Structure discrète des courbes bruités

Couverture tantentielle adaptative et applications en analyse d'image

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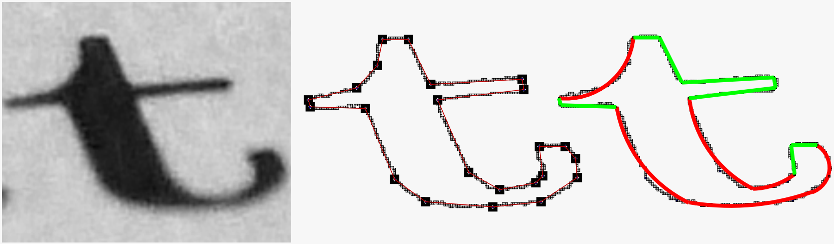
ADAGIo

19 Mai 2016

Motivation

- Estimateurs géométriques
- Description de formes
- Approximation polygonale
- Extraction de caractéristiques



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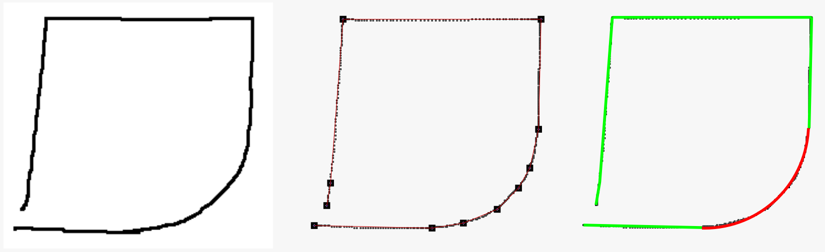

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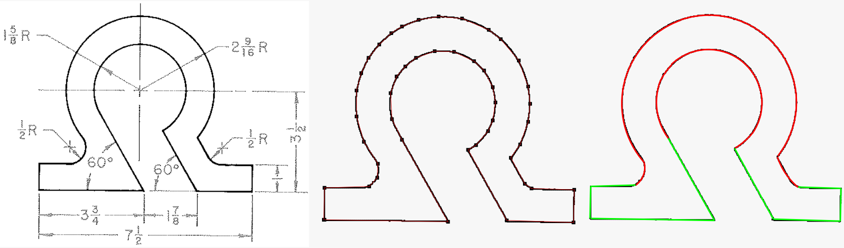

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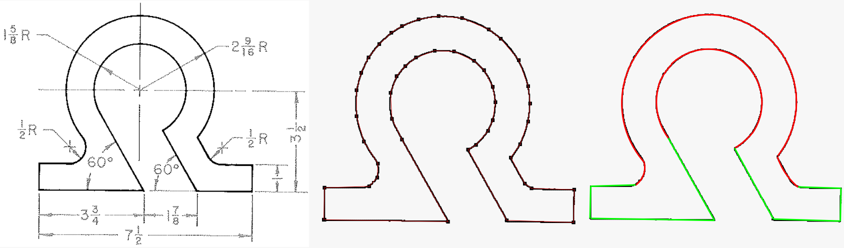

$\Longrightarrow$ Présence de **bruit** dans l'image par l'accquisition !

Plan de la présentation

1. Notions de base
2. Couverture tangentielle adaptative
3. Application : Détection de points dominants
4. Application : Décomposition de courbe en arcs et segments
5. Conclusion & perspectives

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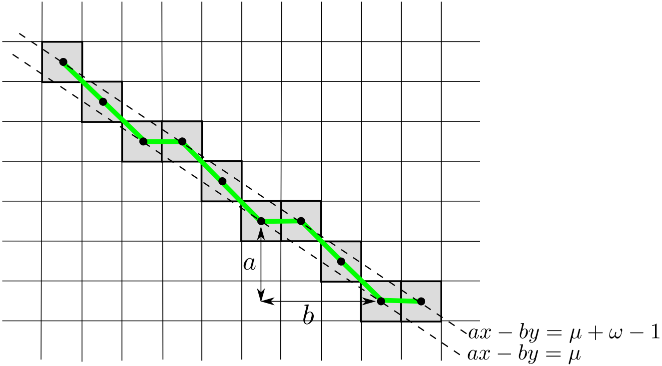
Discrete line and segment

Definition

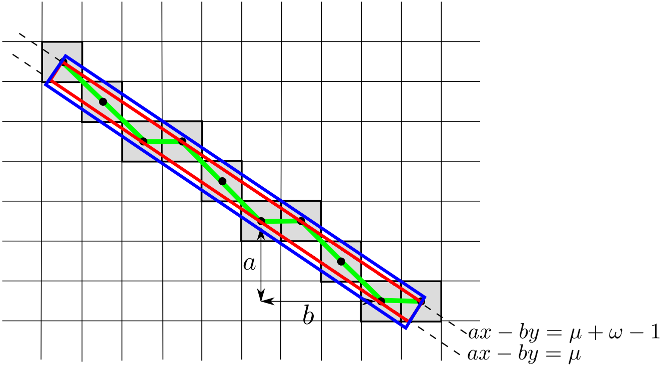
A **discrete line** $\mathcal{D}(a, b, \mu, \omega)$ is the set of integer points (x, y) verifying $\mu \leq ax - by < \mu + \omega$ where a, b, μ, $\omega \in \mathbb{Z}$ and $gcd(a, b) = 1$.



Discrete line and segment

Definition

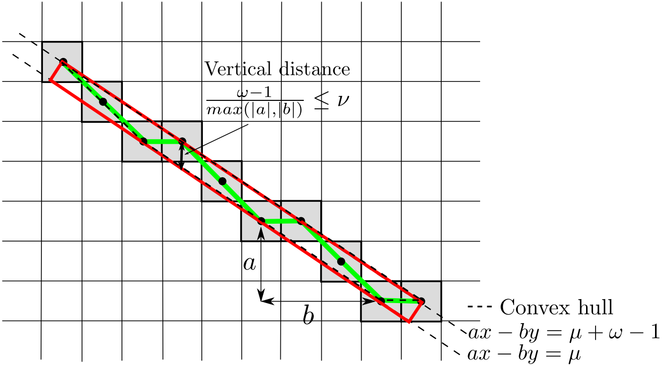
A **discrete segment** is a finite set $\mathcal{S}_f$ of integer points bounded by the discrete line $\mathcal{D}(a, b, \mu, \omega)$.



Discrete line and segment

Definition

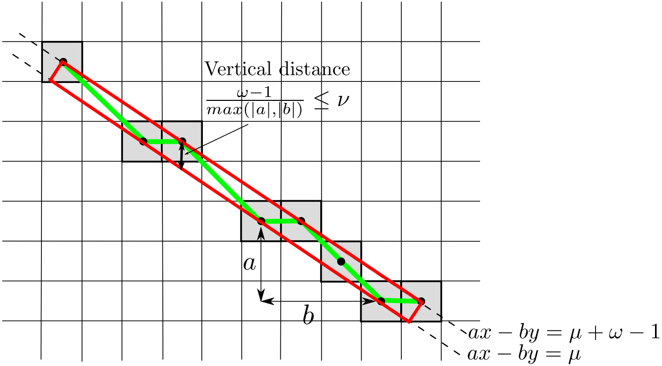
A discrete segment $\mathcal{S}_f$ is **optimal** if its vertical (or horizontal) distance is equal to the vertical (or horizontal) thickness of its convex hull.



Blurred segment

Definition

A sequence integer points $\mathcal{S}_f$ is a **blurred segment of width** ν if its optimal bounding discrete segment $\mathcal{D}(a, b, \mu, \omega)$ has the vertical or horizontal distance less than or equal to ν.



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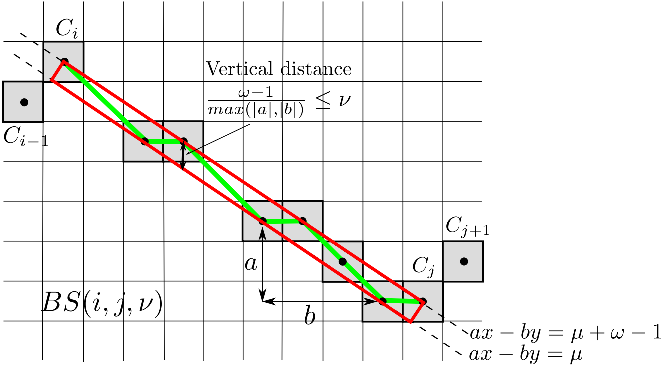
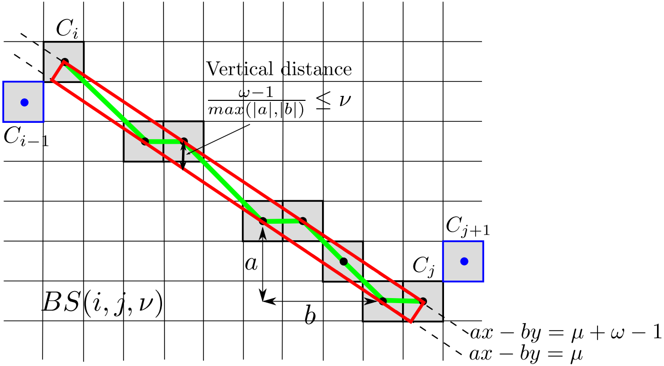


Blurred segment

Definition

A blurred segment of witdth ν $BS(i,j,\nu)$ is **maximal**, and noted $MBS(i,j,\nu)$, iff $\neg BS(i,j+1,\nu)$ and $\neg BS(i-1,j,\nu)$.



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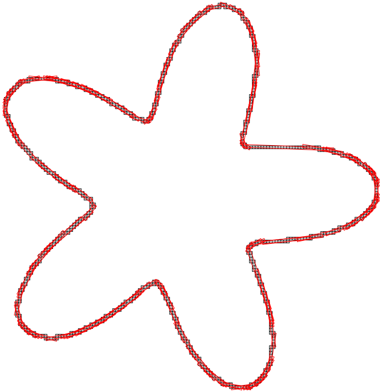
Maximal blurred segment decomposition

Definition

For any discrete curve C, its decomposition into maximal segments is called a **tangential cover** of C.



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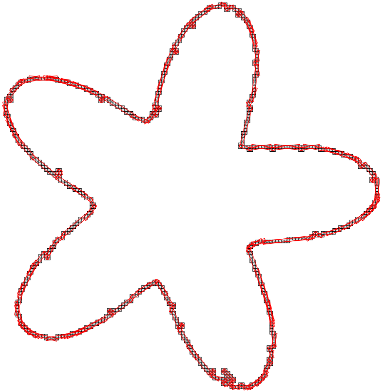
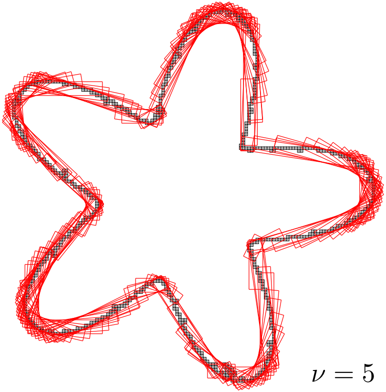


Maximal blurred segment decomposition

Definition

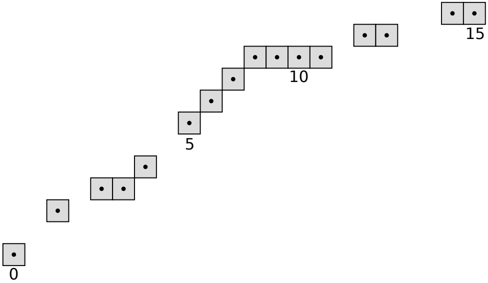
For any discrete curve C, its decomposition into maximal blurred segments of witdth ν is called a **width** ν **tangential cover** of C.



Maximal blurred segment decomposition

Algorithm

- Input: A discrete curve C and a width ν
- Output: The decomposition $MBS_\nu(C)$ of C
- Method: Tangential cover is computed by incrementally adding (resp. removing) a pixel to (resp. from) the considering MBS



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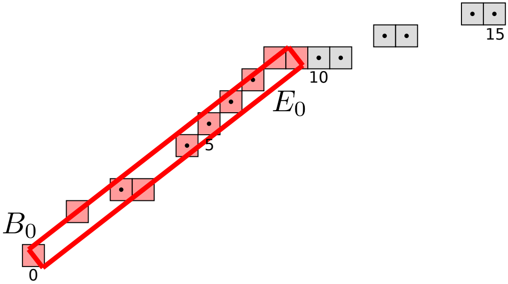

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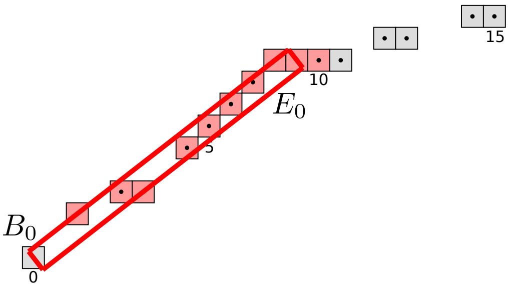

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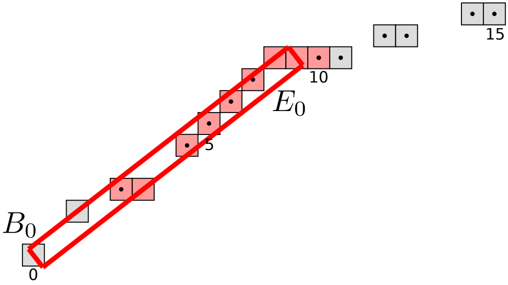

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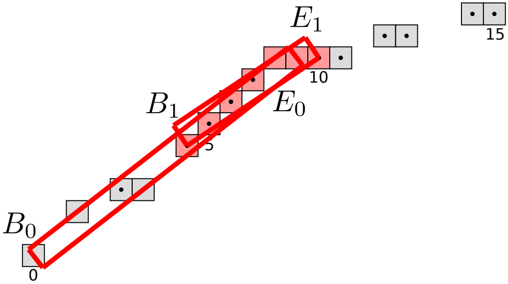

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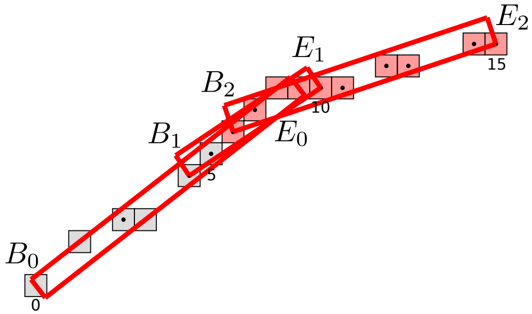

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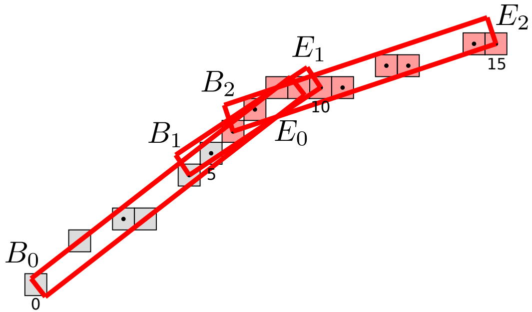


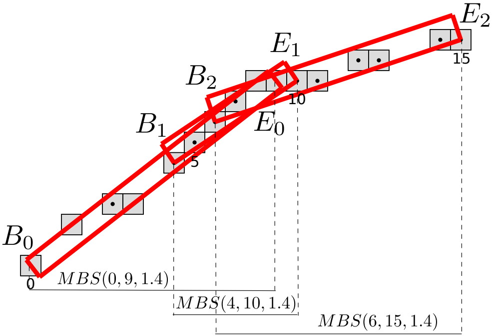
$\Longrightarrow$ Algorithm of decomposition is in quasi-linear time [1]

Maximal blurred segment decomposition

Property

Let $MBS_\nu(C) = \{MBS(B_0, E_0, \nu), \ldots, MBS(B_{m-1}, E_{m-1}, \nu)\}$ be the maximal blurred segment decomposition of witdth ν of C, we have:

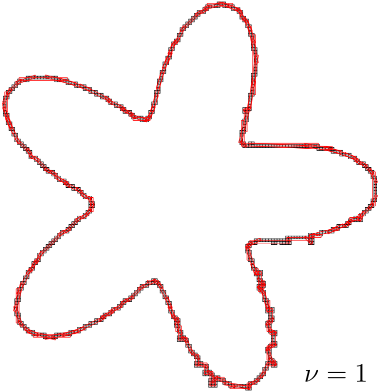
$$B_0 < B_1 < \ldots < B_{m-1} \text{ and } E_0 < E_1 < \ldots < E_{m-1}$$



Maximal blurred segment decomposition

Issues

- Width value ν is manually adjusted to deal with noise
- Mono-width ν is not adapted to local noise along the contour



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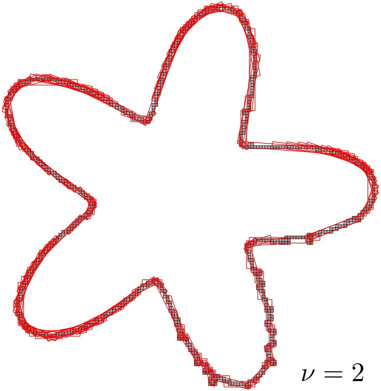

$\nu = 2$

Maximal blurred segment decomposition

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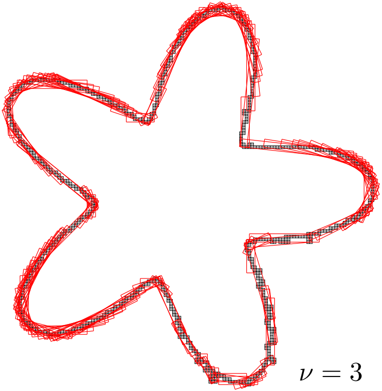

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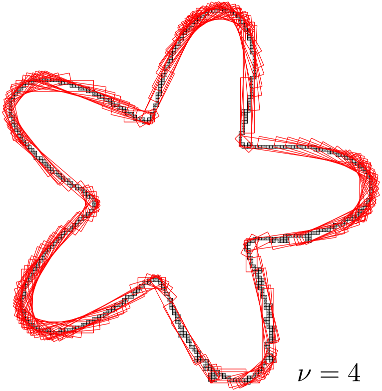

$\nu = 4$

Maximal blurred segment decomposition

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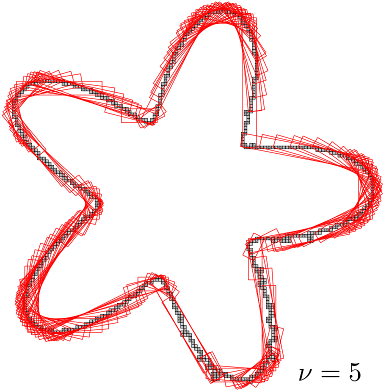

Maximal blurred segment decomposition

Issues

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Solution

Tangential cover of different widths: **Adaptive Tangential Cover**

- appropriated widths based on a local noise estimation
  - **meaningful thickness detection**
- parameter-free computation

Meaningful thickness detection

- Based on the asymtotic properties of the discrete length of maximal segments of perfect shape discretization
- Extend these properties with MBS at each point of the contour
- Compare to determine significatif width of MBS of points

Theorem

- X simple connected shape in R^2 with the boundary δX with a piecewise boundary C^3
- U an open connected neighborhood of $p \in \delta X$,
- (L_j^h) the digital lengths of the maximal segments covering p along the boundary of $Dig_h(X)$, where h is the grid size
  - if U is strictly convex/concave, then $\Omega(1/h^{1/3}) \leq (L_j^h) \leq O(1/h^{1/2})$
  - if U has null curvature everywhere, then $\Omega(1/h) \leq (L_j^h) \leq O(1/h)$

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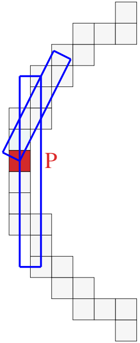

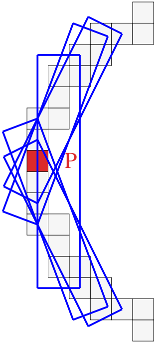

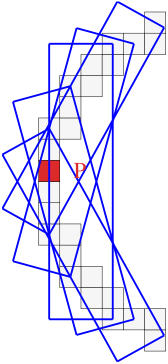

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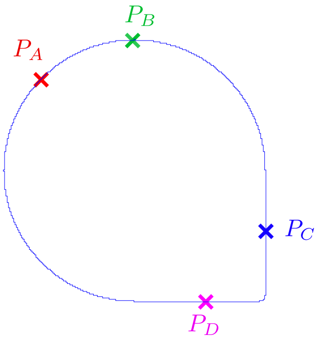

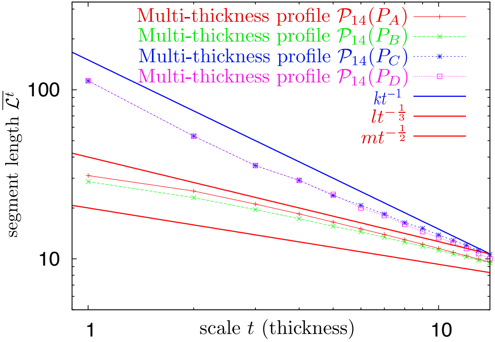

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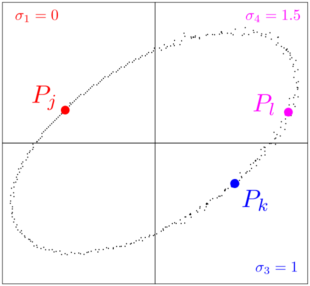

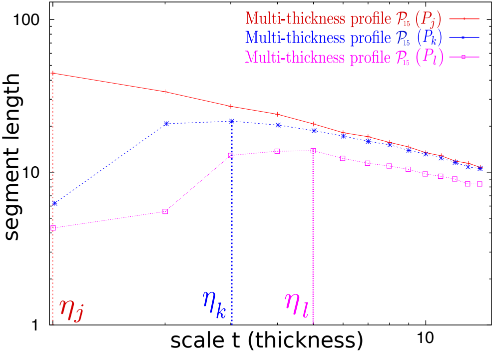

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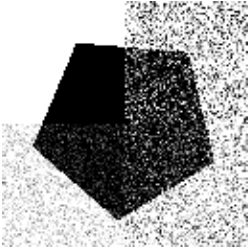

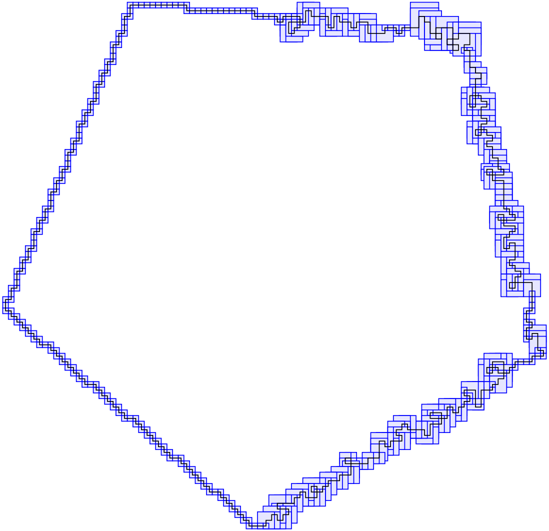

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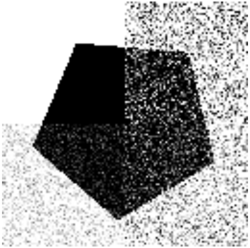
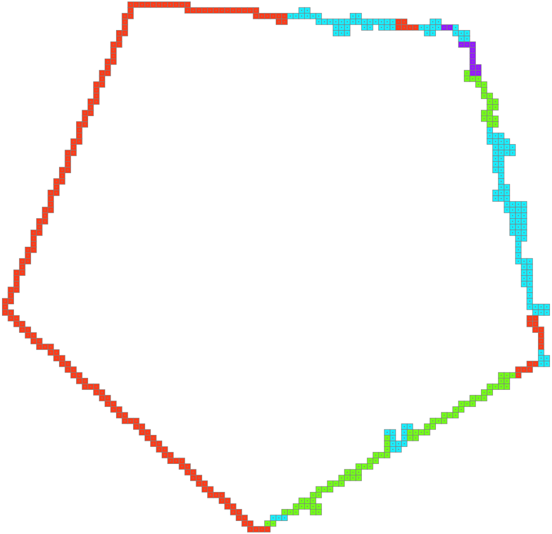
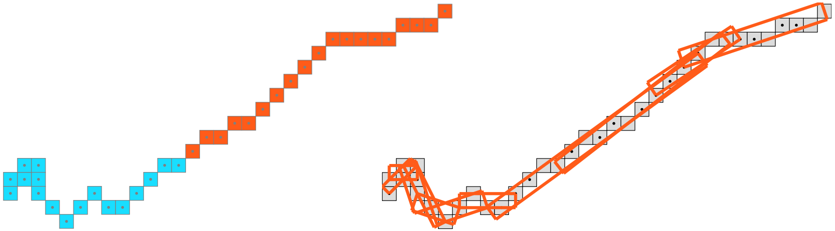




Adaptive tangential cover

Definition

Let $MBS_i = MBS(B_i, E_i, .), MBS_j = MBS(B_j, E_j, .)$ be two MBS. We say MBS_j is **included** in MBS_i, note as $MBS_j \subseteq MBS_i$, if $B_i \leq B_j$ and $E_i \geq E_j$.



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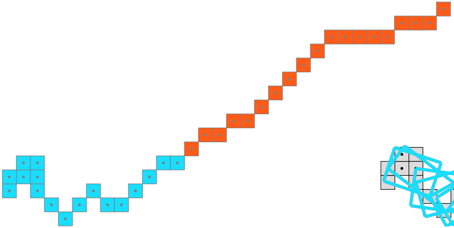

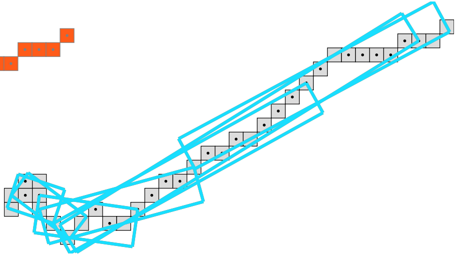

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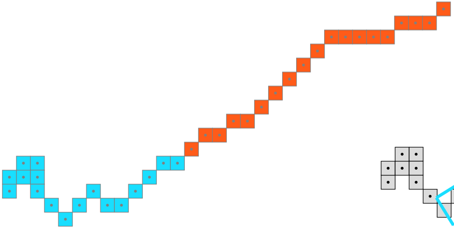
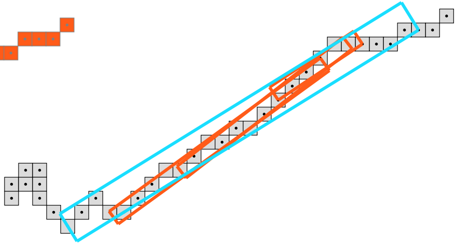
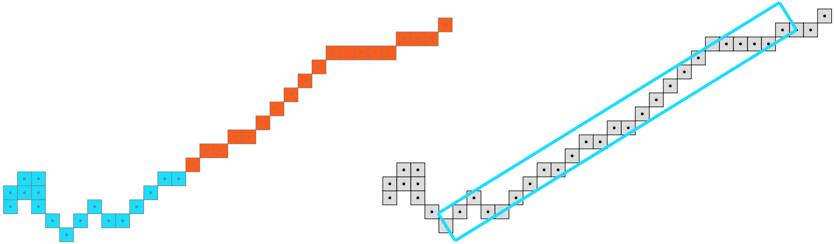




Adaptive tangential cover

Definition

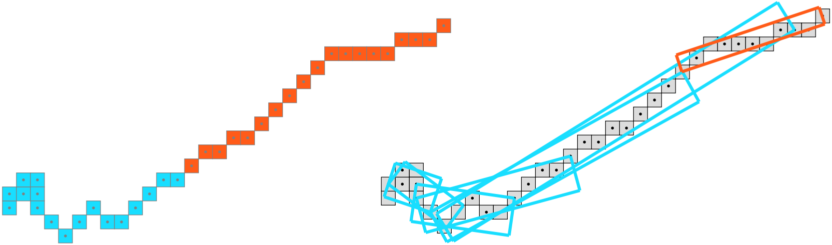
Let $MBS(C)$ be a set of MBS of a discrete curve C. We say $MBS_i \in MBS(C)$ is **largest** if for all $MBS_j \in MBS(C)$ with $i \neq j$, $MBS_j \not\subseteq MBS_i$.



Adaptive tangential cover

Definition

An **adaptive tangential cover (ATC)** associated to the meaningful thickness vector η of C is defined as the set of the largest MBS of $\{MBS_j = MBS(B_j, E_j, \nu_k) \in MBS(C) \mid \nu_k = \max\{\eta_t \mid t \in [\![B_j, E_j]\!]\}\}$.



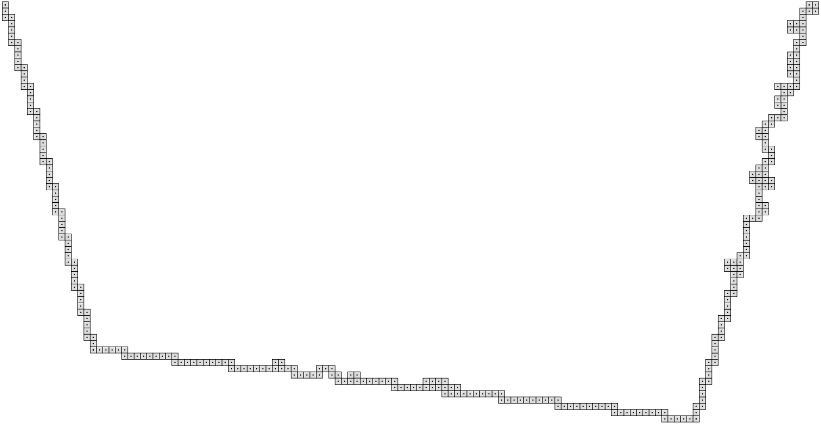
Construction of adaptive tangential cover

Principes

- Input:
  - A discrete curve C of n points
  - Vector of meaningful thickness ν associated to each point of C
- Output:
  - An ATC of C associated to the meaningful thickness vector ν
- The method for computing ATC is divided into two steps:
  - Labeling the points from the meaningful thickness values
    - Maximum meaningful thickness of MBS passing the point
  - Building the ATC with MBS of widths from the obtained labels
    - MBS of width being the label of at least one point in the MBS

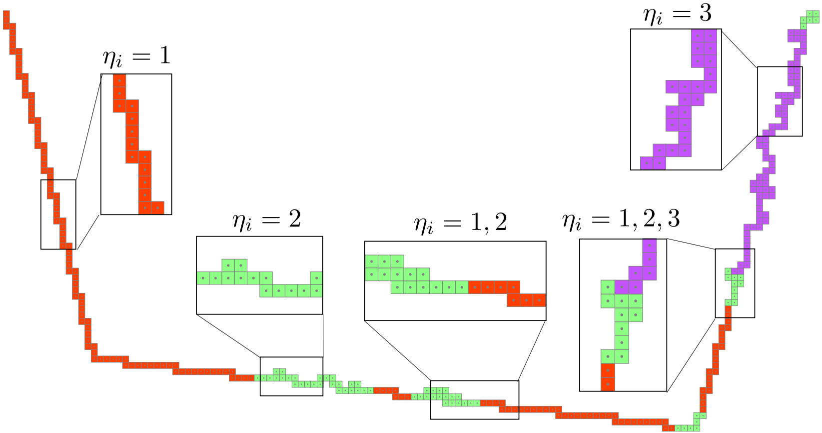
Construction of adaptive tangential cover

- Input curve



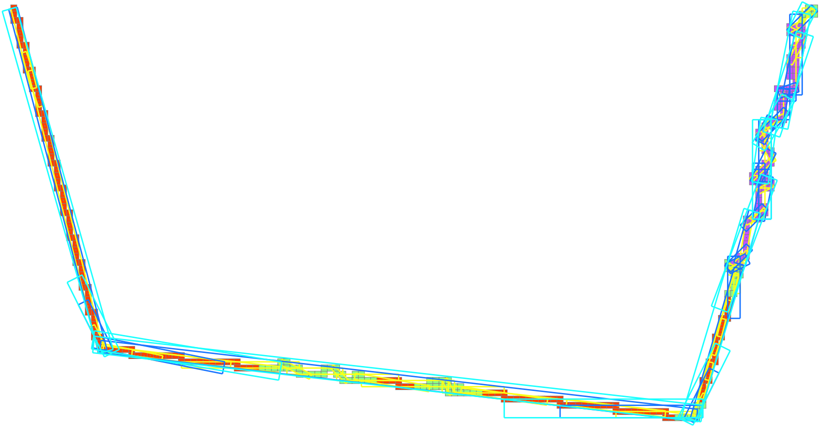
Construction of adaptive tangential cover

- Input curve
- Meaningful thickness vector ν



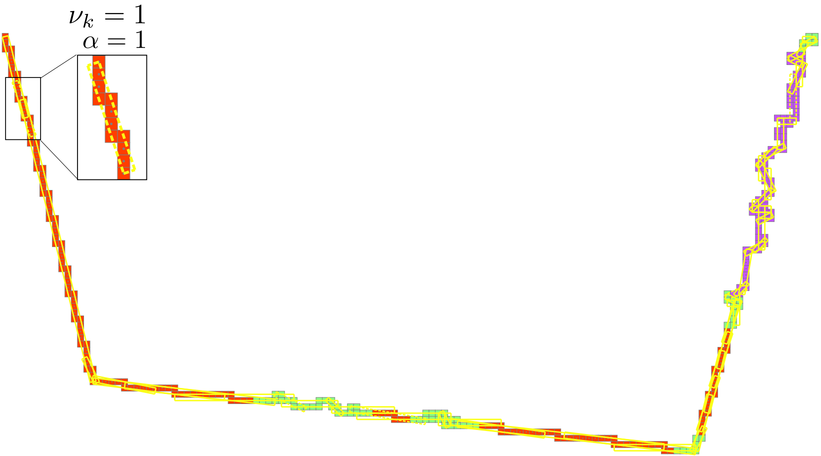
Construction of adaptive tangential cover

- Input curve
- Meaningful thickness vector ν
- Tangent covers of . . .



Construction of adaptive tangential cover

- Step 1: Labeling points from meaningful thickness values
  - α max and γ label and $\gamma_i = \nu_i$ at initialization



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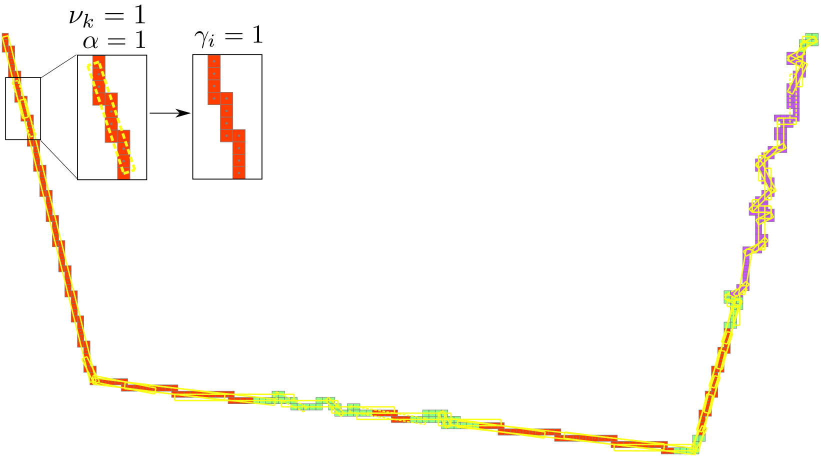

Construction of adaptive tangential cover

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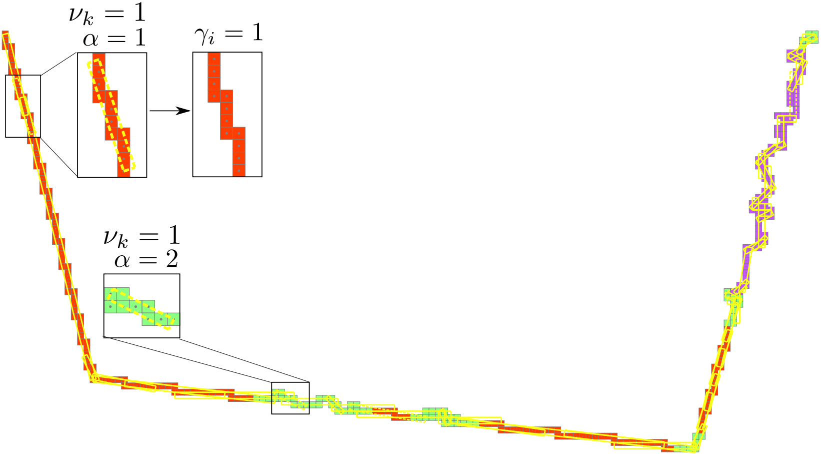

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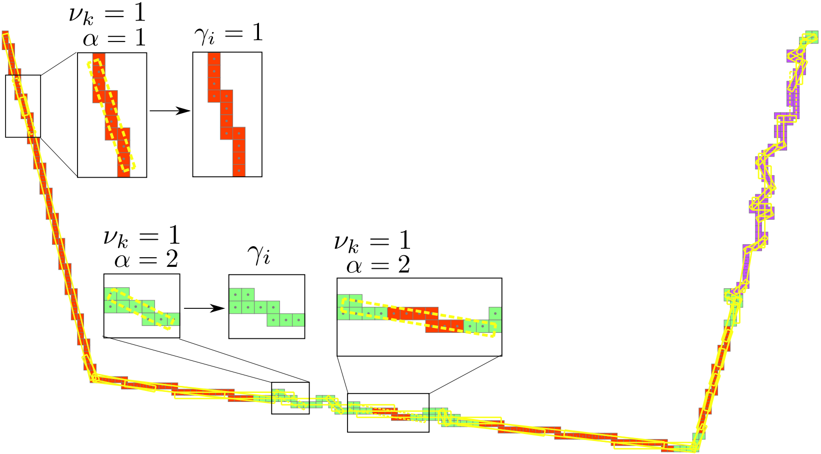

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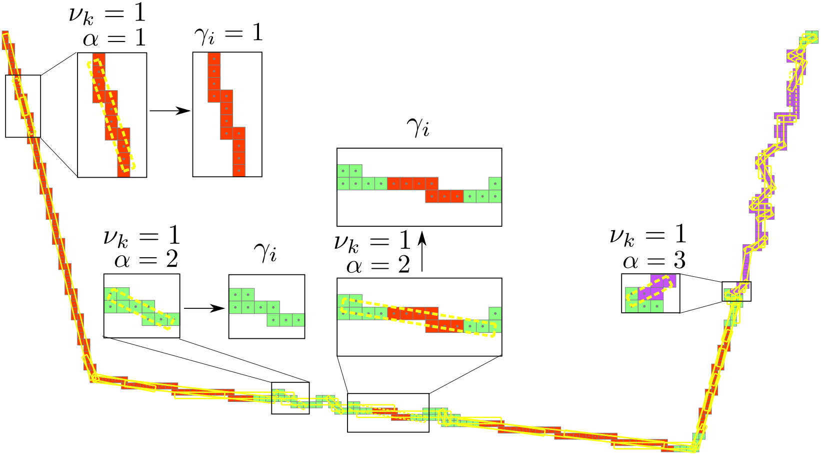

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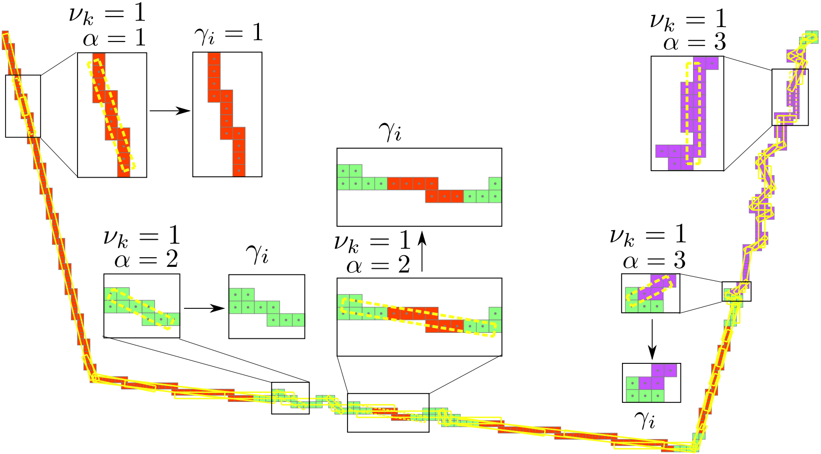

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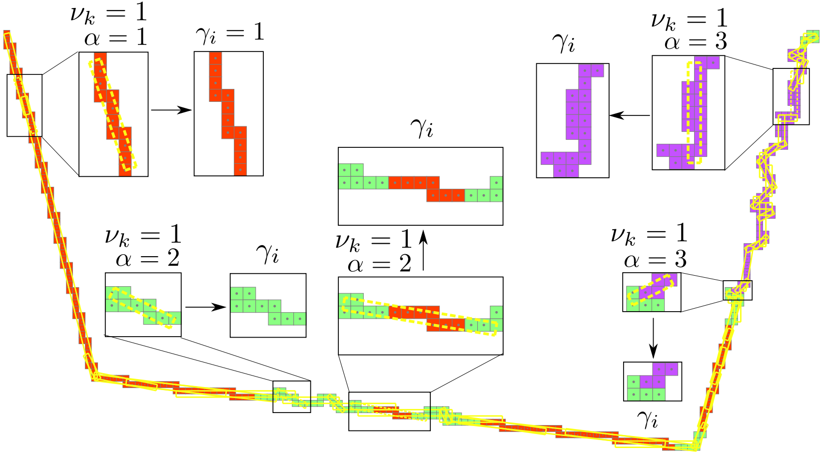

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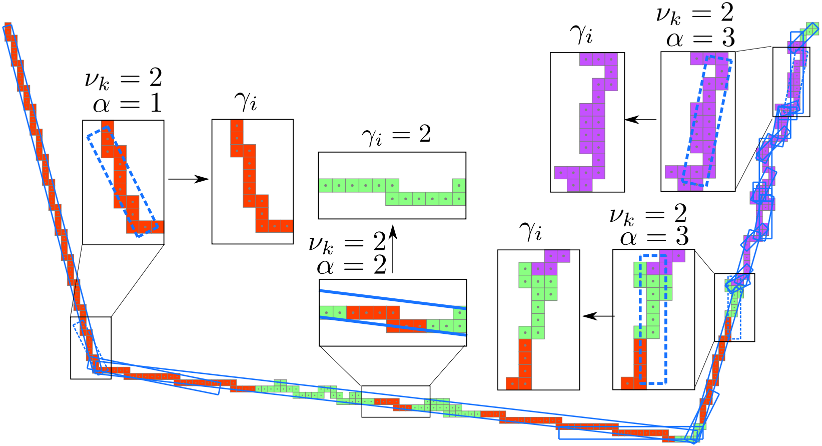

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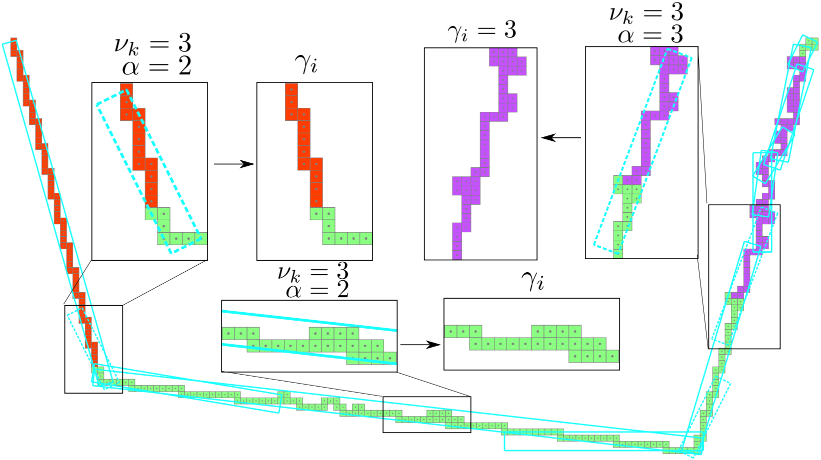

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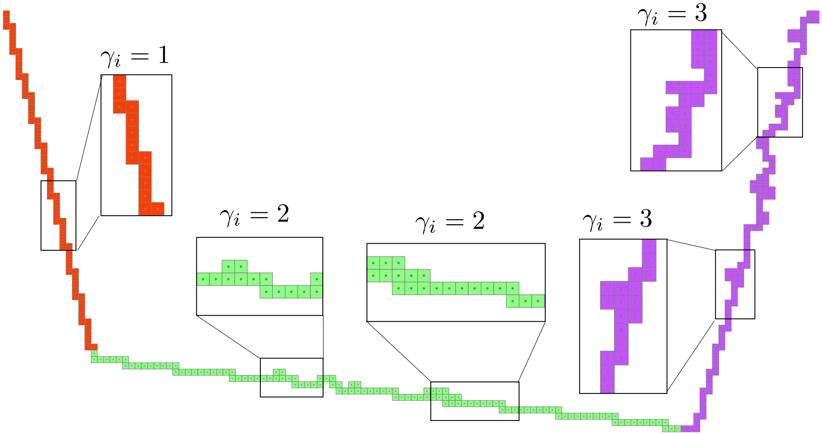
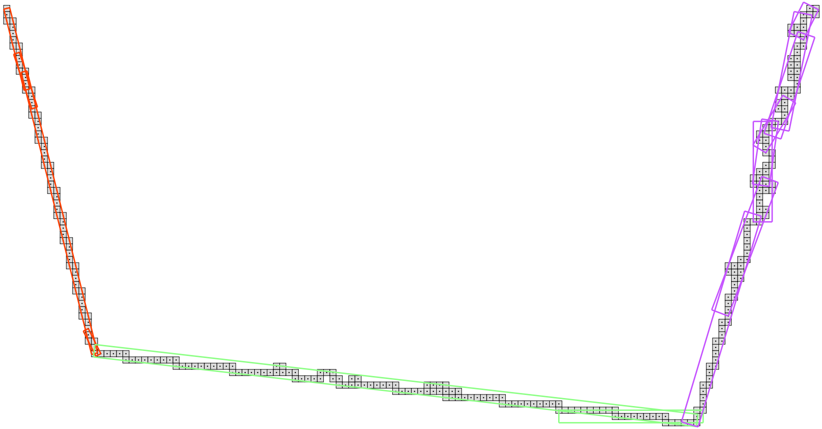


Construction of adaptive tangential cover

- Step 1: Labeling points from meaningful thickness values
  - α max and γ label and $\gamma_i = \nu_i$ at initialization
- Step 2: Determining the MBS of the ATC



Algorithm of adaptive tangential cover construction

Input: $C = (C_i)_{0 \leq i \leq n-1}$ discrete curve of n points
$\eta = (\eta_i)_{0 \leq i \leq n-1}$ vector of MT associated to C
$\nu = \{\nu_k \mid \nu_k \in \eta\}$ ordered set of MT value of η
$MBS(C) = \{MBS_{\nu_k}(C)\}_{k=0}^{m-1}$ sets of MBS of C for $\nu_k \in \nu$
Output: $ATC(C)$ adaptive tangential cover of C

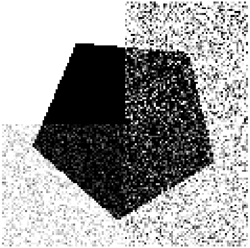
Begin
$ATC(C) = \emptyset$; $\gamma_i = \eta_i$ for $i \in [\![0, n-1]\!]$
for $\nu_k \in \nu$ **do**
  for $MBS(B_i, E_i, \nu_k) \in MBS_{\nu_k}(C)$ **do**
    $\alpha = \max\{\eta_i \mid i \in [\![B_i, E_i]\!]\}$
    if $\alpha = \nu_k$ **then**
      $\gamma_i = \nu_k$ for $i \in [\![B_i, E_i]\!]$
    end if
  end for
end for
...

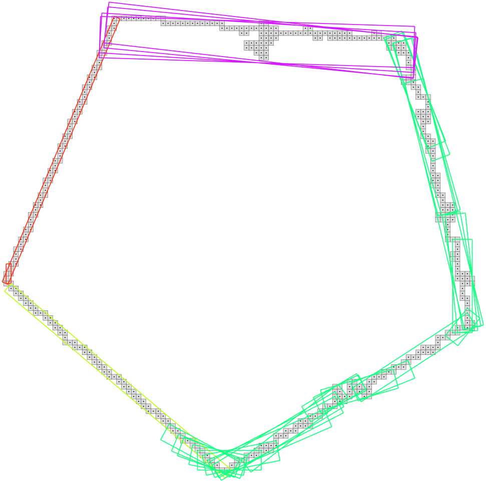
Algorithm of adaptive tangential cover construction

Input: $C = (C_i)_{0 \leq i \leq n-1}$ discrete curve of n points
$\eta = (\eta_i)_{0 \leq i \leq n-1}$ vector of MT associated to C
$\nu = \{\nu_k \mid \nu_k \in \eta\}$ ordered set of MT value of η
$MBS(C) = \{MBS_{\nu_k}(C)\}_{k=0}^{m-1}$ sets of MBS of C for $\nu_k \in \nu$
Output: $ATC(C)$ adaptive tangential cover of C

Begin
...
for $\nu_k \in \nu$ **do**
  for $MBS(B_i, E_i, \nu_k) \in MBS_{\nu_k}(C)$ **do**
    $\alpha = \max\{\eta_i \mid i \in [\![B_i, E_i]\!]\}$
    if $\exists \gamma_i,$ for $i \in [\![B_i, E_i]\!],$ such that $\gamma_i = \nu_k$ **then**
      $ATC(C) = ATC(C) \cup \{MBS(B_i, E_i, \nu_k)\}$
    end if
  end for
end for
End

Examples of Adaptive Tangential Cover





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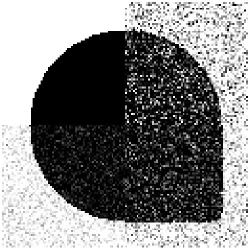

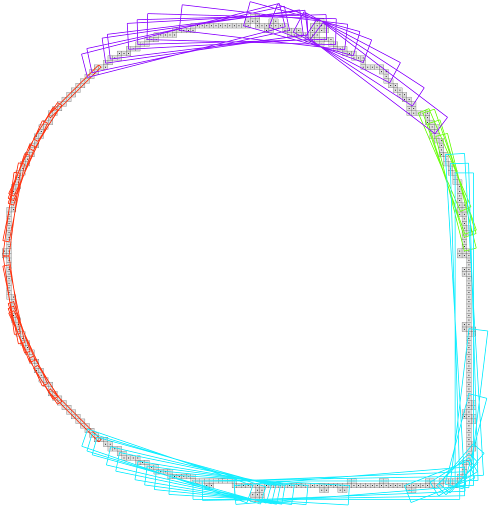

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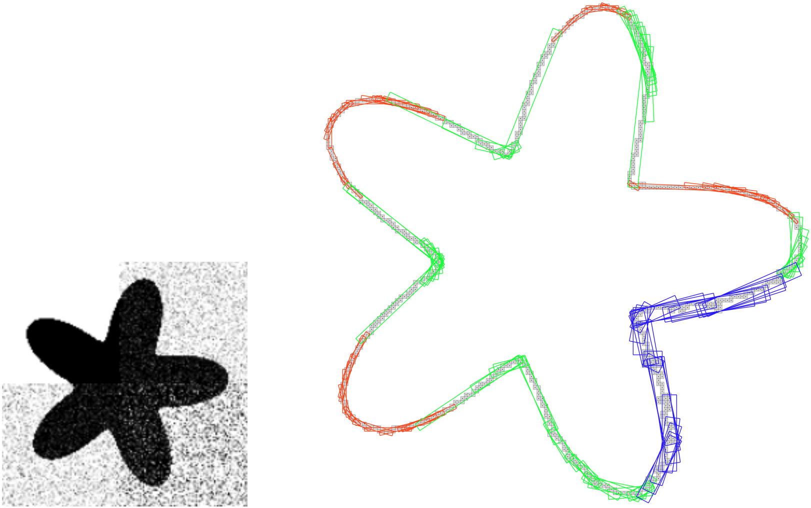

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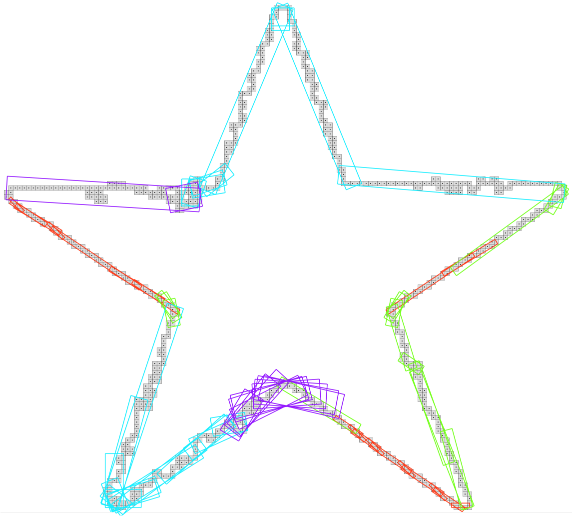

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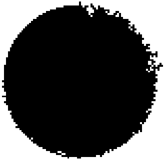
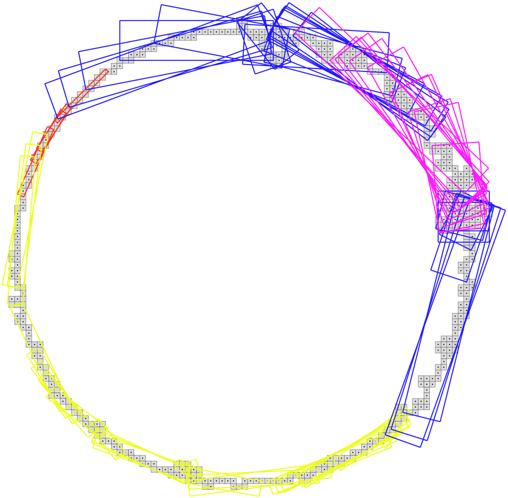
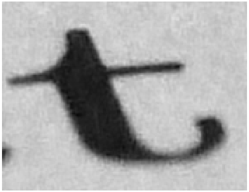
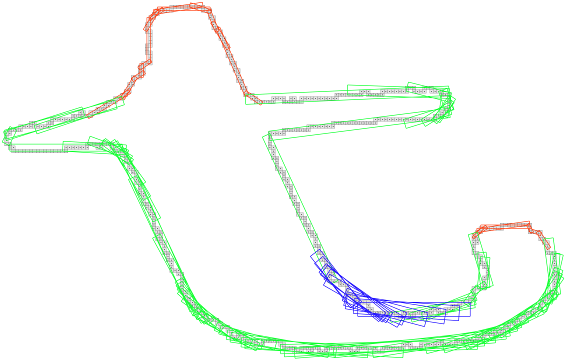




Examples of Adaptive Tangential Cover





Online demonstration

An online demonstration based on the DGtal and ImaGene library at
`http://ipol-geometry.loria.fr/~kerautre/ipol_demo/ATC_IPOLDemo`

Adaptive Tangential Cover for Noisy Digital Contours: Online Demonstration

article | demo | archive

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This demonstration applies the Adaptive Tangential Cover algorithm with the application to curve simplication.

Select Data

Click on an image to use it as the algorithm input.

ellipseNoise | flowerNoise | pentagonNoise | polygoneNoise | squareImageNoise

image credits

Upload Data

Upload your own image files to use as the algorithm input.

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Plan de la présentation

1 Notions de base

2 Couverture tangentielle adaptative

3 Application : Détection de points dominants

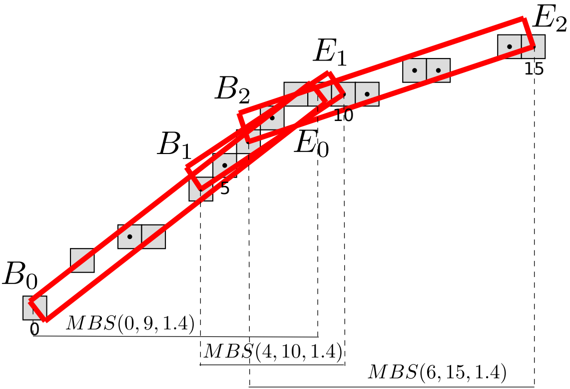
4 Application : Décomposition de courbe en arcs et segments

5 Conclusion & perspectives

Dominant point

Definition

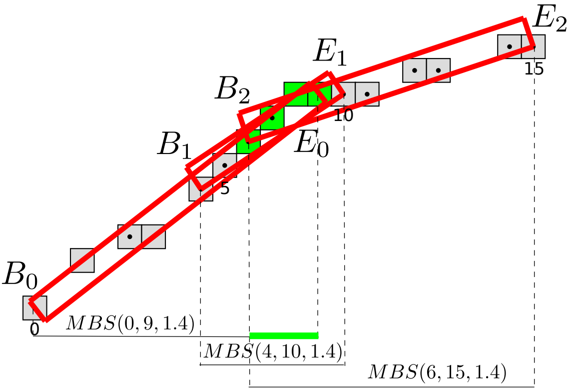
A **dominant point** (corner point) on a curve is a point of local maximum curvature.



Dominant point detection [2]

Proposition

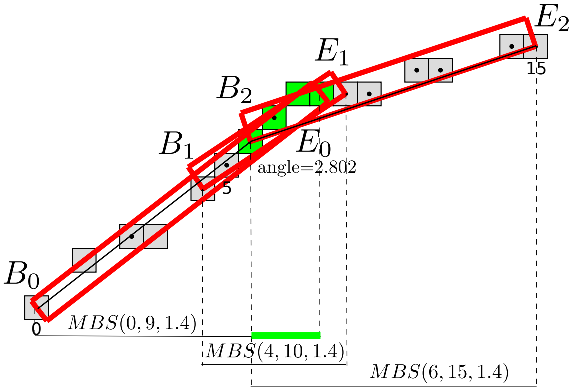
Dominant points of the curve is located in the **common zones** of successive maximal blurred segments.



Dominant point detection [2]

Strategy

Dominant point is detected as the point with **minimum angle measure** estimated with extremities of the MBS composing the common zone.



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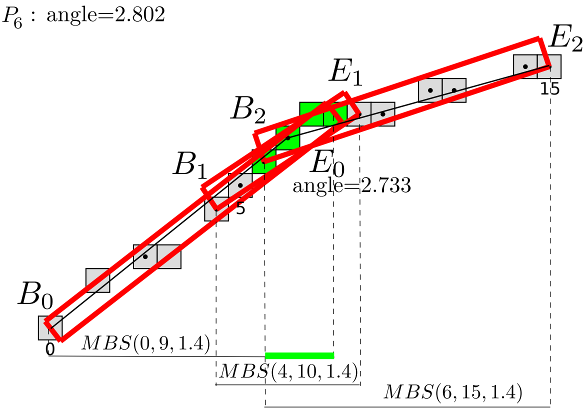

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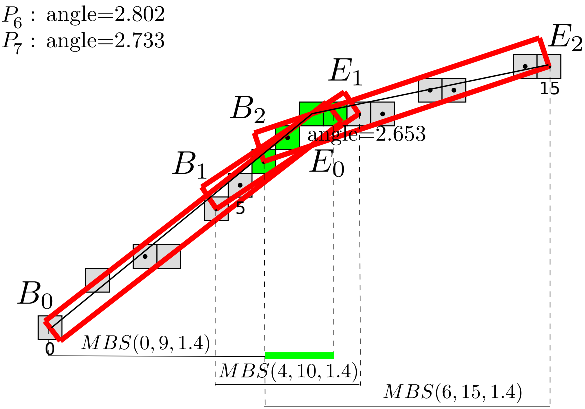

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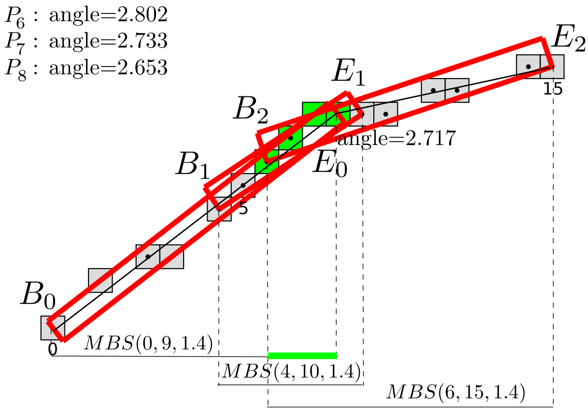
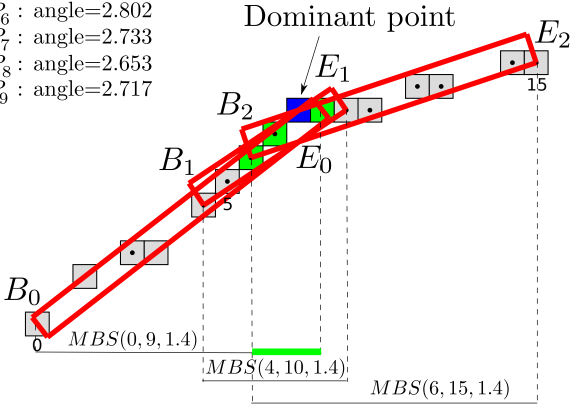


Dominant point detection [2]

Strategy

Dominant point is detected as the point with **minimum angle measure** estimated with extremities of the MBS composing the common zone.

P_6 : angle=2.802
P_7 : angle=2.733
P_8 : angle=2.653
P_9 : angle=2.717



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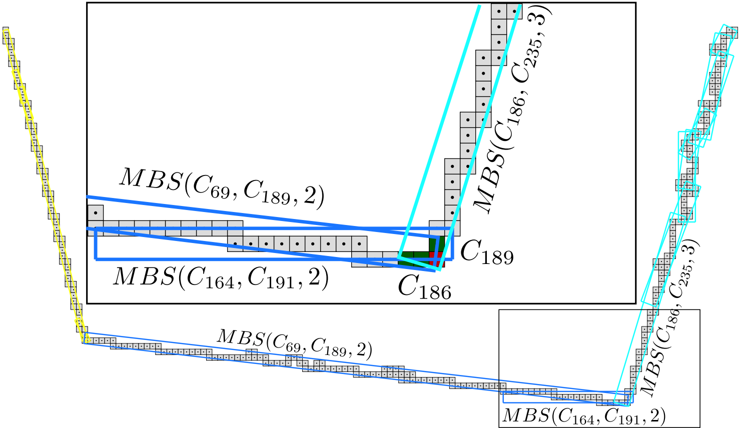


Algorithm of dominant point detection

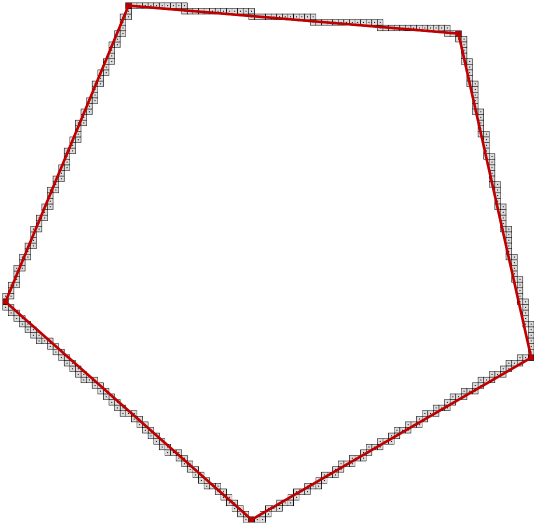
Input: C discrete curve of n points
Output: D set of dominant points

Begin
Build $ATC = \{MBS(B_i, E_i, .)\}_{i=0}^{m-1}$
$n = |C|; m = |ATC|$
$q = 0; p = 1; D = \emptyset$
while $p < m$ **do**
  while $E_q > B_p$ **do**
    $p++$
  end while
  $D = D \cup \min\{Angle(C_{B_q}, C_i, C_{E_{p-1}}) \mid i \in [\![B_{p-1}, E_q]\!]\}$
  $q = p - 1$
end while
End

Experimental results

Mean tangential cover [6]

Adaptive tangential cover



Experimental results

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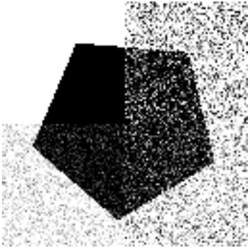

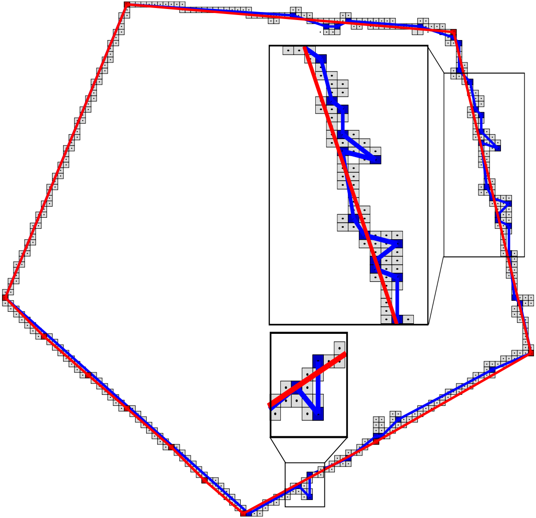

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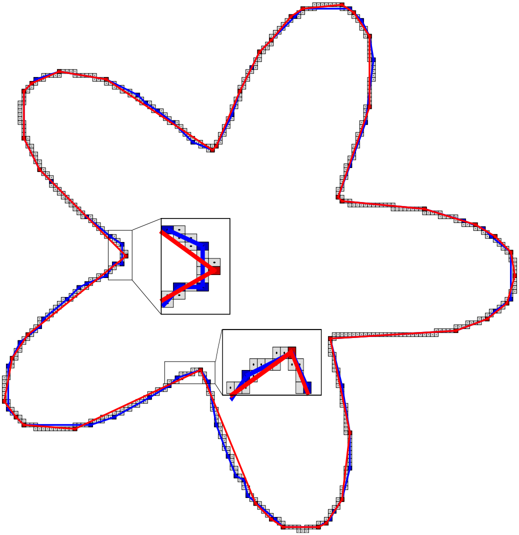

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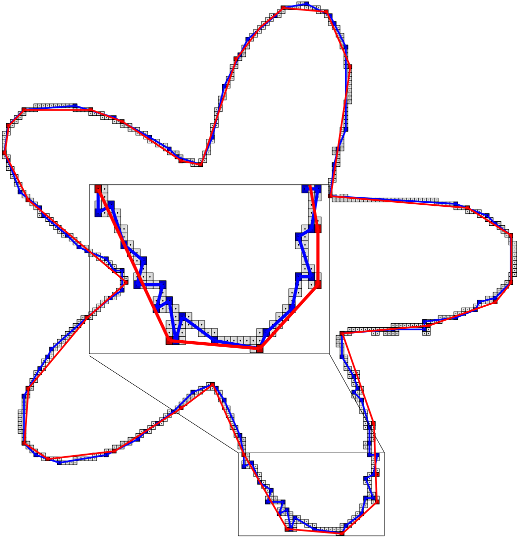

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Arcs and segments decomposition

Motivation

Arcs and segments are the most appearing primitives in images

- Detection of shapes
  - medical imaging, technical images, manual drawings
- Automatic character recognition
  - sketch, scanned documents

Arcs and segments decomposition

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Arcs and segments are the most appearing primitives in images

- Detection of shapes
  - medical imaging, technical images, manual drawings
- Automatic character recognition
  - sketch, scanned documents

Tools

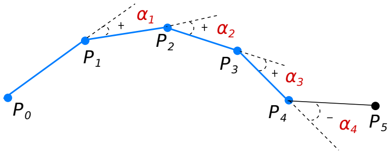
- Adaptive tangent cover
- Dominant point detection
- Tangent space representation

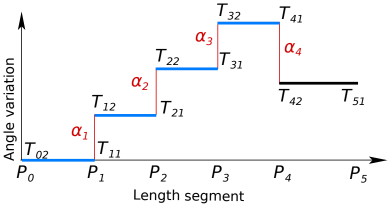
Tangent space representation

Definition

Let $P = \{P_i\}_{i=0}^{m}$ be a polygon, $l_i = |\overrightarrow{\mathrm{P_iP_{i+1}}}|$ and $\alpha_i = \angle(\overrightarrow{\mathrm{P_{i-1}P_i}}, \overrightarrow{\mathrm{P_iP_{i+1}}})$ s.t. $\alpha_i > 0$ if P_{i+1} is on the right side of $\overrightarrow{\mathrm{P_{i-1}P_i}}$ and $\alpha_i < 0$ otherwise.
A tangent space representation $T(P)$ of P is a step function which is constituted of segments $T_{i2}T_{(i+1)1}$ and $T_{(i+1)1}T_{(i+1)2}$ for $0 \leq i < m$ with

- $T_{02} = (0,0)$,
- $T_{i1} = (T_{(i-1)2}.x + l_{i-1}, T_{(i-1)2}.y)$ for $1 \leq i \leq m$,
- $T_{i2} = (T_{i1}.x, T_{i1}.y + \alpha_i)$, $1 \leq i \leq (m-1)$.

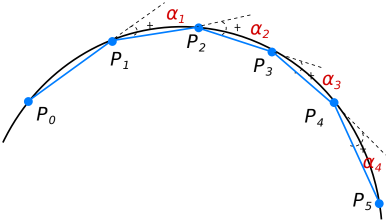


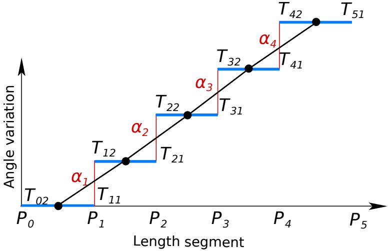


Tangent space representation

Proposition

Let $P = \{P_i\}_{i=0}^{m}$ be a polygon, $l_i = \mid \overrightarrow{\mathrm{P_iP_{i+1}}} \mid$, $\alpha_i = \angle(\overrightarrow{\mathrm{P_{i-1}P_i}}, \overrightarrow{\mathrm{P_iP_{i+1}}})$ s.t. $\alpha_i \leqslant \alpha \leqslant \frac{\pi}{4}$ for $0 \leq i < n$, $T(P)$ the tangent space representation of P and $T(P)$ constitutes of segments $T_{i2}T_{(i+1)1}$, $T_{(i+1)1}T_{(i+1)2}$ for $0 \leq i < m$, $M = \{M_i\}_{i=0}^{m-1}$ the midpoint set of $\{T_{i2}T_{(i+1)1}\}_{i=0}^{m-1}$.
P is a polygon whose vertices are on a real arc only if M is a set of *quasi collinear* points.

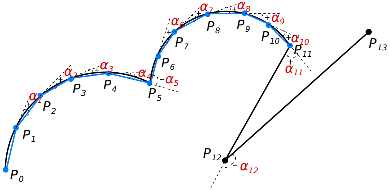


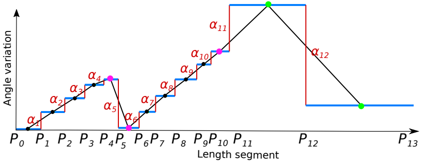


Tangent space representation

In the tangent space representation, the midpoints can be classified as

- **isolated point** if either $(| M_i.y - M_{i-1}.y |> \alpha)$ or $(| M_i.y - M_{i+1}.y |> \alpha) \Longrightarrow$ a jonction between two primitives
- **fully isolated point** if $(| M_i.y - M_{i-1}.y |> \alpha)$ and $(| M_i.y - M_{i+1}.y |> \alpha) \Longrightarrow$ a segment
- **arc point** otherwise $\Longrightarrow$ an arc chord





Algorithm of arcs and segments decomposition

Input: $C = (C_i)_{0 \leq i \leq n-1}$ discrete curve of n points
ν, α test of collinear and admissible angle in tangent space
Output: $ARCs$ and $SEGs$ sets of arcs and segments of C

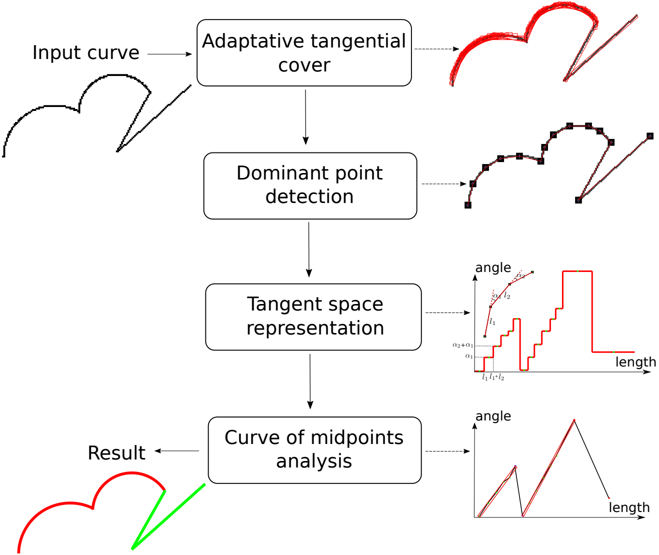
Begin
$ARCs \leftarrow \emptyset, SEGs \leftarrow \emptyset$
Detect the dominant point D of C
Transform D into the tangent space $T(D)$
Construct the midpoint curve $\{M_i\}_{i=0}^{m-1}$ of $T(D)$
for $i \leftarrow 1$ to $m-2$ **do**
  $C_{b_i}C_{e_i}$ the part of C corresponds to M_i
  if $(\mid M_i.y - M_{i-1}.y \mid > \alpha) \& (\mid M_i.y - M_{i+1}.y \mid > \alpha)$ **then**
    $SEGs \leftarrow SEGs \cup \{$find a segment from $C_{b_i}C_{e_i}\}$
    $MBS_\nu \leftarrow \emptyset$
  else
    ...
  end if
end for

Algorithm of arcs and segments decomposition

Input: $C = (C_i)_{0 \leq i \leq n-1}$ discrete curve of n points
ν, α test of collinear and admissible angle in tangent space
Output: $ARCs$ and $SEGs$ sets of arcs and segments of C

Begin
...
for $i \leftarrow 1$ to $m-2$ **do**
  $C_{b_i}C_{e_i}$ the part of C corresponds to M_i
  ...
    if $MBS_\nu \leftarrow MBS \cup \{M_i\}$ is a MBS of width ν **then**
      $MBS_\nu \leftarrow MBS_\nu \cup \{M_i\}$
      $pARC \leftarrow pARC \cup \{C_{b_i}C_{e_i}\}$
    else
      $ARCs \leftarrow ARCs \cup \{$find an arc from $pARC\}$
      $pARC \leftarrow \emptyset$
    end if
end for
End

Algorithm of arcs and segments decomposition



Experimental results

. . .

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Conclusion

Contributions

- Algorithm based on discrete structure of the curve
- Algorithm without heuristic but a simple measure of angle

Perspectives

- Parameter free method
- Adaptive-thickness

Thank you for your attention!

References

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