[Re:] Image partitioning into convex polygons

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CS 6319.001-Computational Geometry

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Image partitioning into convex polygons

Image partitioning into convex polygons

Digital Image - A moment in real life captured and stored in digital form.

Image: https://news.utdallas.edu/students-teaching/secret-student-behind-temoc-is-all-fired-up/

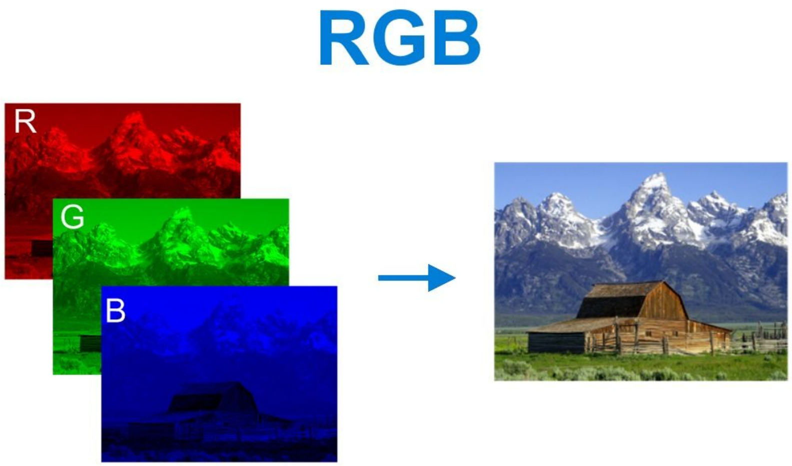
Image partitioning into convex polygons

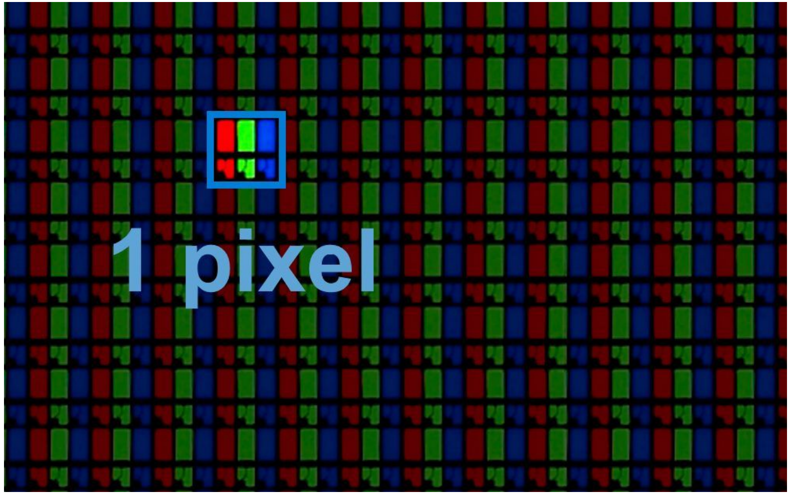
Popular

List of color spaces • Color models	
CIE	CIEXYZ • CIELAB • CIECAM02 • CIELUV • Yuv • CIEUVW • CIE RGB
RGB	color spaces • sRGB • Adobe • Wide Gamut • ProPhoto • scRGB
YUV	YUV (PAL) • YDbDr (SECAM) • YIQ (NTSC) • YCbCr • YPbPr • xvYCC
Other	LMS • HSL, HSV • CMYK • CcMmYK • Hexachrome • RYB • Munsell • NCS • Pantone • RAL OSA-UCS • Coloroid • RG • PCCS • ISCC-NBS • Imaginary color

Source: https://psychology.fandom.com/wiki/Color_space

Image partitioning into convex polygons





Source: https://www.latelierducable.com/tv-televiseur/yuv-420-ycbcr-422-rgb-444-cest-quoi-le-chroma-subsampling/

Image **partitioning** into convex polygons

Source: researchgate

Image partitioning into **convex polygons**

Source: [researchgate]

From **Pixels** to **SuperPixels**

A superpixel is a **group** of **adjacent pixels** in a digital image that are **similar** in color or texture and are often used as a **preprocessing step** for many downstream tasks

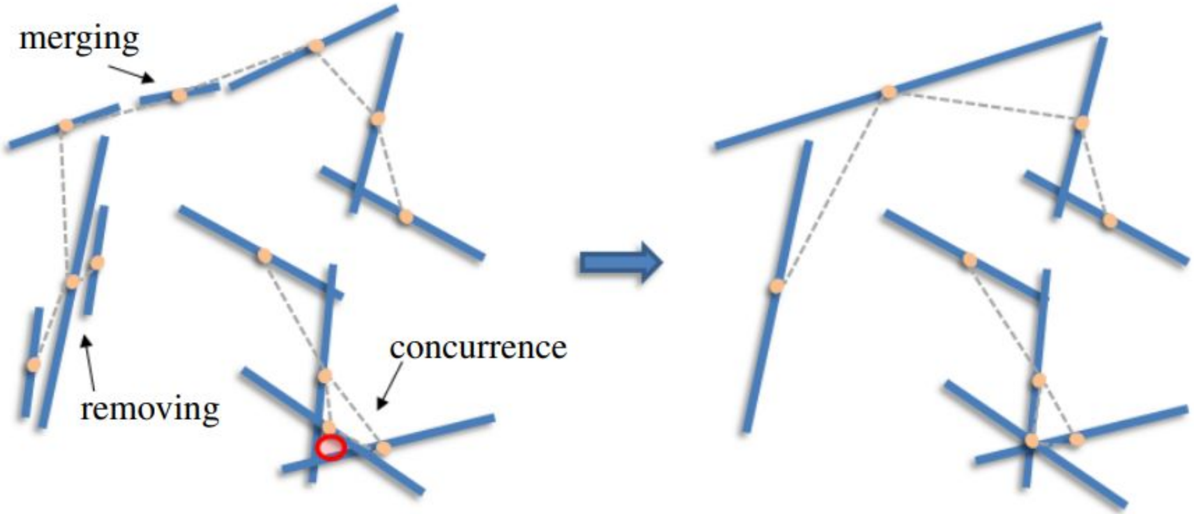
Algorithm

Step-1: Line Segment Consolidation

Step-2: Conforming Voronoi Partition

Step-3: Spatial Homogenization

Step-1: Line Segment Consolidation



Assumption: Shown set of line segments are adjacent.

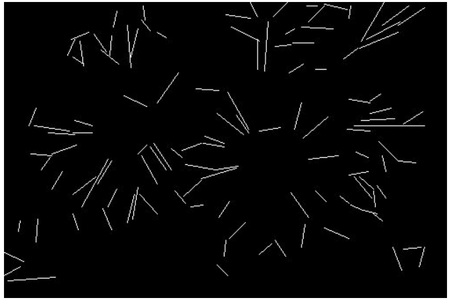
Two line-segments L1 and L2 are considered as adjacent if d(L1 , L2) ≤ ε, where d(., .) is the minimal euclidean distance between any pair of points of the two line-segments.

Step-1: Line Segment Consolidation

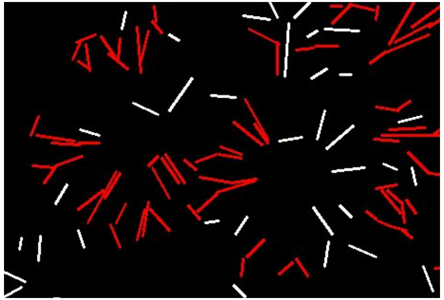
Works with any available Line Segment Detector +

Sample Image

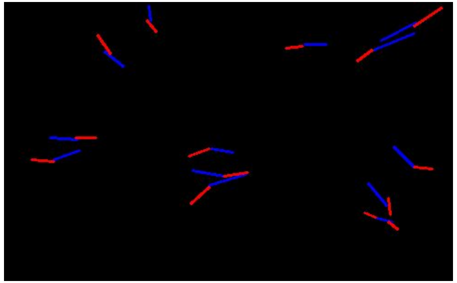
Detect Line Segments (LS) [*]



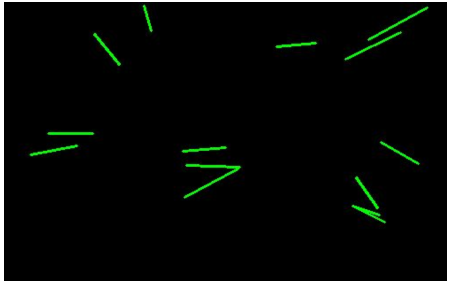
Detected Line Segments



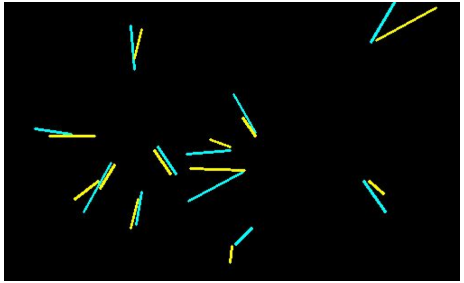
Identify Adjacent Line Segments



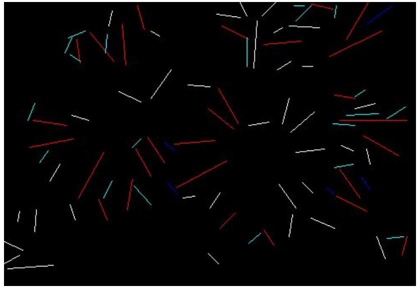
Near Collinear Line Segments (NCLS)



Merge NCLS



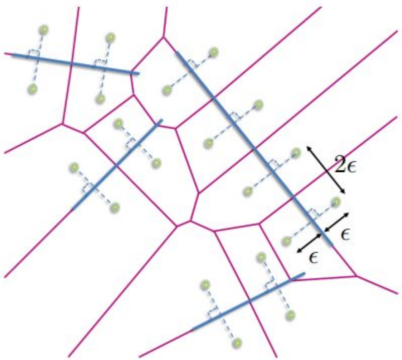
Remove small and **keep** large LS



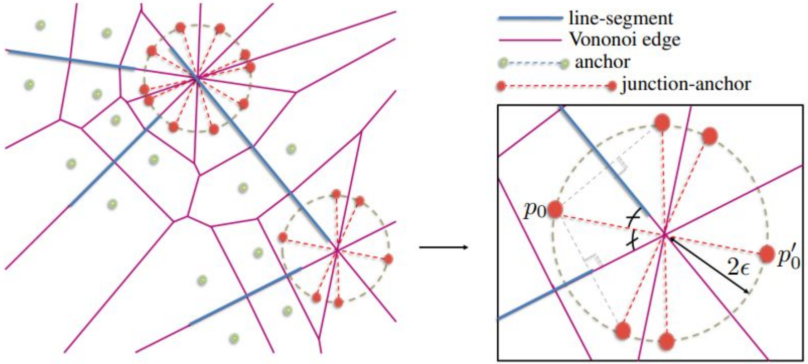
LS after consolidation process

[*] LSD: A Fast Line Segment Detector with a False Detection Control

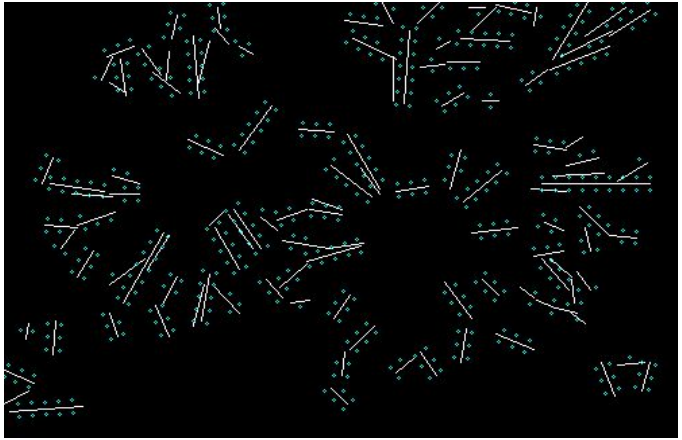
Step-2: Conforming Voronoi Partition

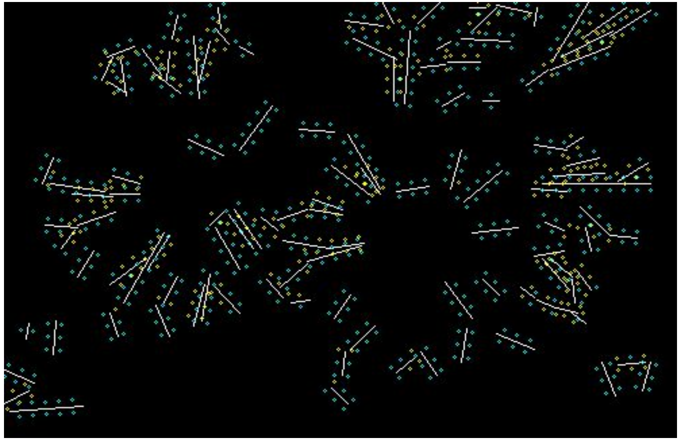


Anchoring

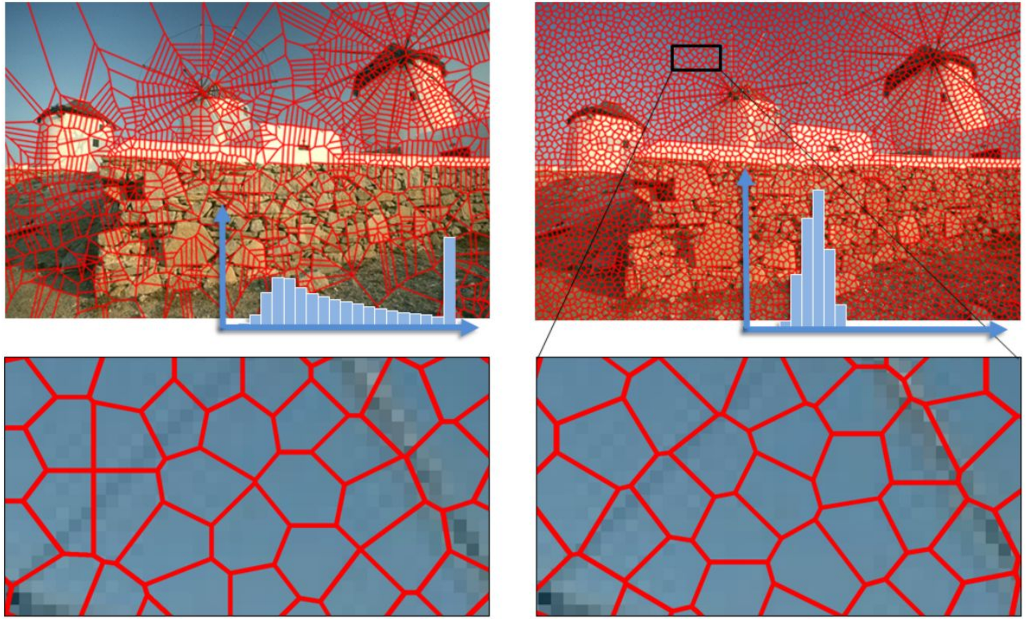


Junction Preservation



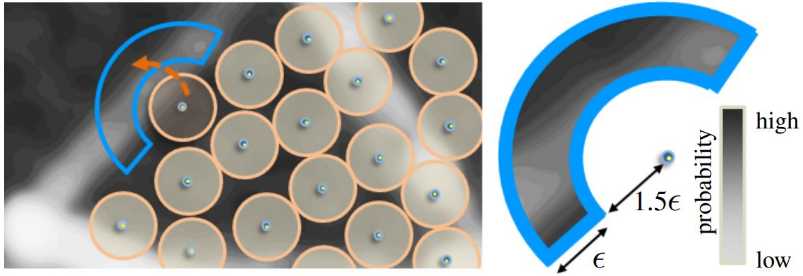


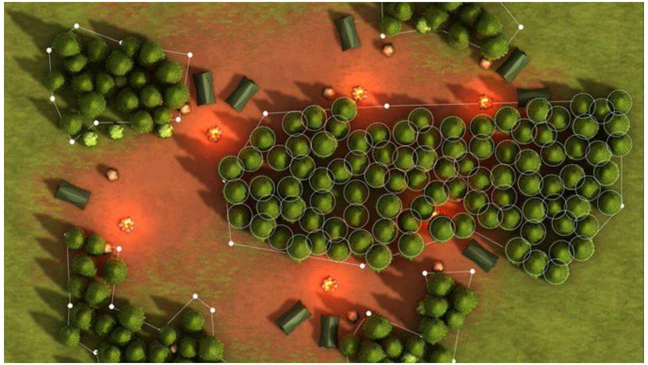
Step-3: Spatial Homogenization


uniform sampling gradient-driven sampling

Step-3: Spatial Homogenization

Poisson Disk Sampling





Video: https://twitter.com/PicoTanks/status/1001615698907418624?s=20

Output: Success Cases

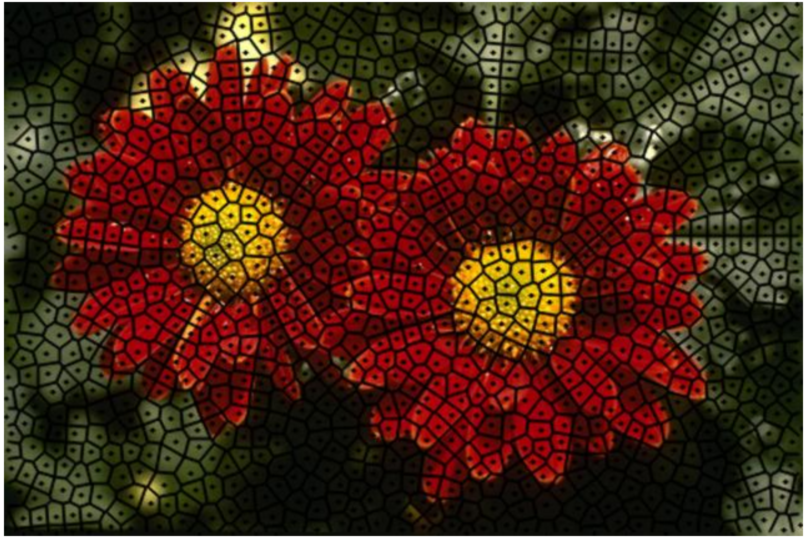
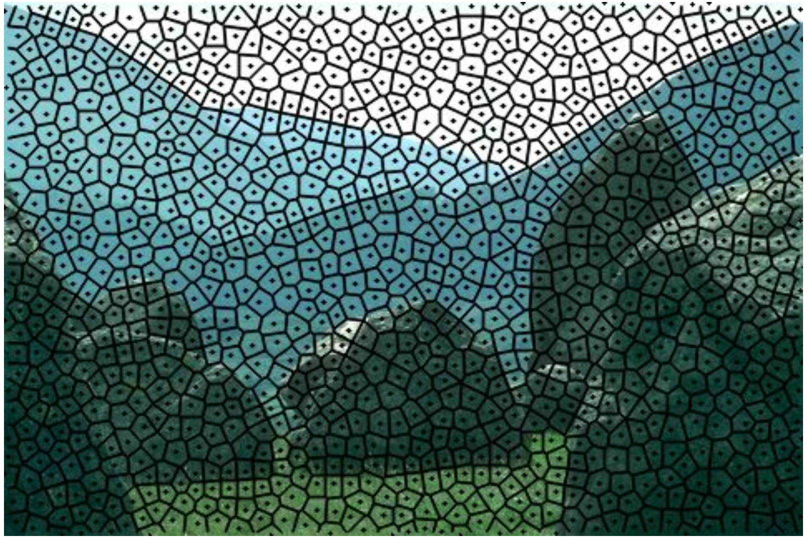


Image-Alias: 7i

Output: Success Cases



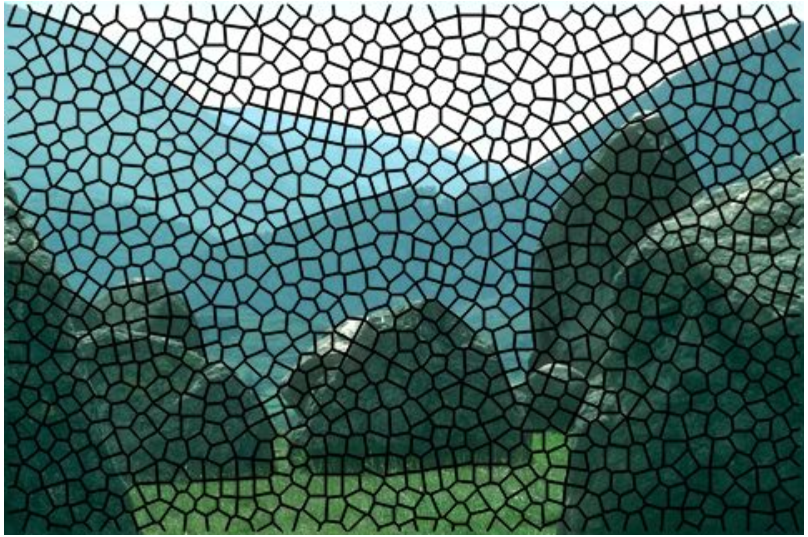


Image-Alias: 7a

Output: Success Cases

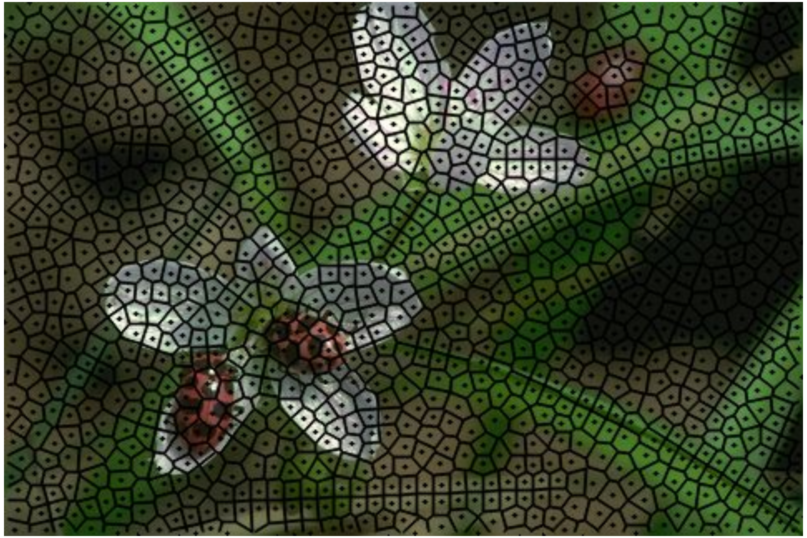


Image-Alias: 7b

Output: Success Cases

Image-Alias: 7c

Output: Success Cases

Image-Alias: 7d

Output: Success Cases

Image-Alias: 7e

Output: Success Cases

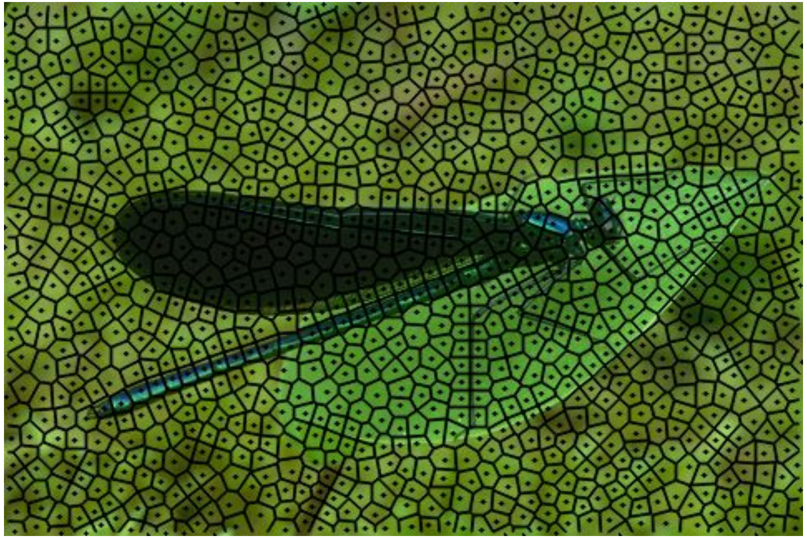
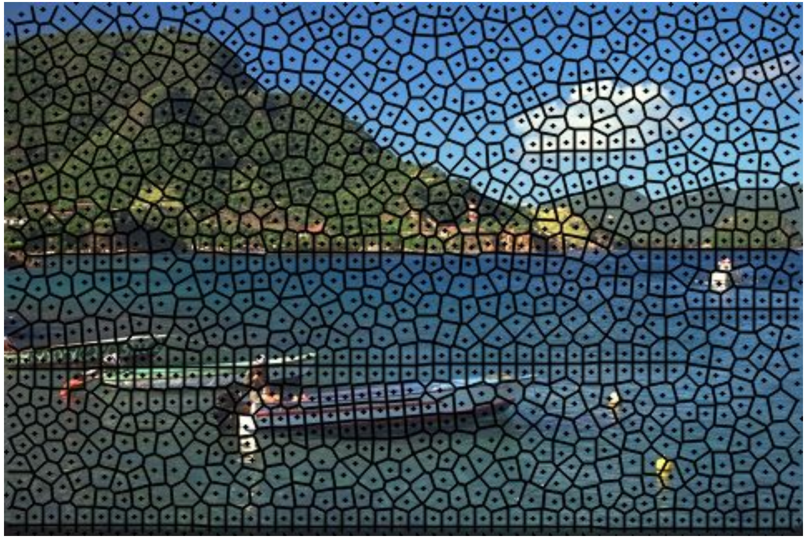


Image-Alias: 7f

Output: Success Cases



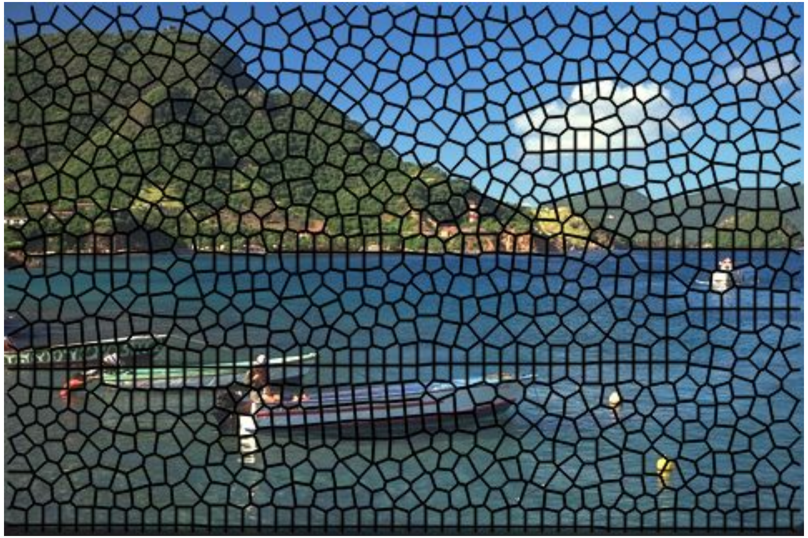


Image-Alias: 7g

Output: Success Cases

Image-Alias: 7h

Output: Success Cases

Image-Alias: 7j Zoomed

Output: Success Cases Misc.

A high-resolution satellite image(source: MIT Tech. Review). Input image resolution: 1166x656.

Output: Success Cases Misc.

A high-resolution dog image(source: unknown). Input image resolution: 1999x1499.

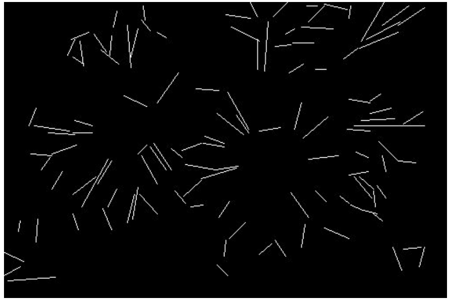
Limitations (Orig. Work & [Re:])

The algorithm is intended to partition images by approximating the boundaries of regions with polygons. While this approach may be suitable for man-made environments, it may not be as effective for images with less distinct geometric features.

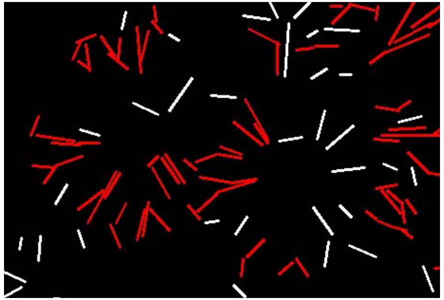
Limited by the line segment detector's quality

Sample Image

Detect Line Segments (LS)



Detected Line Segments



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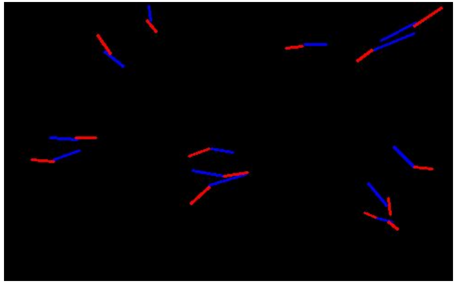
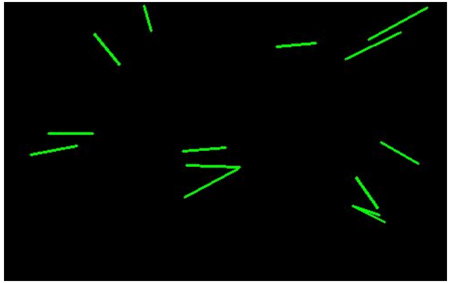
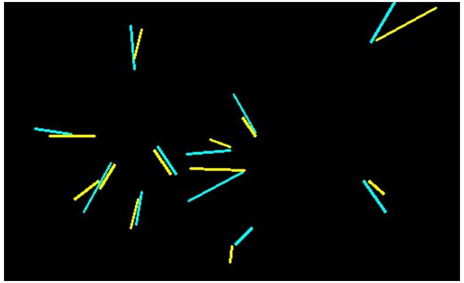


Near Collinear Line Segments (NCLS)



Merge NCLS



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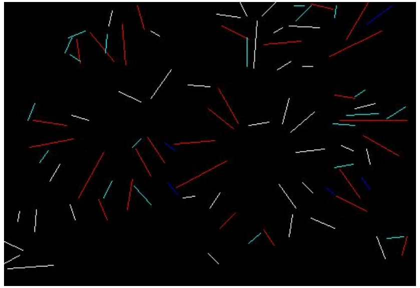


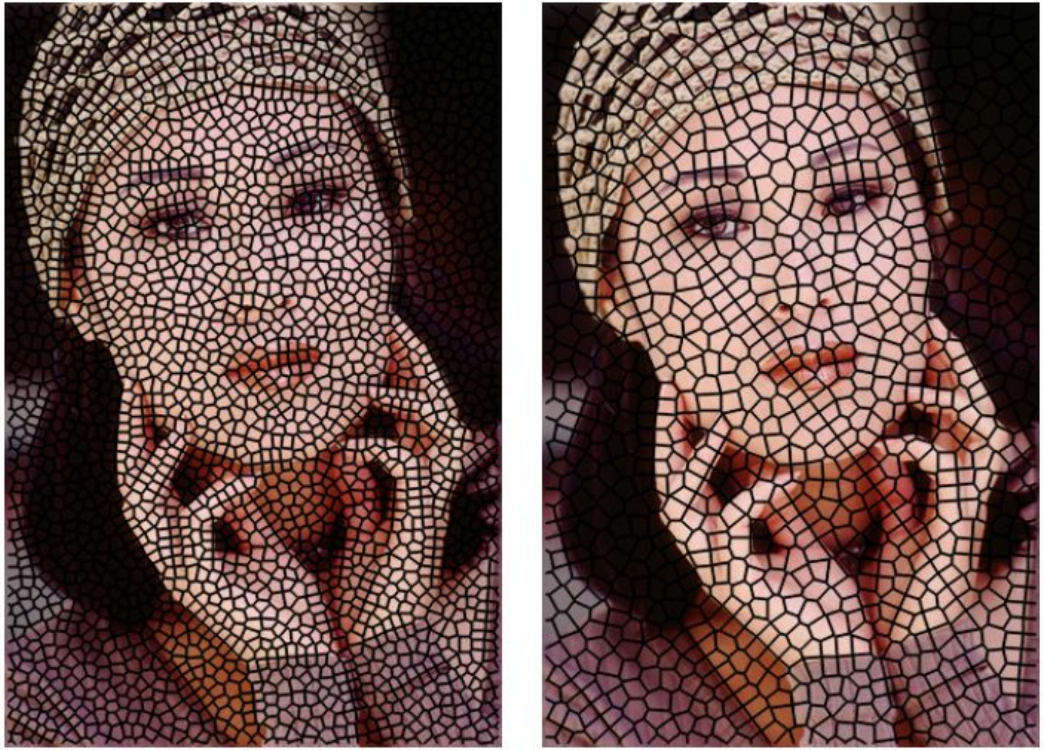
LS after consolidation process

[Re:] Concurrence operation not implemented due to bugs + ↑ dev & run time. It's an edge case. Fortunately it didn't come up in any of the testing images.

Failure Cases

Reason: Line segment detector failed to detect line segments

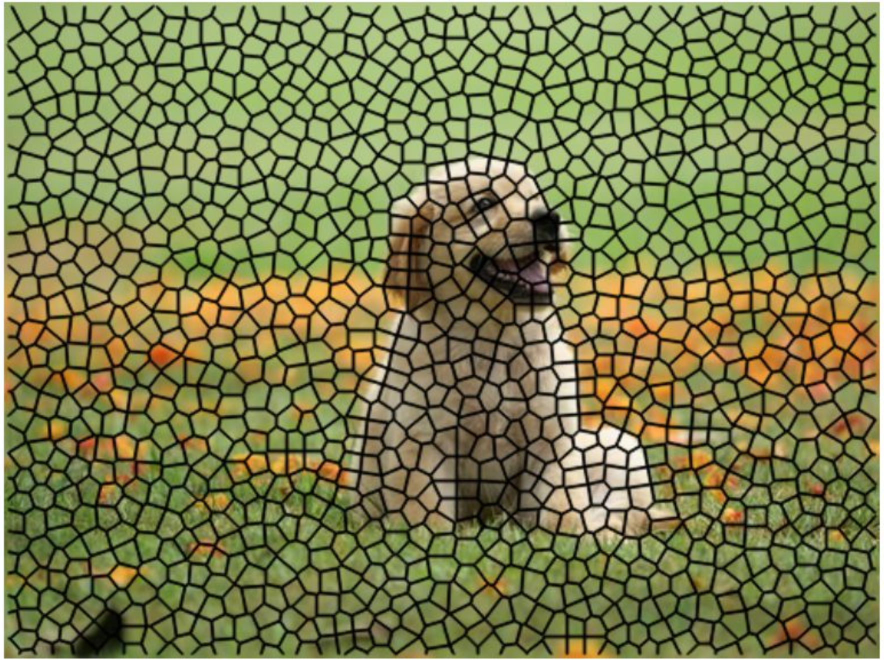
Ablation Study



(a) $\epsilon = 10$ (b) $\epsilon = 25$

An example that demonstrates how varying values of ε can impact a single input image

Ablation Study



(a) Low resolution: 500x375

(b) High resolution: 1999x1499

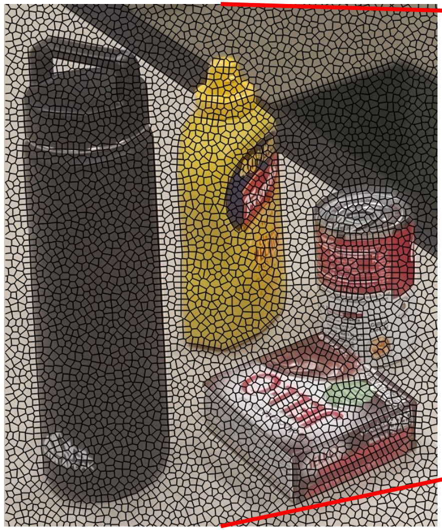
Effect of high and low resolution images of the same input image keeping ε constant. Here, ε=25.

Execution Statistics

Image	Execution time (seconds)	Image Resolution	Line segments processed	Seeds (start)	Seeds (end)	homogeneous Seeds
train/35010 (7c)	1.81	481x321	134	980	634	464
test/37073 (7e)	1.92	481x321	76	878	491	587
train/25098 (7j)	1.95	321x481	89	994	669	491
train/35008 (7b)	1.96	481x321	80	906	546	566
test/241004 (7a)	1.97	481x321	42	392	312	738
train/95006 (7h)	1.98	481x321	42	516	264	769
train/124084 (7i)	1.99	481x321	89	746	484	607
train/35058 (7d)	2.01	481x321	39	516	365	708
train/35070 (7f)	2.02	481x321	73	840	411	658
train/68077 (7g)	2.07	481x321	27	676	439	667
satellite (8)	50.56	1166x656	314	4570	2354	2993
dog.jpg (9)	842.37	1999x1499	278	2188	1730	17334

Longest run time of all samples

- Image Resolution: **2376x2695**
- ε=25
- Processed Line Segments = 545
- Seeds (start) = 11562
- Seeds (start) = 8622
- Homogeneous seeds = **33531**
- Run-Time: **75.06** **mins**



Visual Comparison with Original Work

Input | Original | Re-Implemented (ε=10)

The absence of the official code and the lack of information about the value of ε in the paper have posed a challenge in performing statistical comparisons of the results.

Visual Comparison with Original Work

Input

Original

Re-Implemented (ε=25)

The absence of the official code and the lack of information about the value of ε in the paper have posed a challenge in performing statistical comparisons of the results.

Implementation Details

- Language: C++
- Libraries
  - OpenCV
  - CGAL
  - Boost
- Dataset
  - The Berkeley Segmentation Dataset and Benchmark
- Paper
  - https://openaccess.thecvf.com/content_cvpr_2015/papers/Duan_Image_Partitioning_Into_2015_CVPR_paper.pdf

Questions?