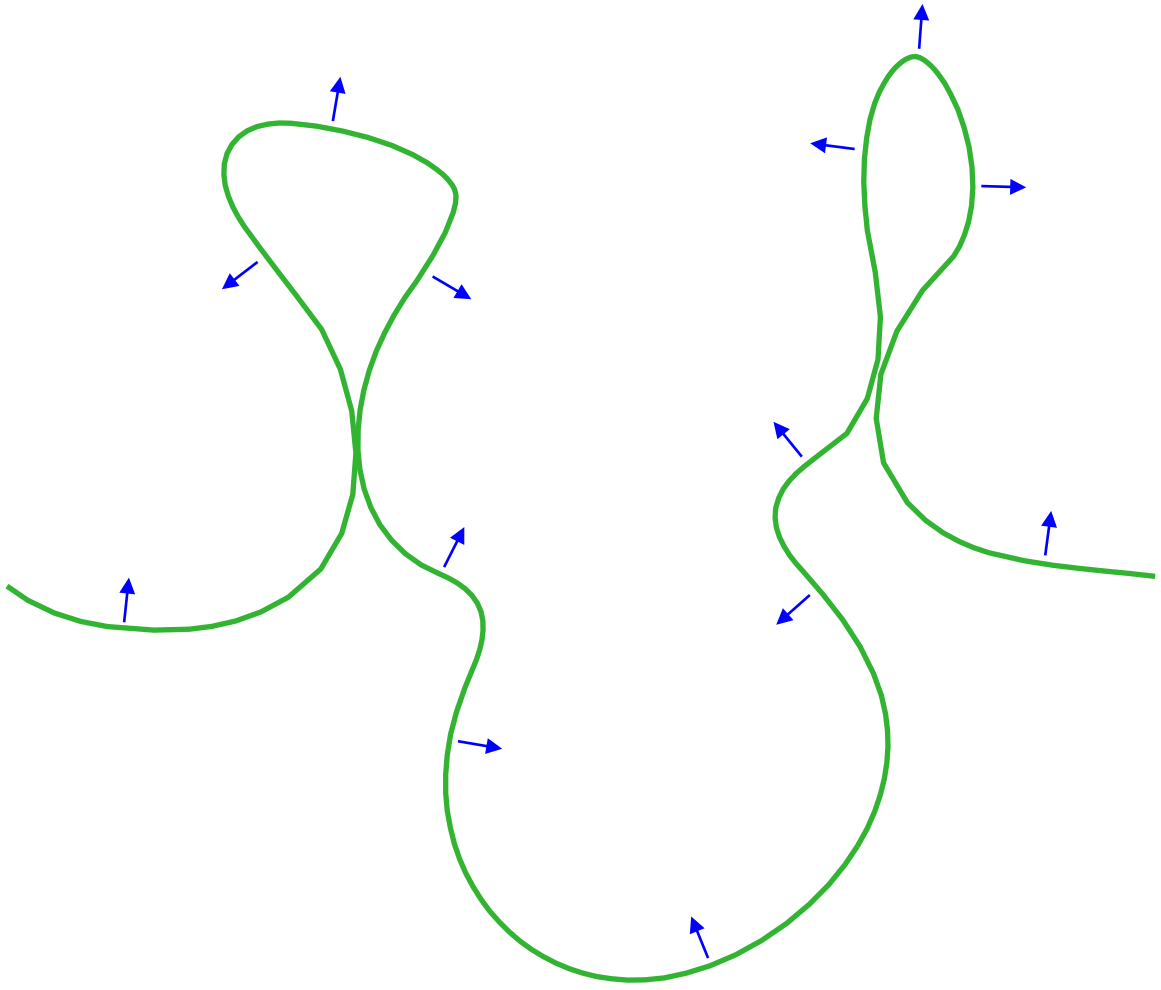


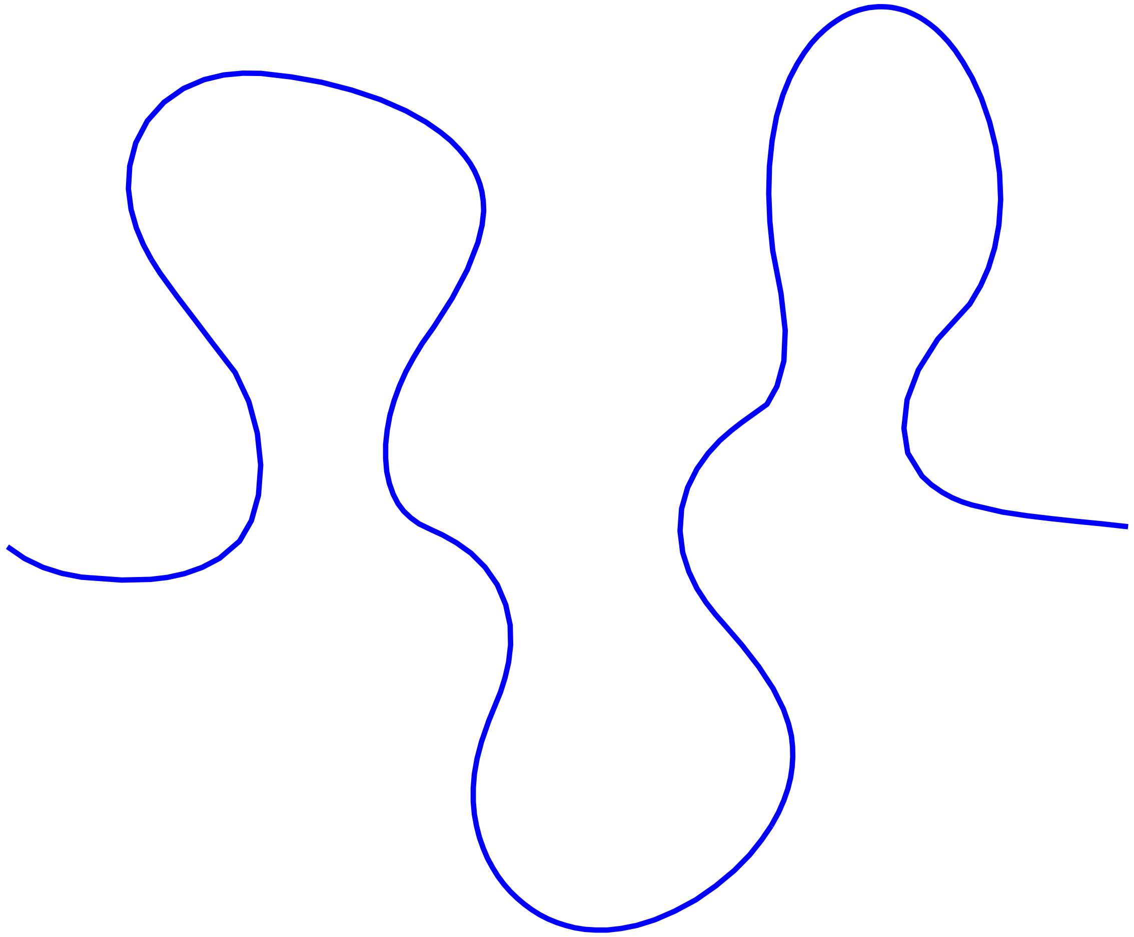


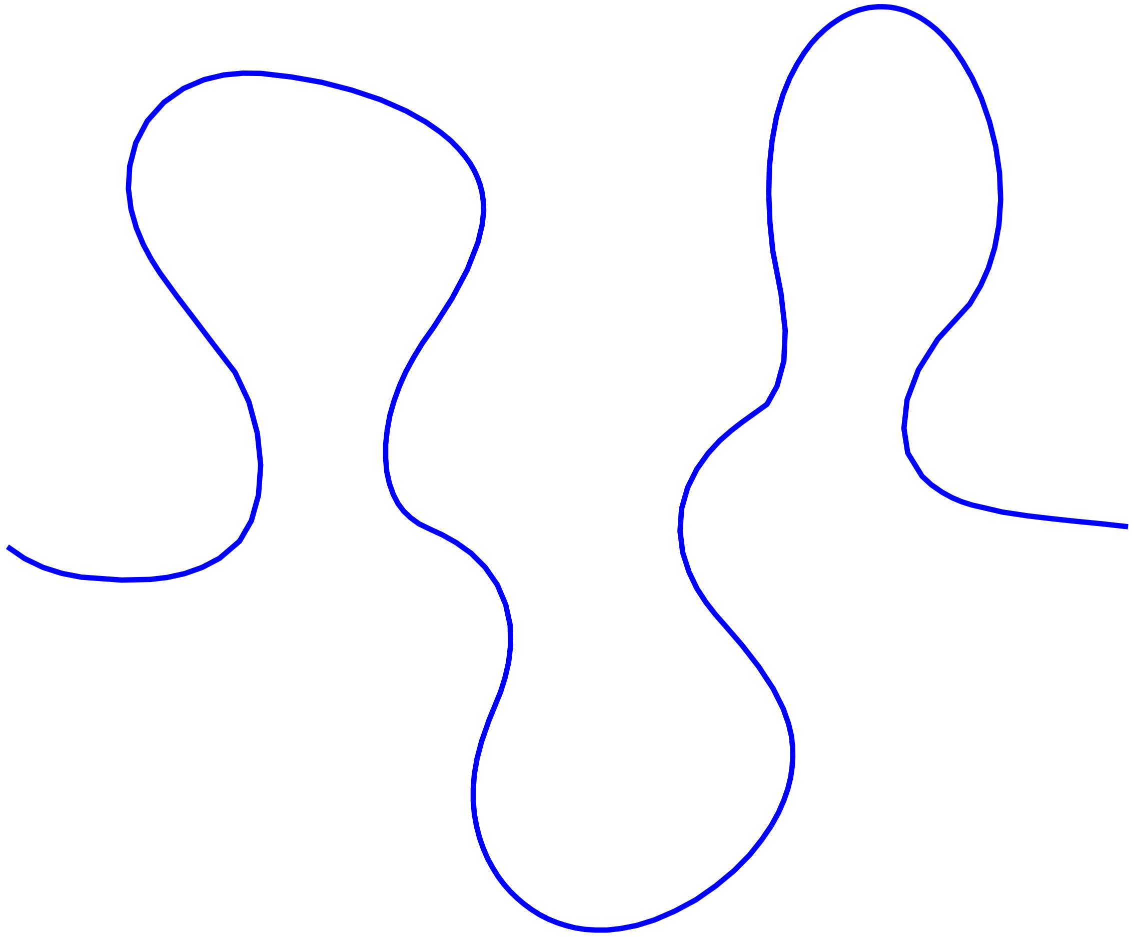


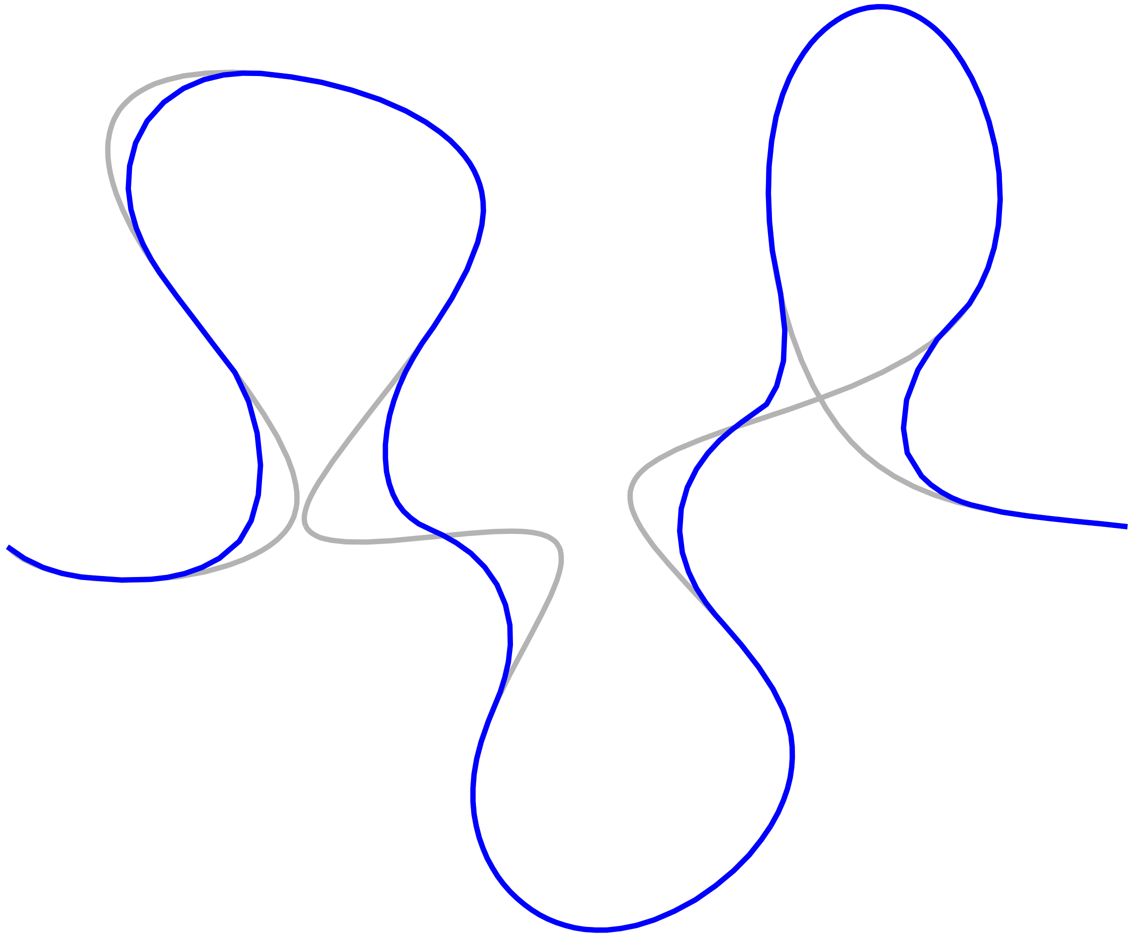


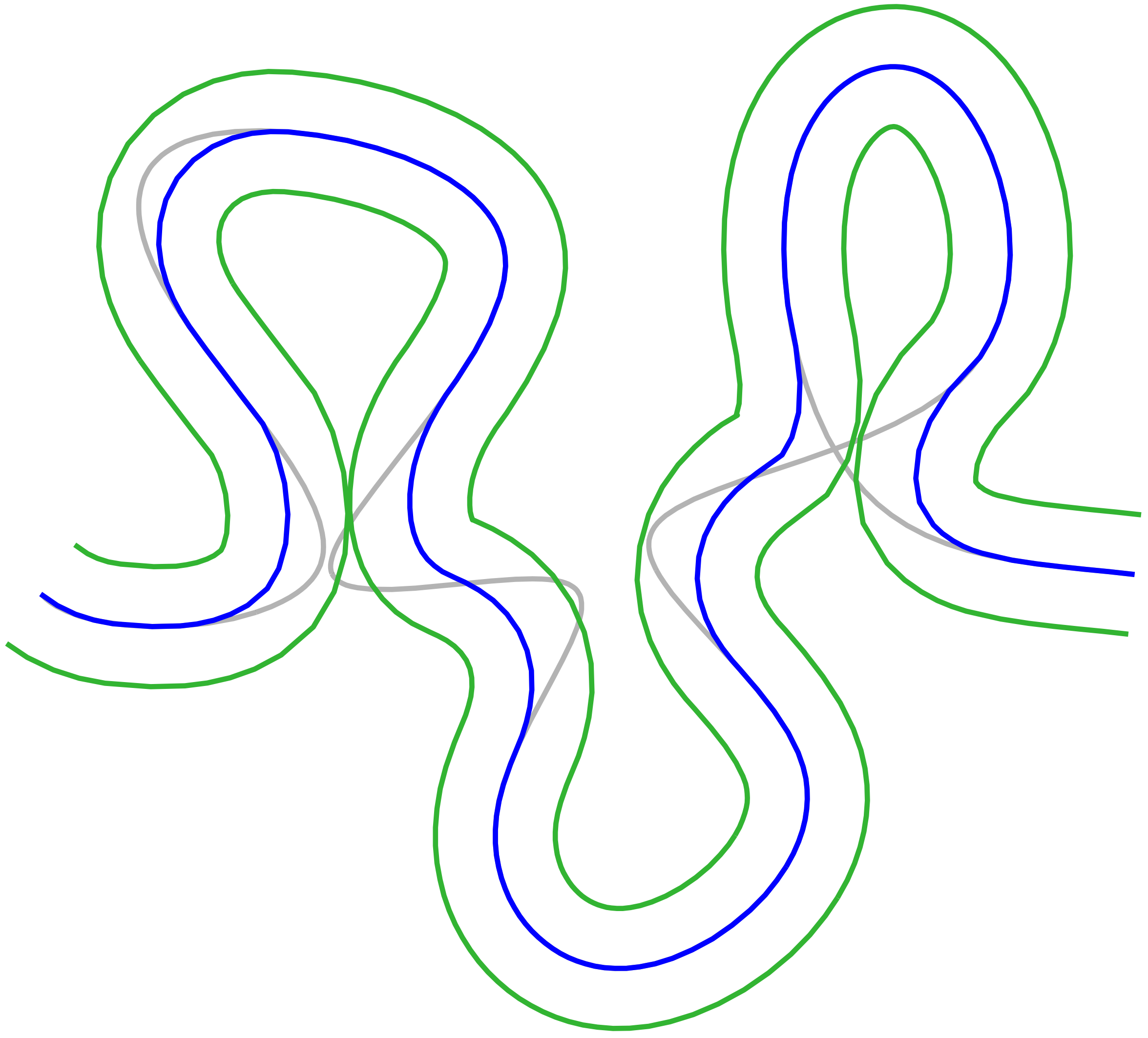


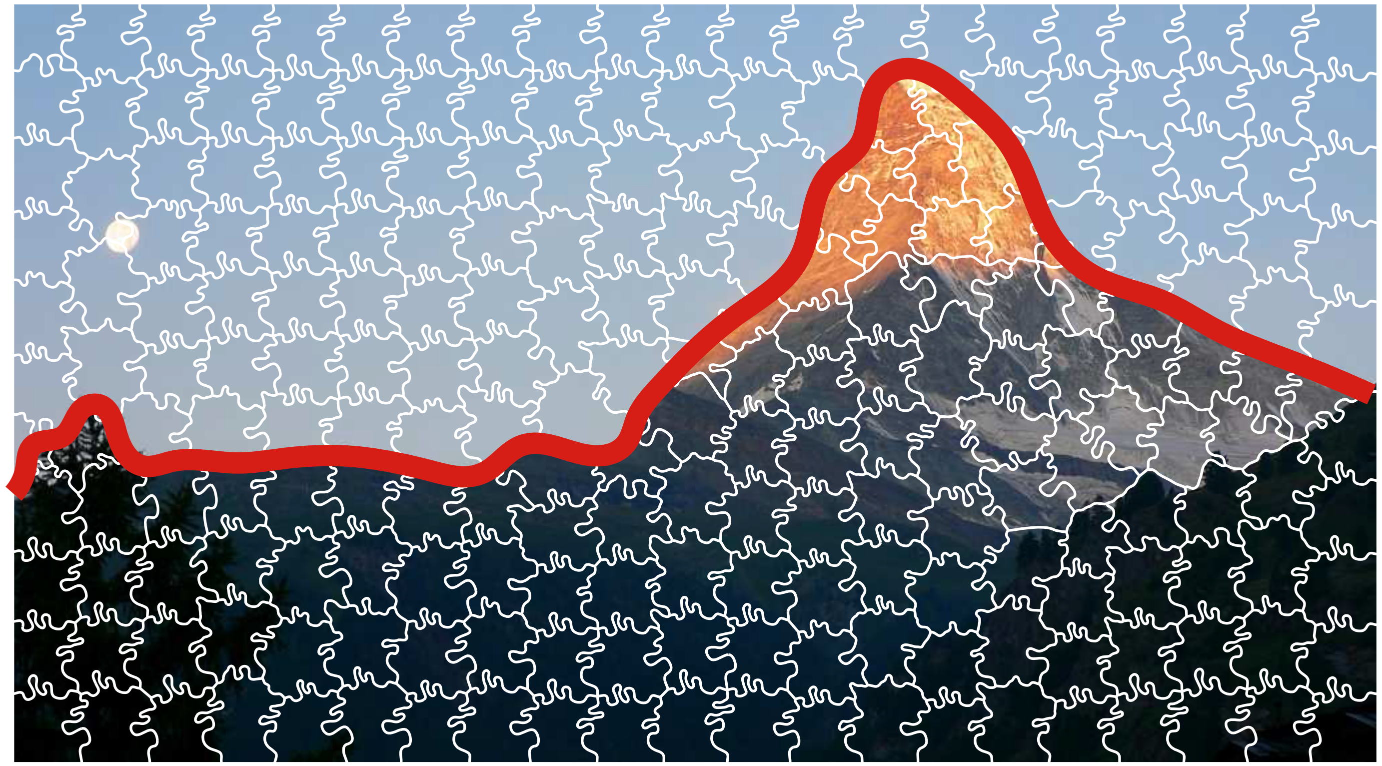


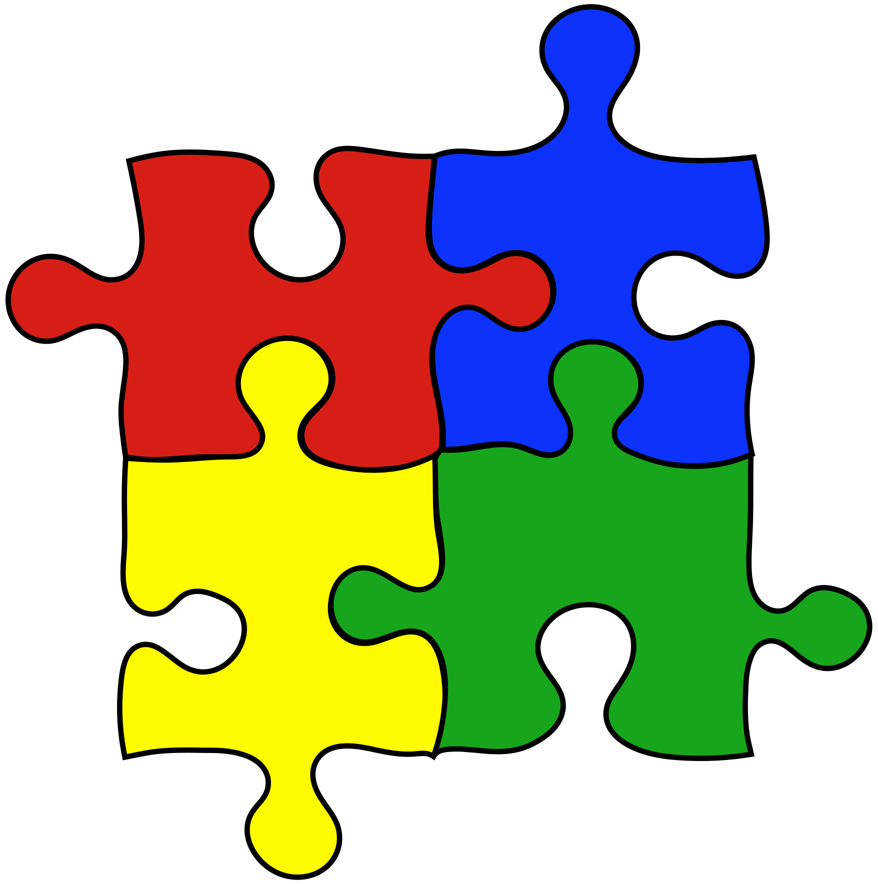






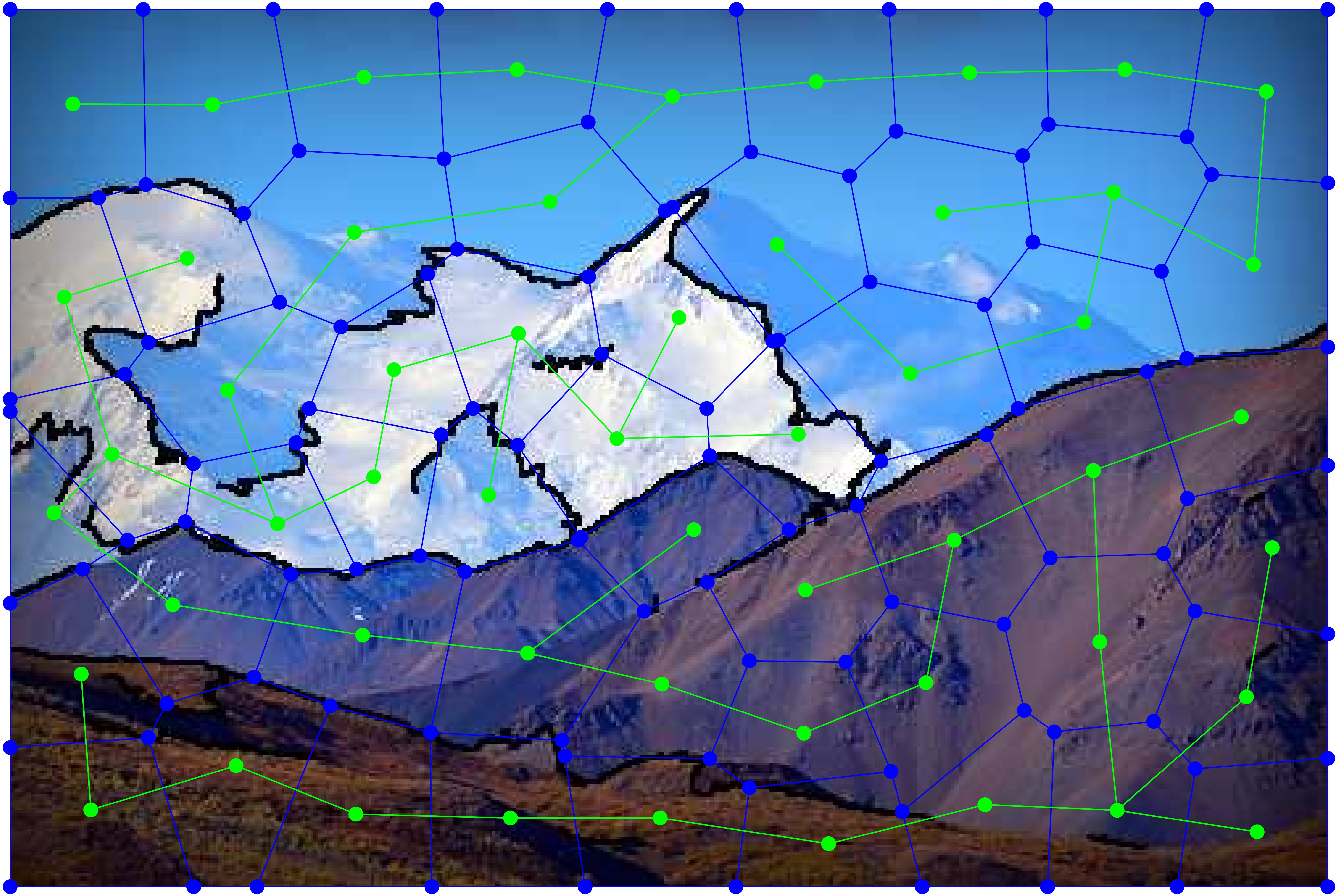




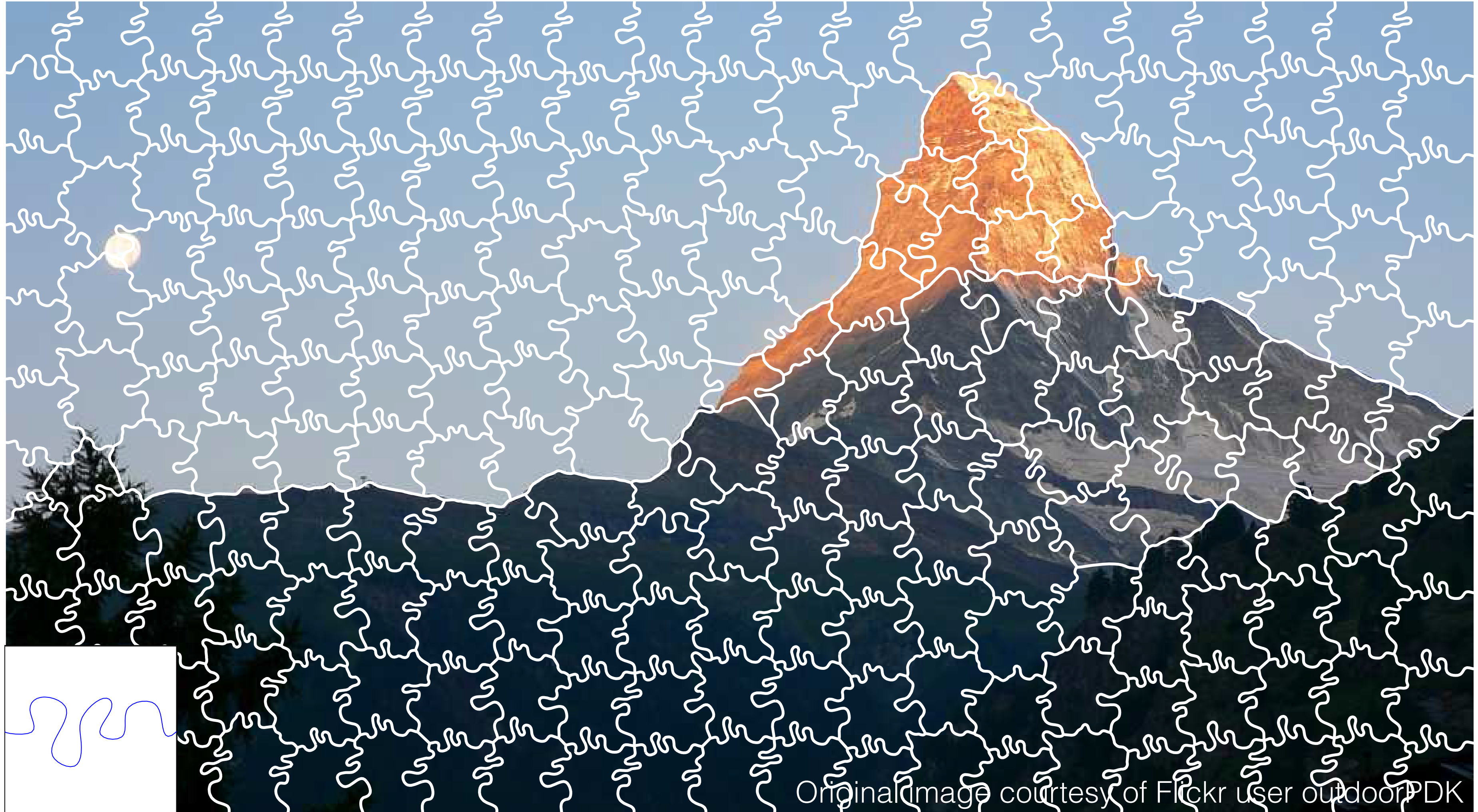


color line cutting

interlocking




Original image courtesy of Flickr user blmiers2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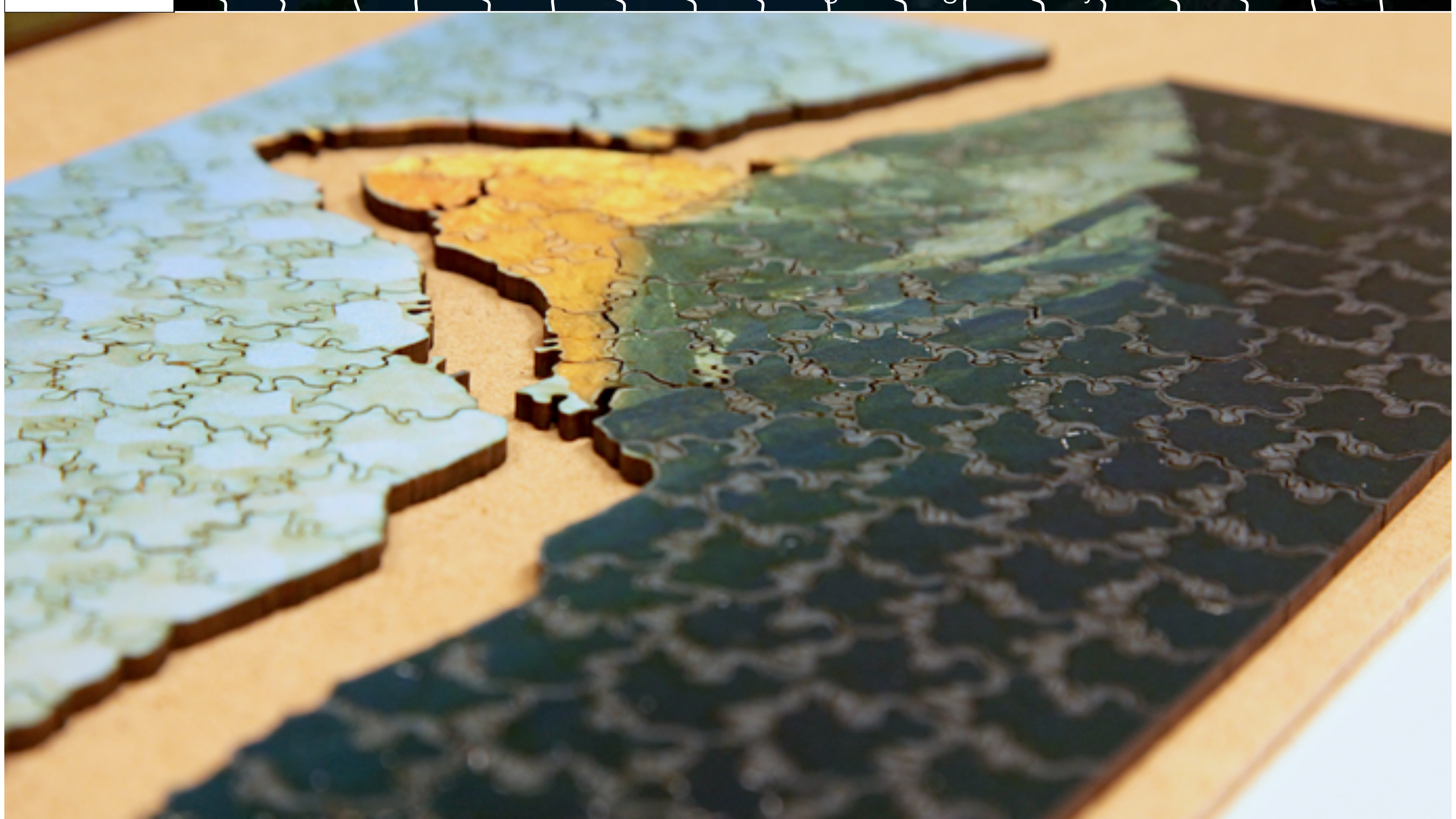


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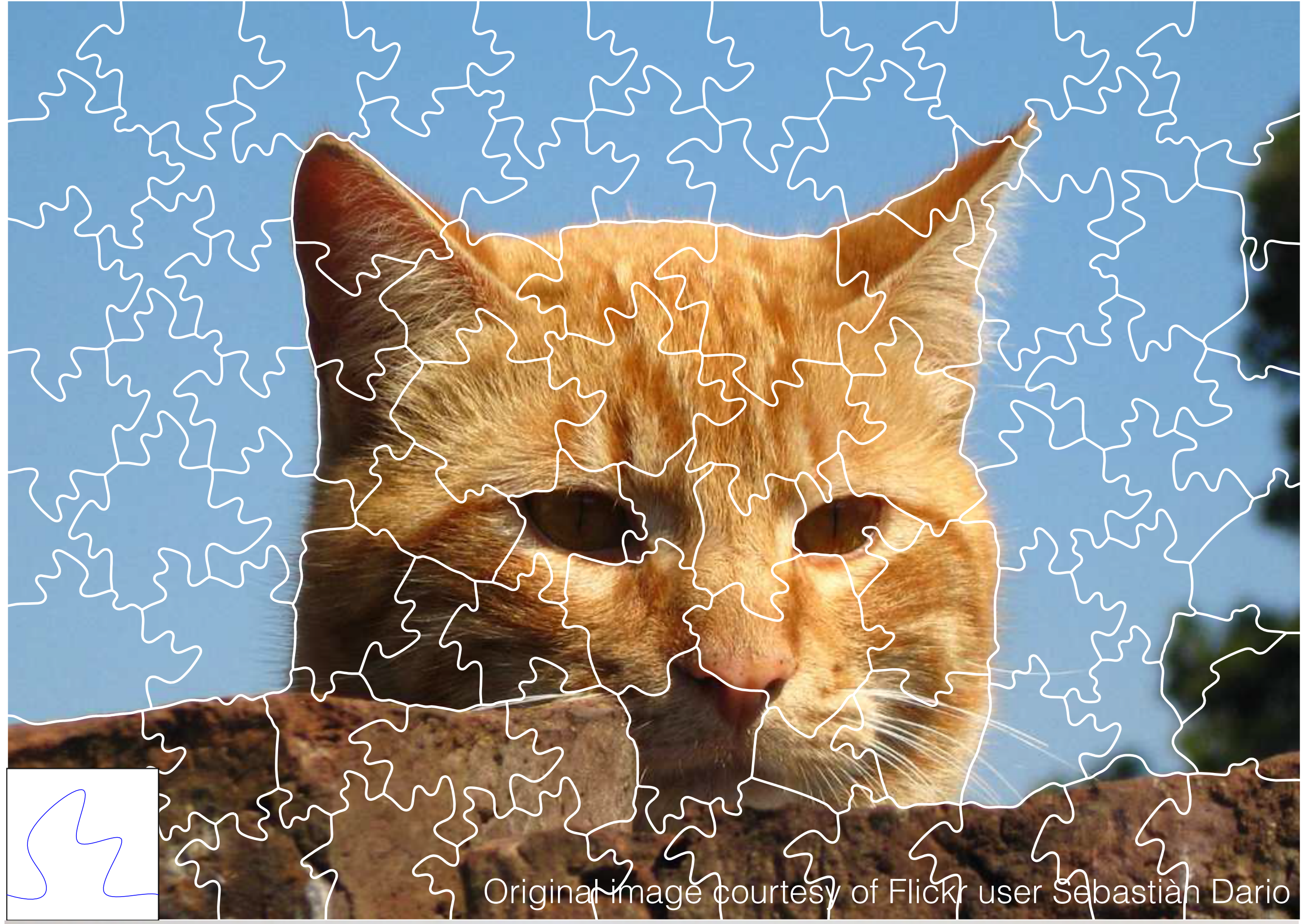
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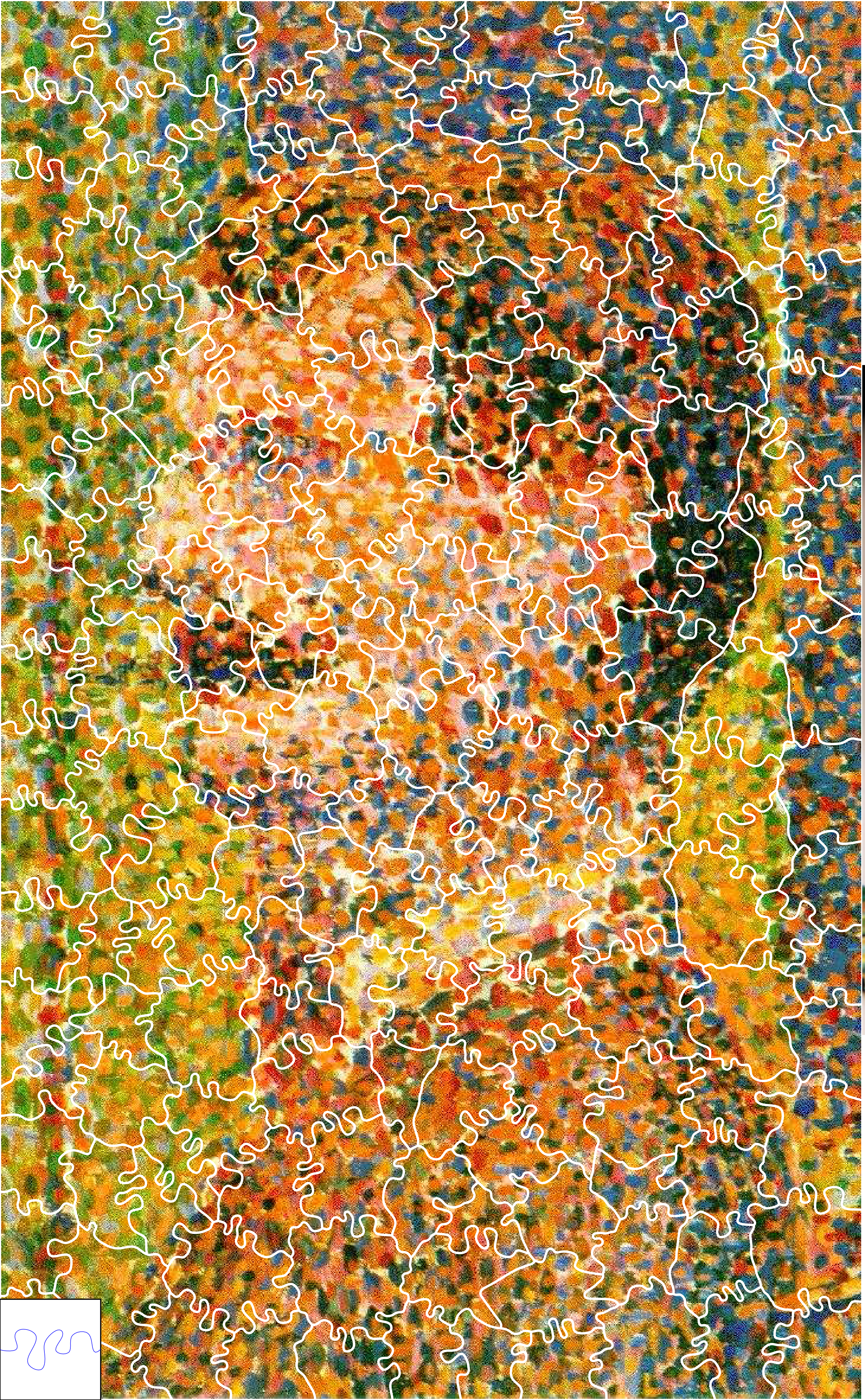
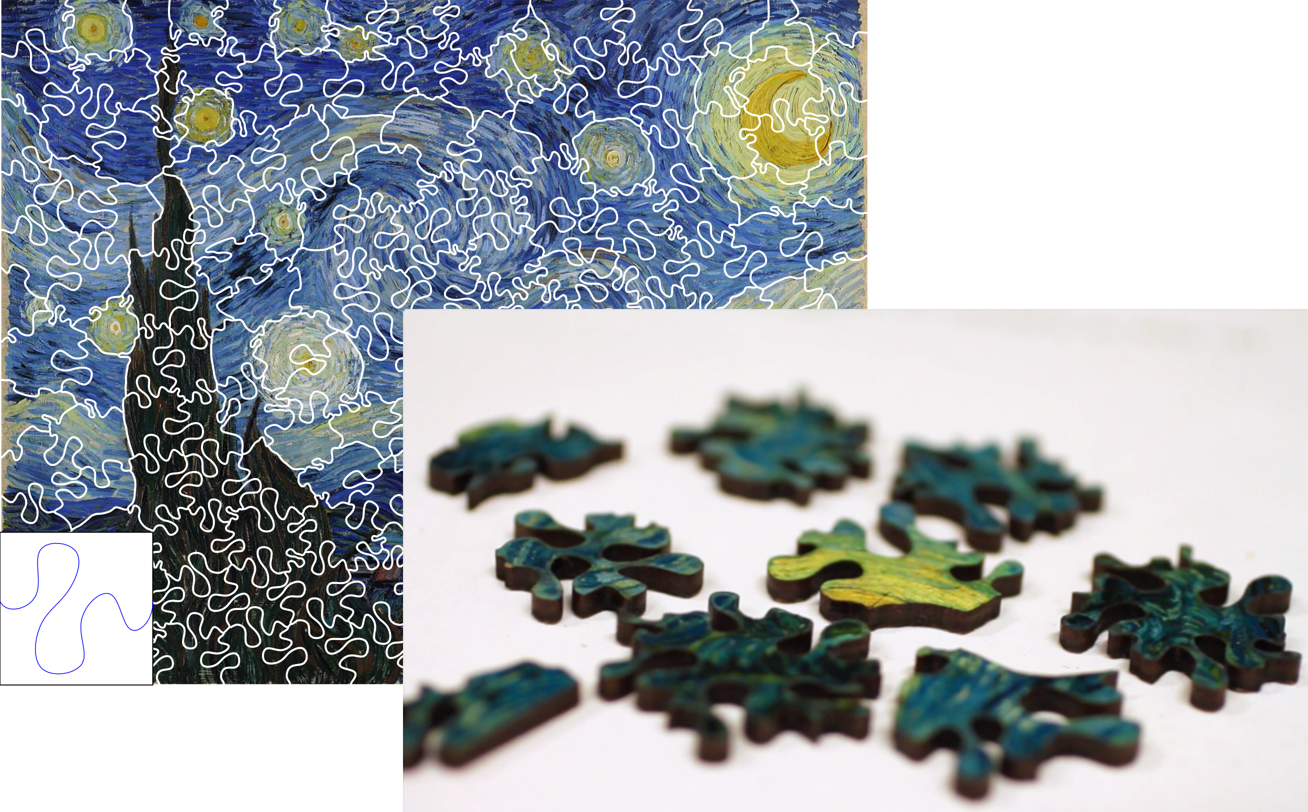
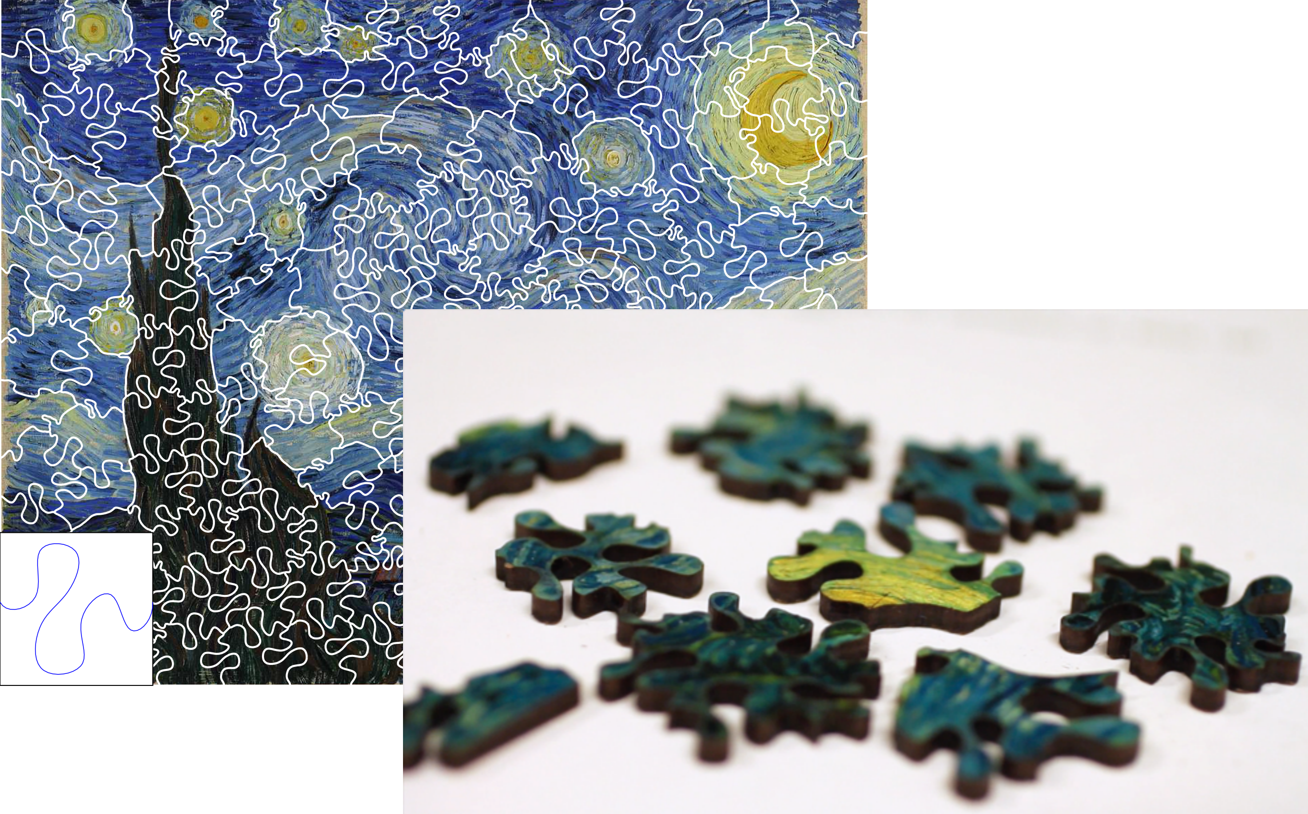
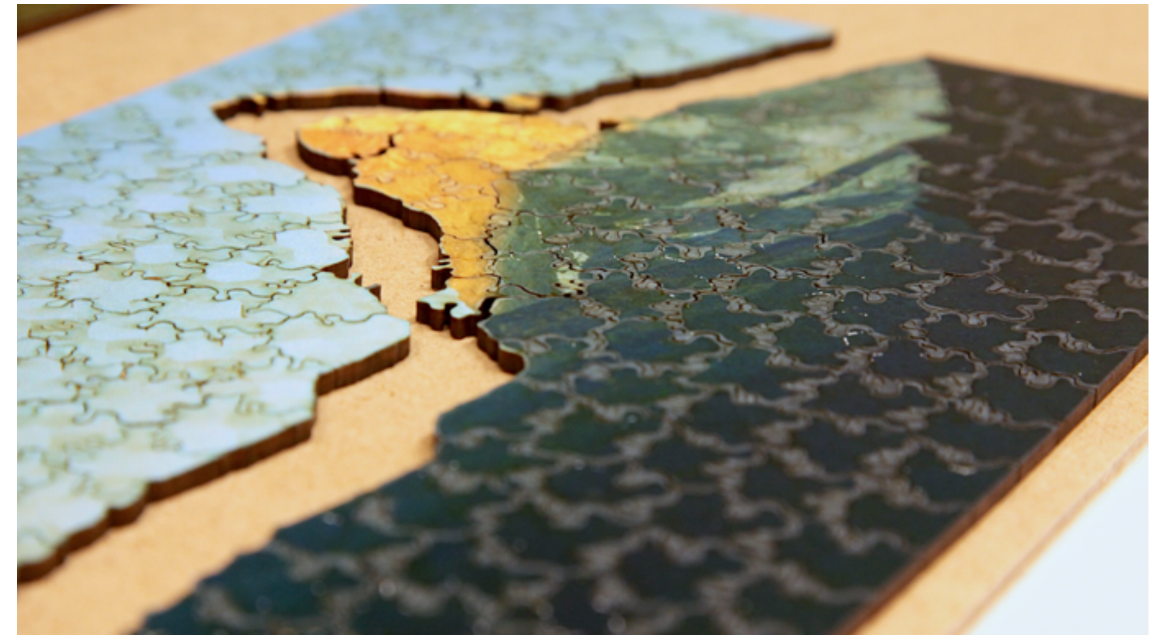




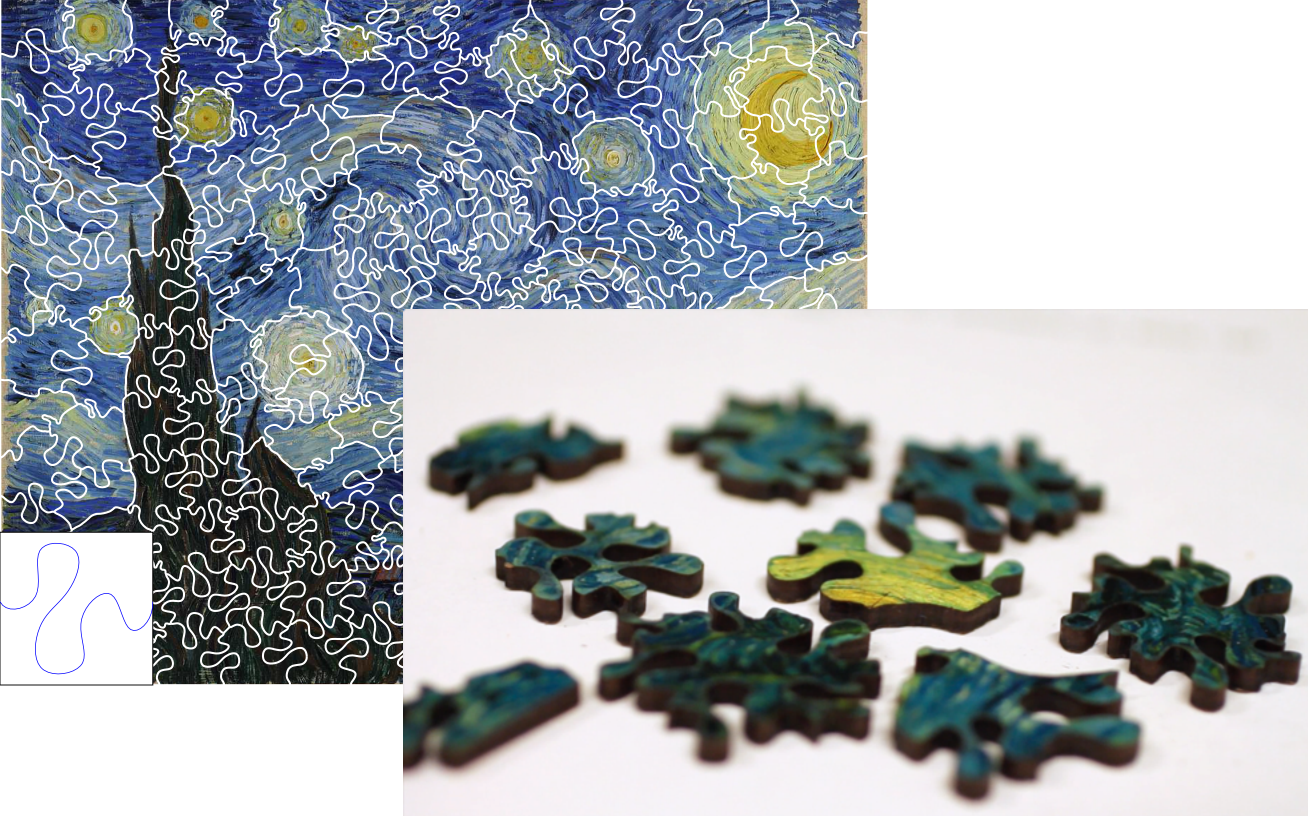
tool for creating customized jigsaw puzzles



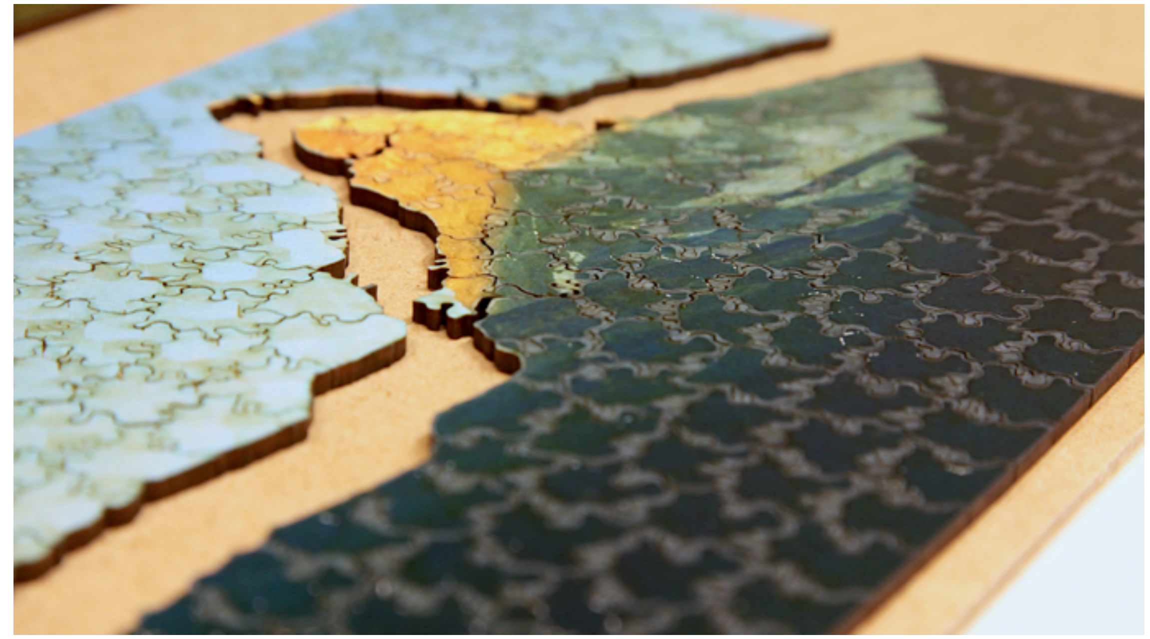
tool for creating customized jigsaw puzzles



color line cutting



tool for creating customized jigsaw puzzles



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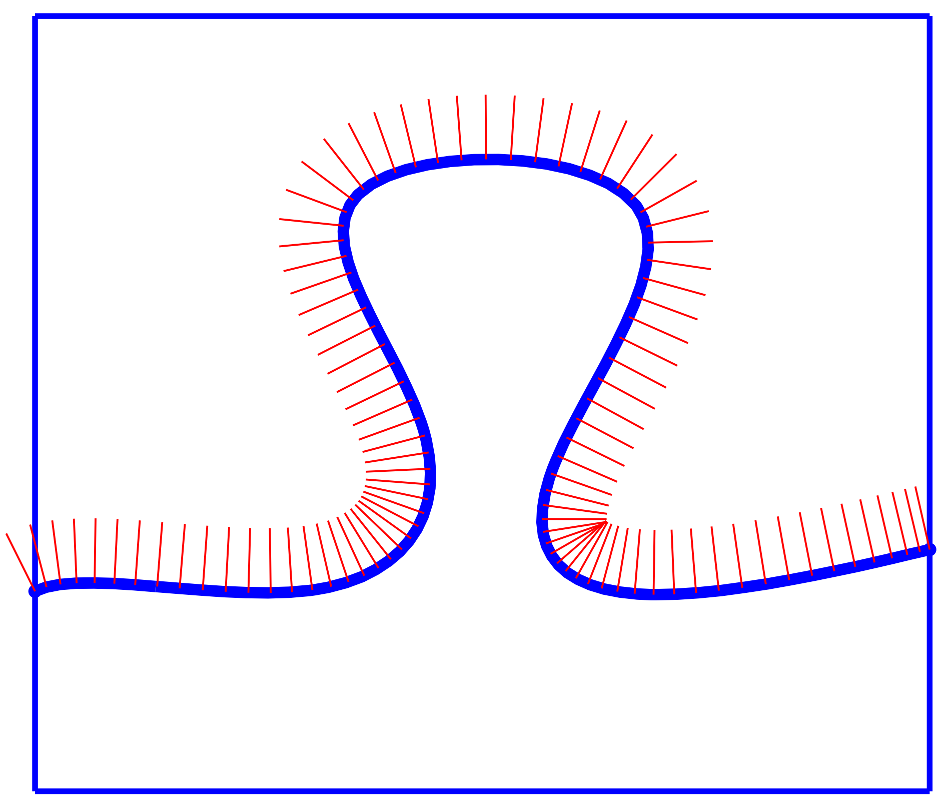
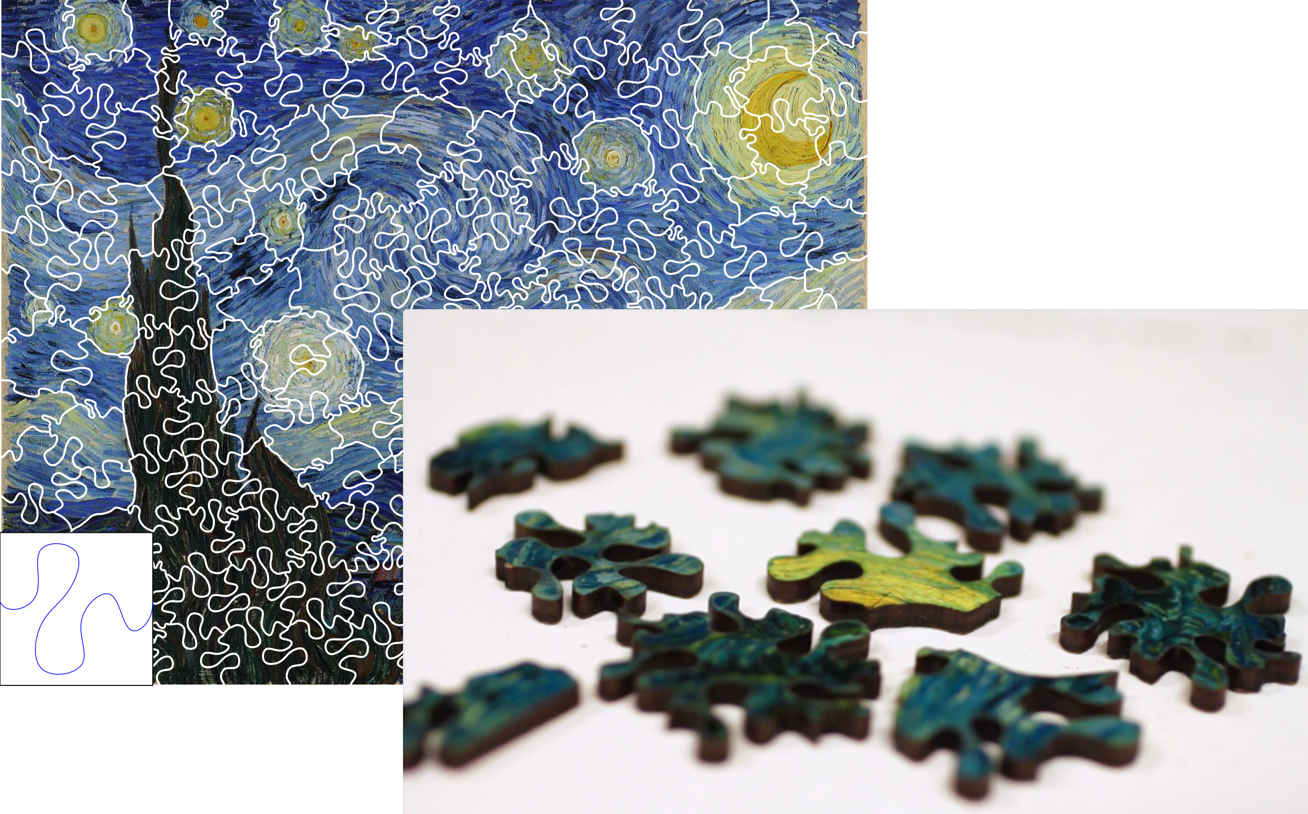
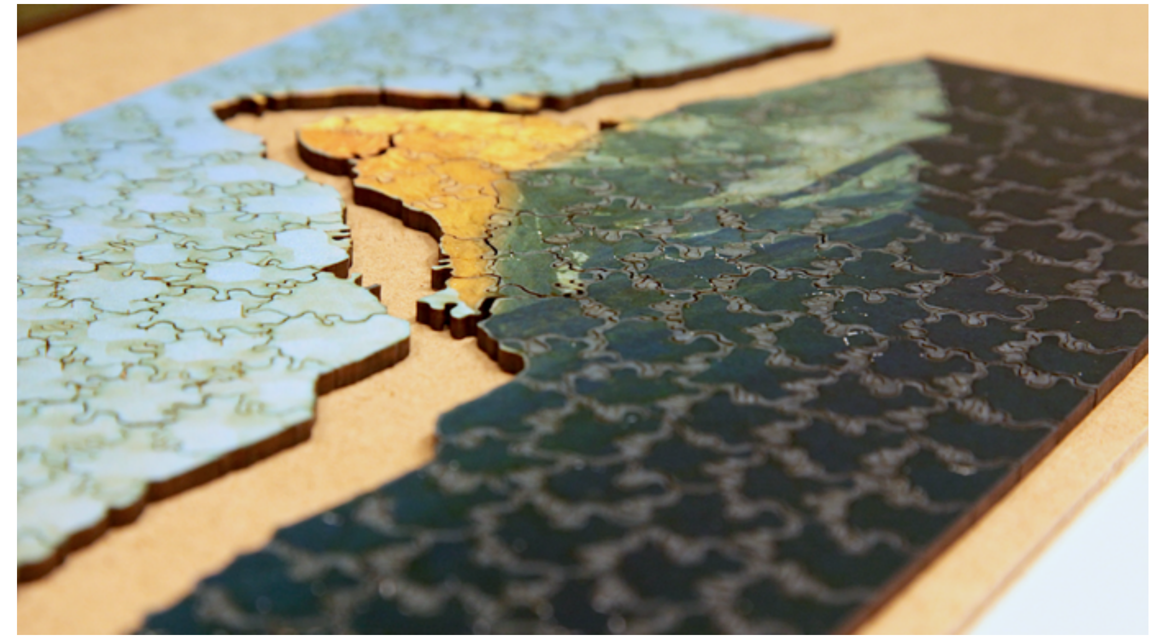


interlocking constraint



tool for creating customized jigsaw puzzles



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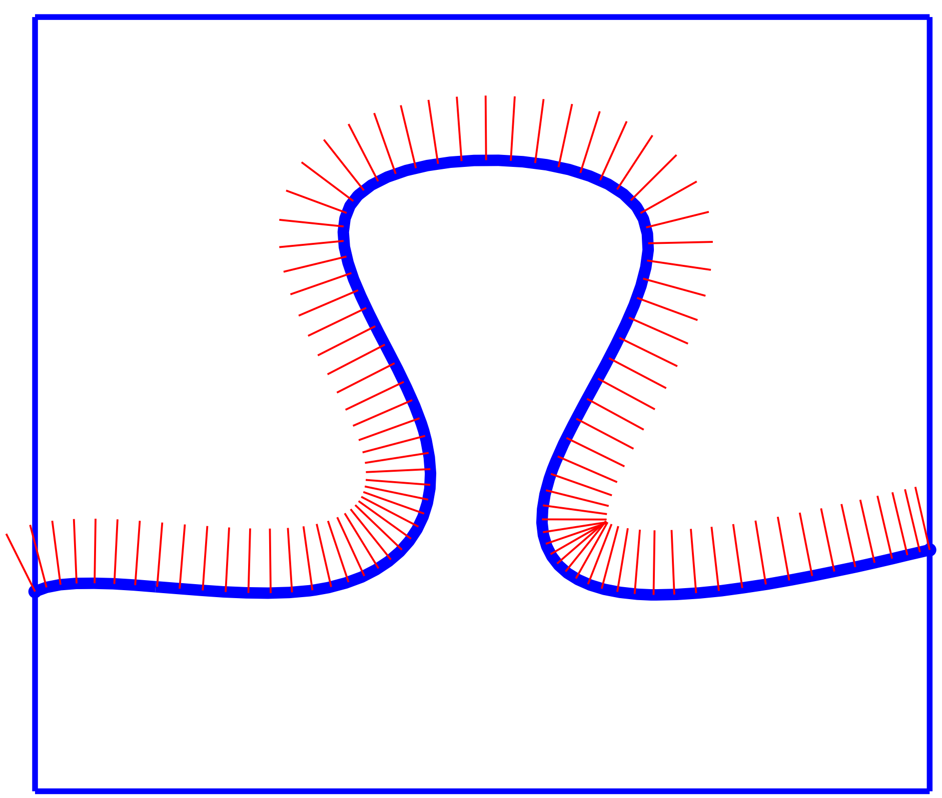
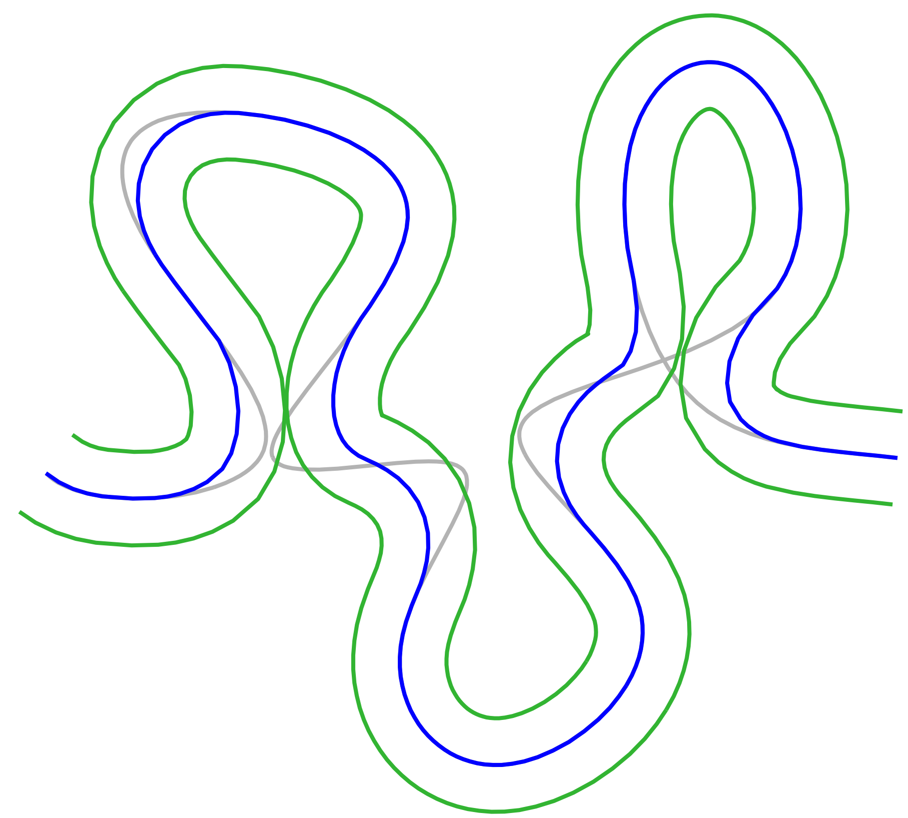


interlocking constraint



self-intersection and min width constraints


Thank you.