A discrete approach for decomposing noisy digital contours into arcs and segments

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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

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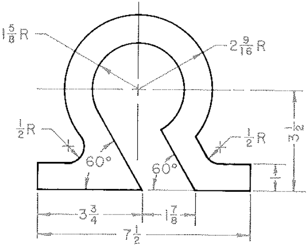

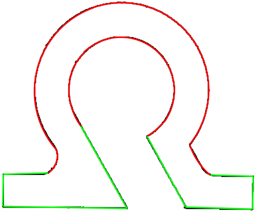

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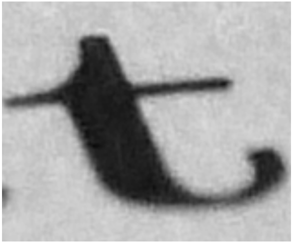

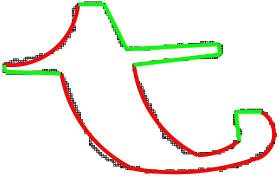

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Tools

- Adaptive tangential cover [Ngo16]
- Dominant point detection [Ngo15]
- Tangent space representation [Nguyen11a]

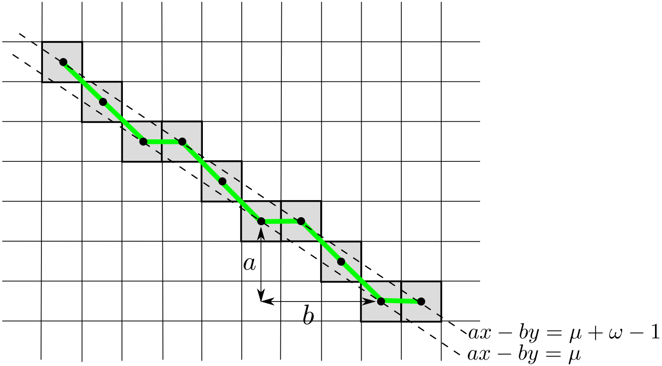
Overview

Overview

Discrete line and segment

Definition

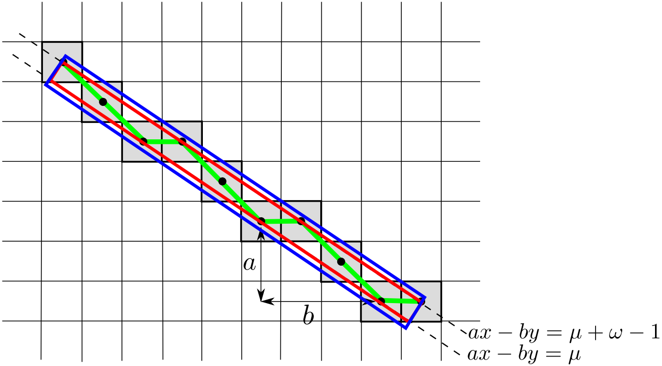
A **discrete line** $\mathcal{D}(a, b, \mu, \omega)$ is the set of integer points (x, y) verifying $\mu \leq ax - by < \mu + \omega$ where $a, b, \mu, \omega \in \mathbb{Z}$ and $gcd(a, b) = 1$.



Discrete line and segment

Definition

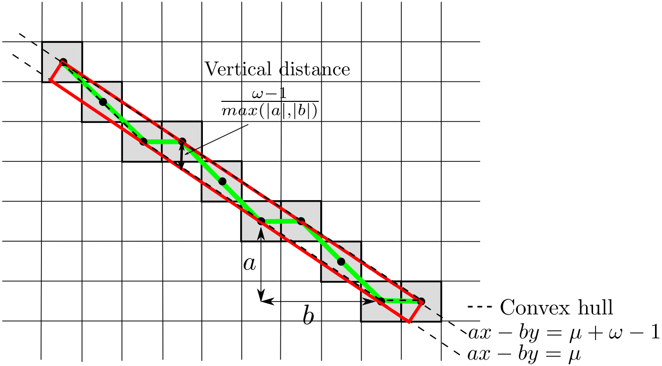
A **discrete segment** is a finite set $\mathcal{S}_f$ of integer points bounded by the discrete line $\mathcal{D}(a, b, \mu, \omega)$.



Discrete line and segment

Definition

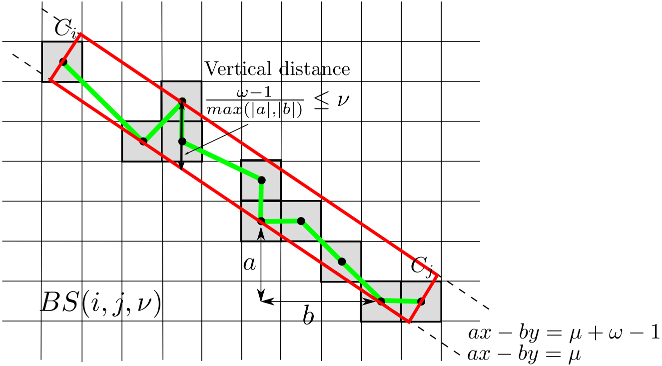
A discrete segment $\mathcal{S}_f$ is **optimal** if its vertical (or horizontal) distance is equal to the vertical (or horizontal) thickness of its convex hull.



Blurred segment

Definition

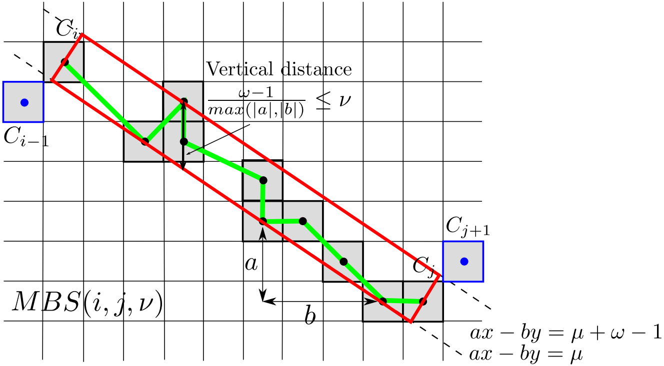
A sequence integer points $\mathcal{S}_f$ is a **blurred segment of width** ν if its optimal bounding discrete segment $\mathcal{D}(a, b, \mu, \omega)$ has the vertical or horizontal distance less than or equal to ν.



Blurred segment

Definition

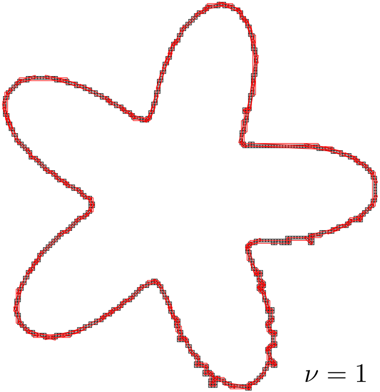
A blurred segment of witdth ν $BS(i,j,\nu)$ is **maximal**, and noted $MBS(i,j,\nu)$, iff $\neg BS(i,j+1,\nu)$ and $\neg BS(i-1,j,\nu)$.



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.



$\nu = 1$

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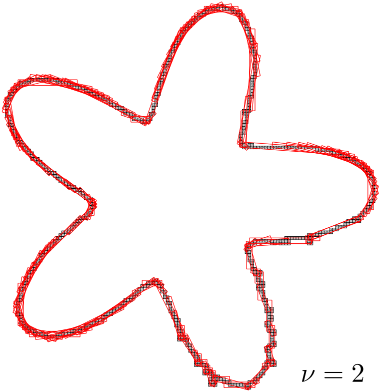

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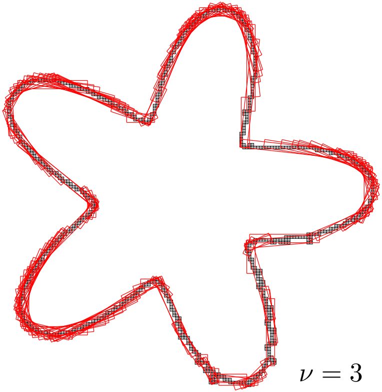

$\nu = 3$

Maximal blurred segment decomposition

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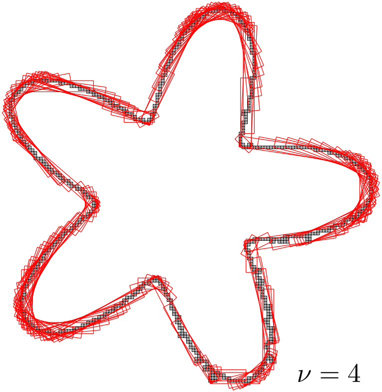

$\nu = 4$

Maximal blurred segment decomposition

Definition

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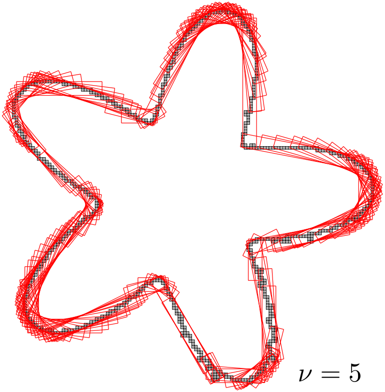


$\nu = 5$

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.

Solution

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

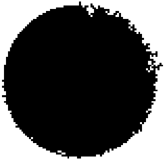
- appropriated widths based on a local noise estimation
  - **meaningful thickness detection** [Kerautret12]
- parameter-free computation

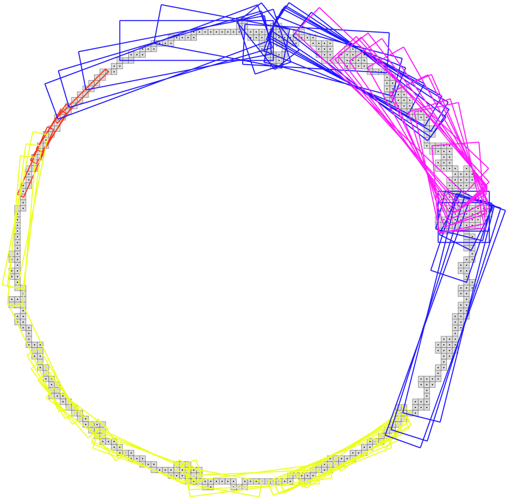
Construction of adaptive tangential cover

Principes [Ngo16]

- Input:
  - A discrete curve C of n points
  - Vector of meaningful thickness η associated to each point of C
- Output:
  - An ATC of C associated to the meaningful thickness vector η
- 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

Examples of Adaptive Tangential Cover





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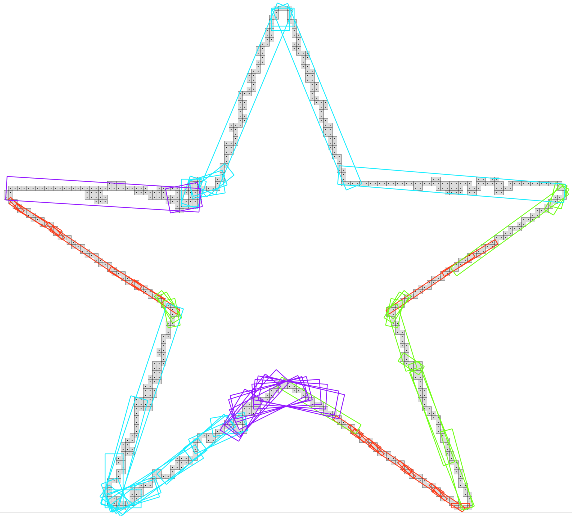

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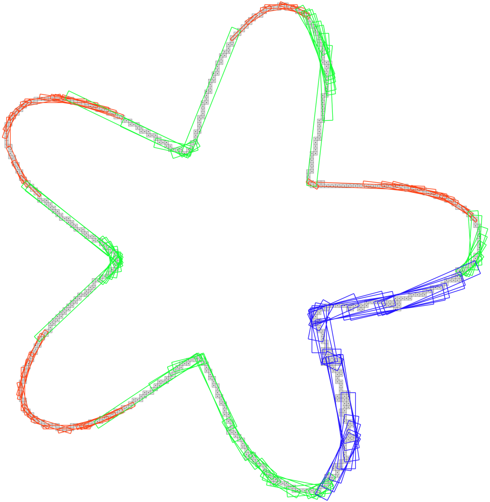

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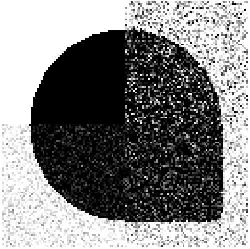

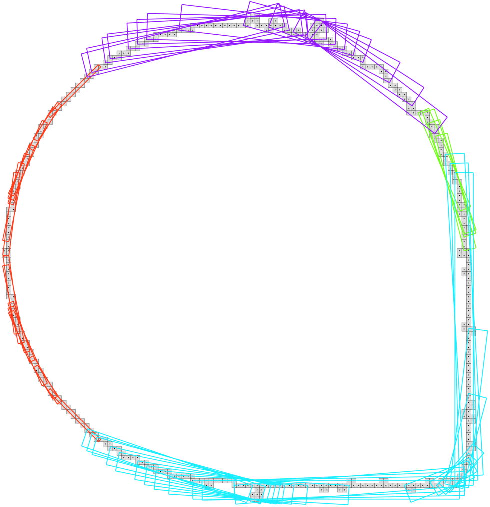

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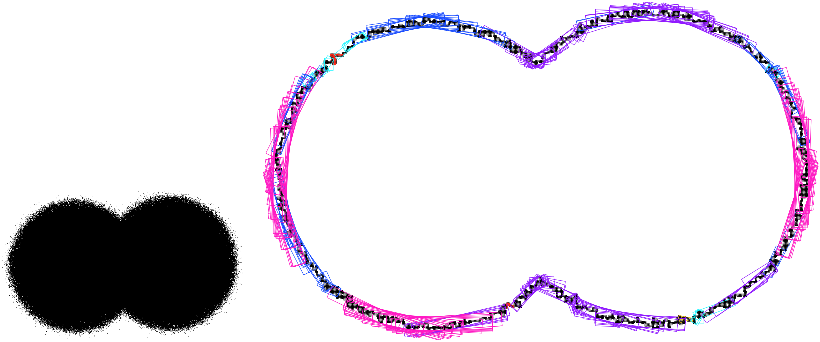

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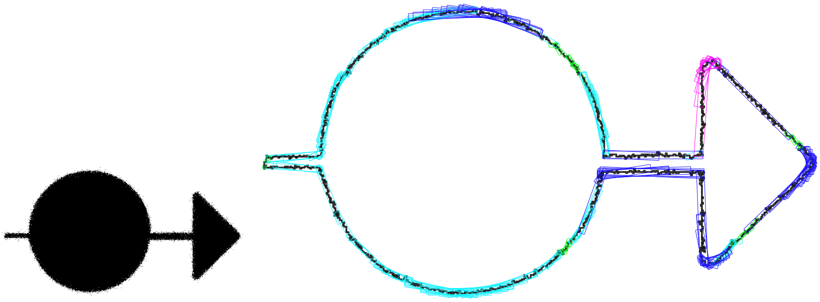

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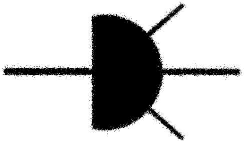

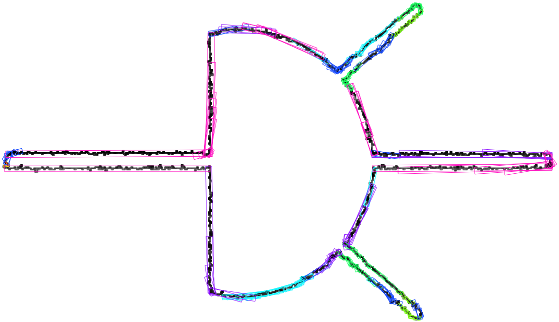

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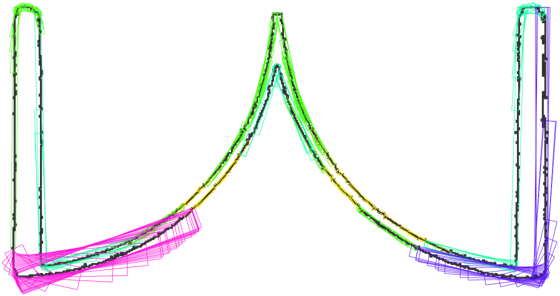
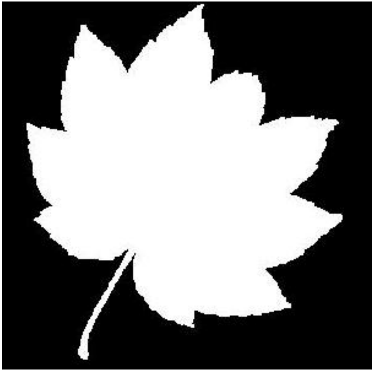


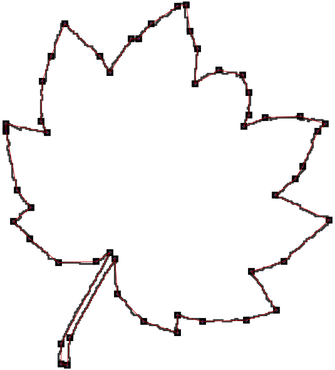
Overview

Dominant point

Definition

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

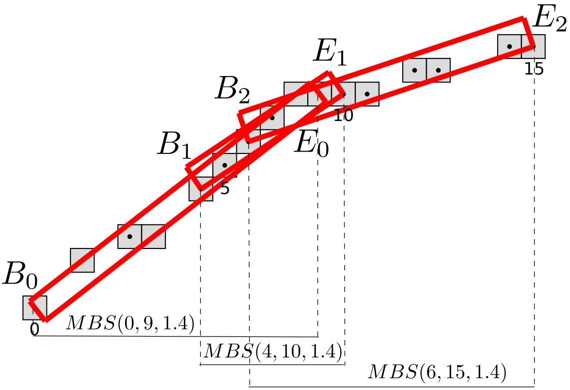




Dominant point detection

Proposition [Nguyen11b]

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



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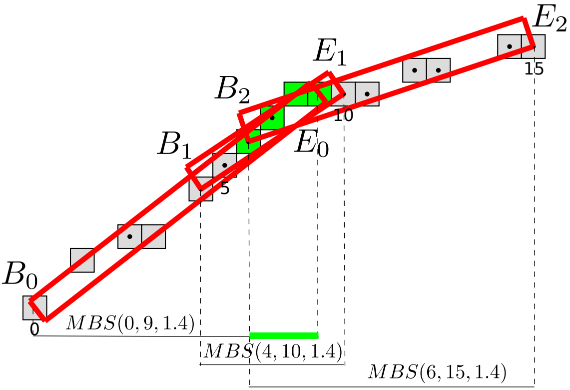
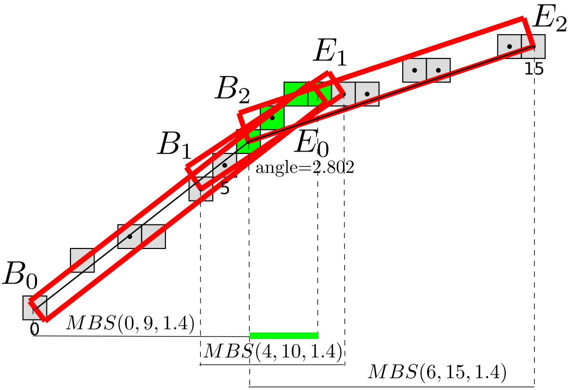


Dominant point detection

Proposition [Ngo15]

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



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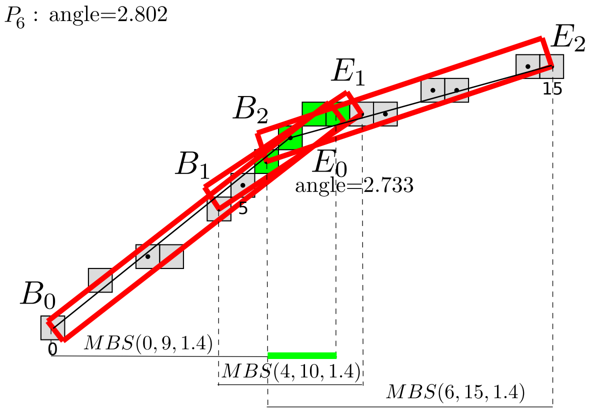

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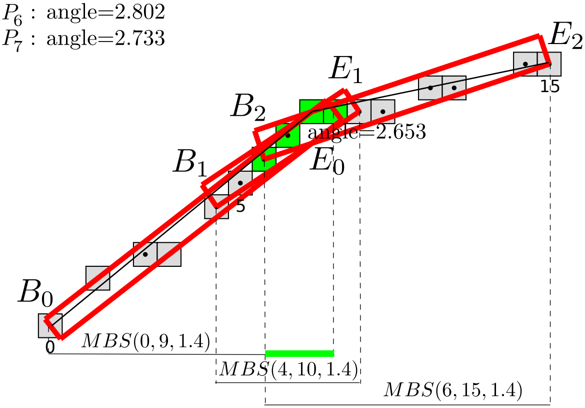

Dominant point detection

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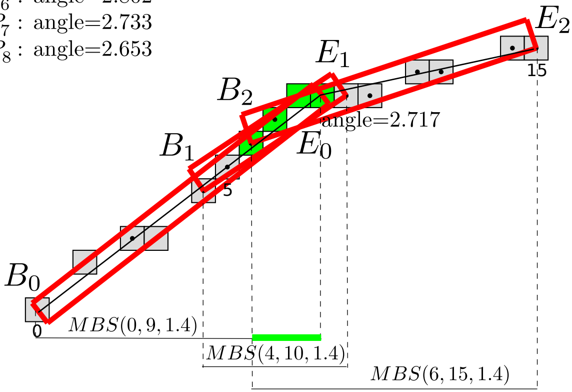
Dominant point is detected as the point with **minimum angle measure** estimated with extremities of MBS composing the common zone.

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



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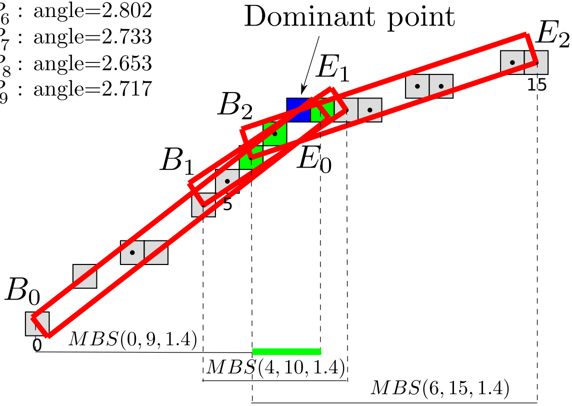
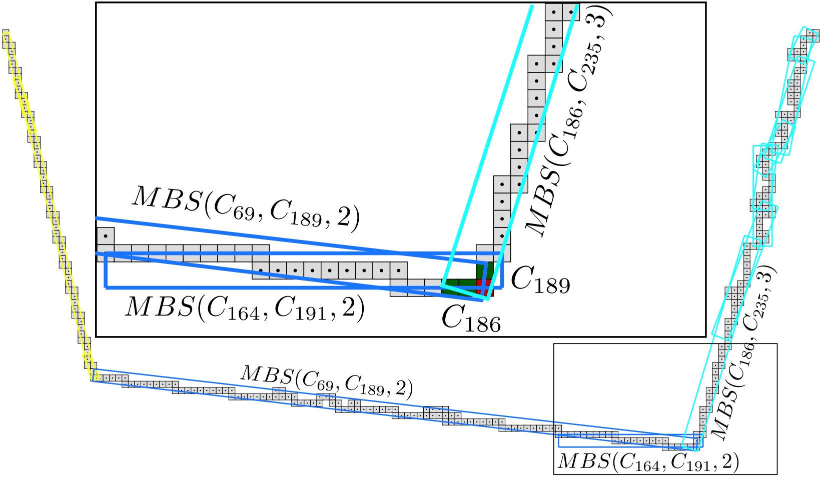
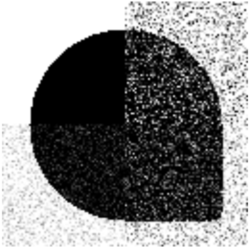
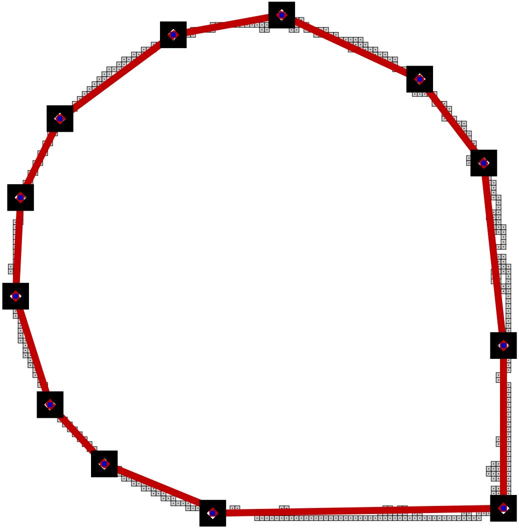


Dominant point detection



Dominant point detection results





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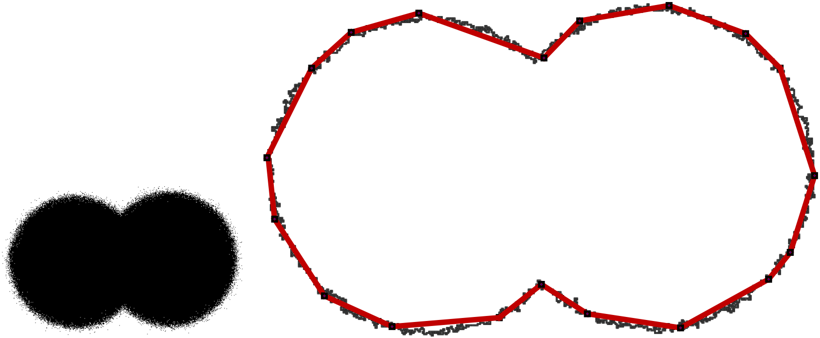

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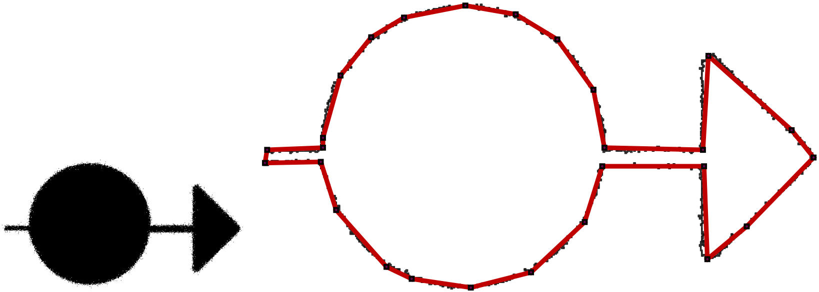

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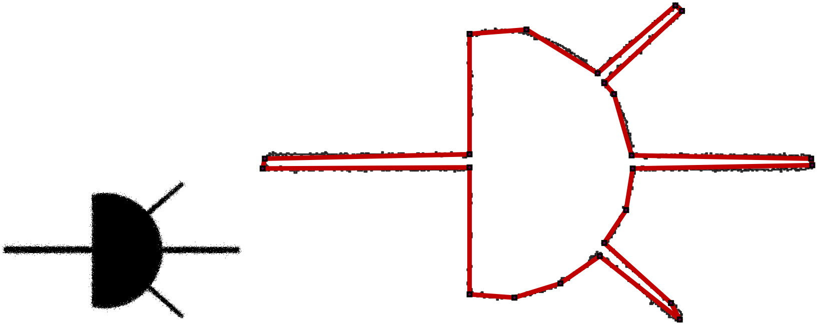

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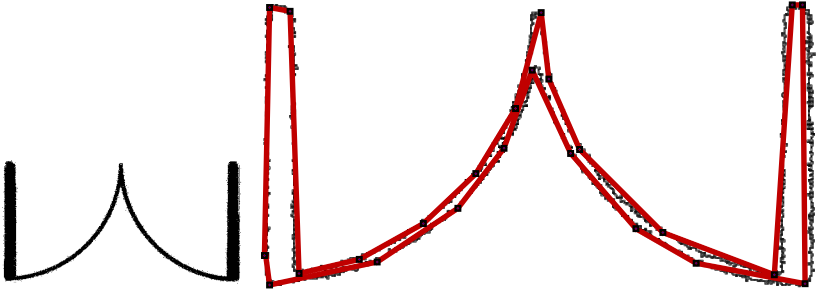


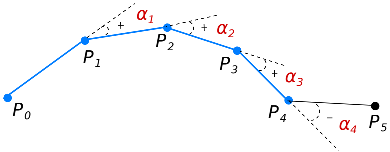
Overview

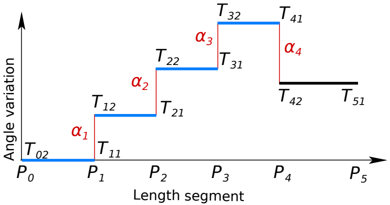
Tangent space representation

Definition

Let $P = \{P_i\}_{i=0}^{m}$ be a polygon, $l_i = \mid \overrightarrow{P_iP_{i+1}} \mid$ and $\alpha_i = \angle(\overrightarrow{P_{i-1}P_i}, \overrightarrow{P_iP_{i+1}})$ s.t. $\alpha_i > 0$ if P_{i+1} is on the right side of $\overrightarrow{P_{i-1}P_i}$ 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 $1 \leq i \leq m$,
- $T_{i2} = (T_{i1}.x, T_{i1}.y + \alpha_i)$, $1 \leq i \leq (m-1)$.

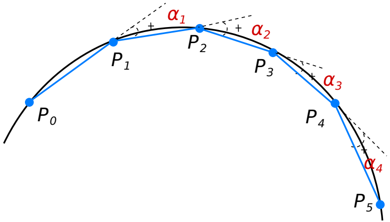


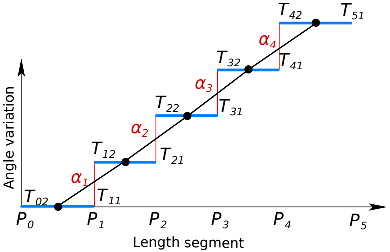


Tangent space representation

Proposition [Nguyen11a]

Let $P = \{P_i\}_{i=0}^{m}$ be a polygon, $l_i = |\overrightarrow{\mathrm{P_iP_{i+1}}}|$, $\alpha_i = \angle(\overrightarrow{\mathrm{P_{i-1}P_i}}, \overrightarrow{\mathrm{P_iP_{i+1}}})$ 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_i belongs to a small width strip bounded by two real parallel lines, namely *quasi collinear* points.

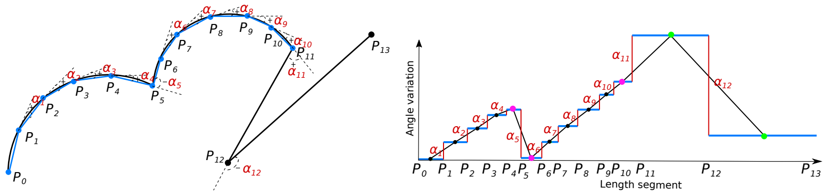




Tangent space representation

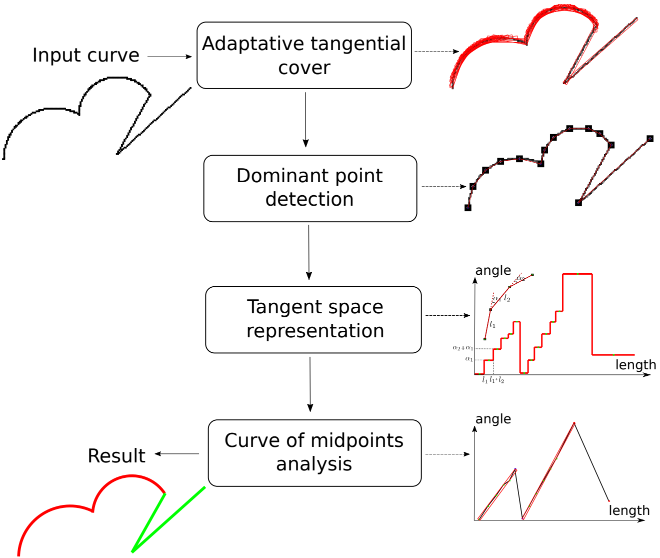
In the tangent space representation, the midpoints can be classified as

- **isolated point** if either $(| M_i.y - M_{i-1}.y |> \alpha)$ or $(| M_i.y - M_{i+1}.y |> \alpha) \Longrightarrow$ a junction 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



Overview

Algorithm of arcs and segments decomposition



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 from ATC 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 $(| M_i.y - M_{i-1}.y | > \alpha) \& (| M_i.y - M_{i+1}.y | > \alpha)$ **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

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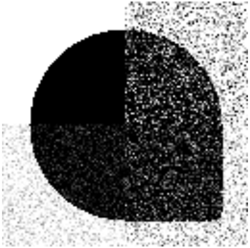
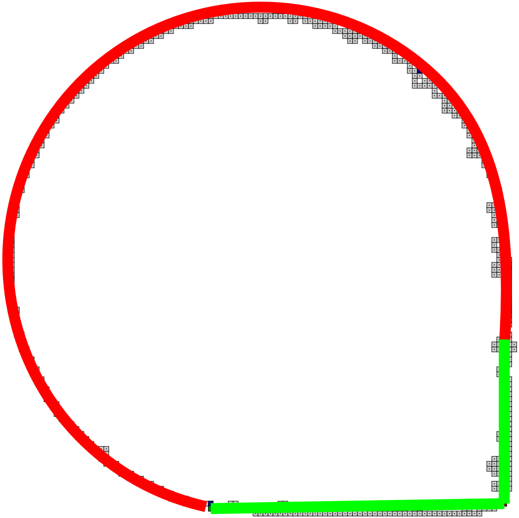
Begin
...
for $i \leftarrow 1$ to $m-2$ **do**
$C_{b_i}C_{e_i}$ the part of C corresponds to M_i
...
if $MBS_\nu \leftarrow MBS \cup \{M_i\}$ is a MBS of width ν **then**
$MBS_\nu \leftarrow MBS_\nu \cup \{M_i\}$
$pARC \leftarrow pARC \cup \{C_{b_i}C_{e_i}\}$
else
$ARCs \leftarrow ARCs \cup \{\text{find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

Experimental results





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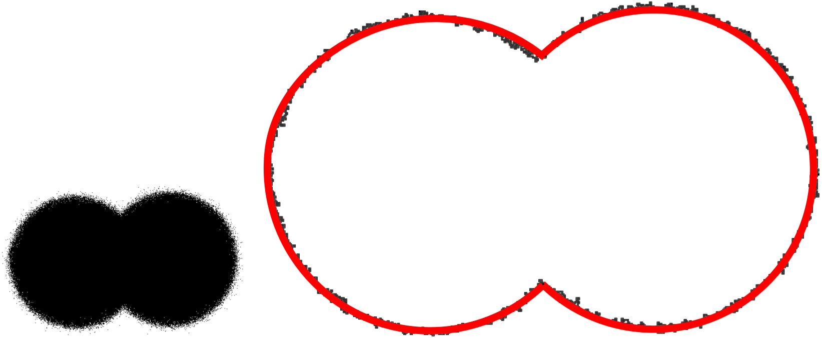
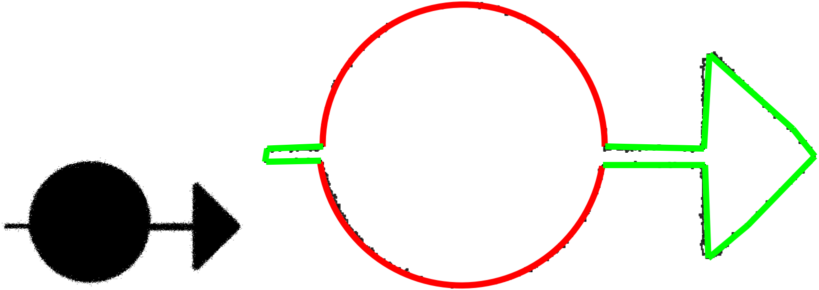
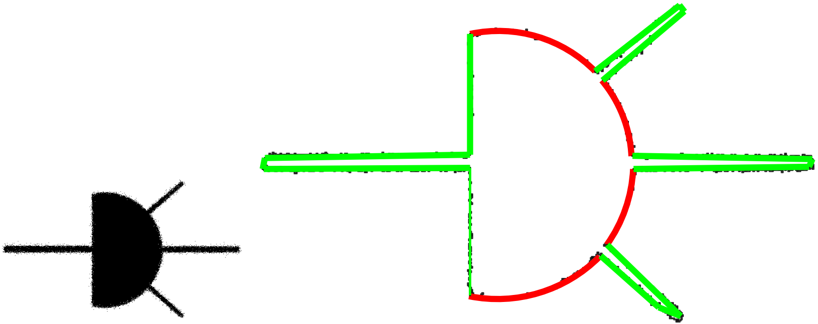


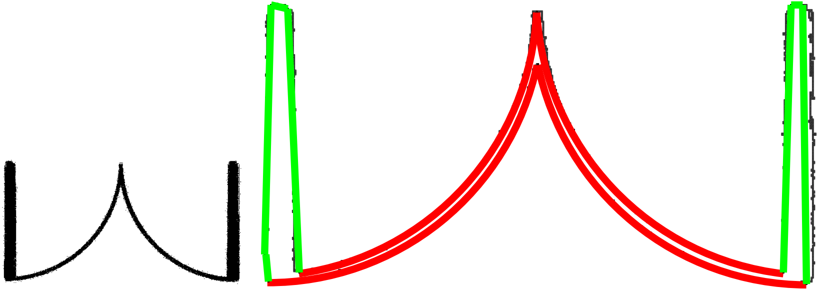
Experimental results



Experimental results



Experimental results



Online demonstration

An online demonstration based on the DGtal and ImaGene library at

`http://ipol-geometry.loria.fr/~phuc/ipol_demo/ATC_ArcSegDecom_IPOLDemo`

Arcs and Segments Decomposition of Digital Contours: Online Demonstration

article | demo | archive

Please cite the reference article if you publish results obtained with this online demo.

This demonstration applies the Adaptive Tangential Cover algorithm for arcs and segments decomposition of noisy digital curves.

Select Data

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

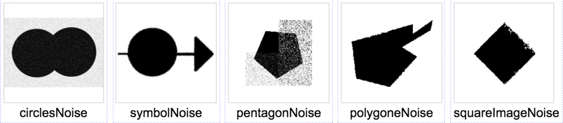


image credits

Upload Data

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

input image | Choose file | No file chosen | upload

Images larger than 16777216 pixels will be resized. Upload size is limited to 16MB per image file and 10MB for the whole upload set .
TIFF, JPEG, PNG, GIF, PNM (and other standard formats) are supported. The uploaded will be publicly archived unless you switch to private mode on the result page.
Only upload suitable images. See the copyright and legal conditions for details.

Overview

Conclusion

- Curve decomposition into arcs and segments with
  - Adaptive tangential cover
  - Dominant point detection
  - Tangent space representation
- Perspectives
  - Extension to other primitives
  - Reduction of the number of parameters
  - Integration of topology into the decomposition

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Thank you for your attention!