Practical Morphological Anti-Aliasing on the GPU

SIGGRAPH 2010 Talk

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Geometrical antialiasing

- Without antialiasing
- Supersampling
- Multisampling [Akeley 93] and Coverage sampling [Nvidia]

Limitations

- Not trivial with deferred shading
- Memory consumption. Geometrical dependency

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Post processing antialiasing

MorphoLogical AntiAliasing (MLAA) [Reshetov, HPG 09]
Similar technique used in God of War III and Saboteur (PS3)

Limitations

- Full CPU implementation, low rendering time on 1024x768 image
- Costly data transfer between GPU & CPU

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Antialiasing as a post process

From that ...

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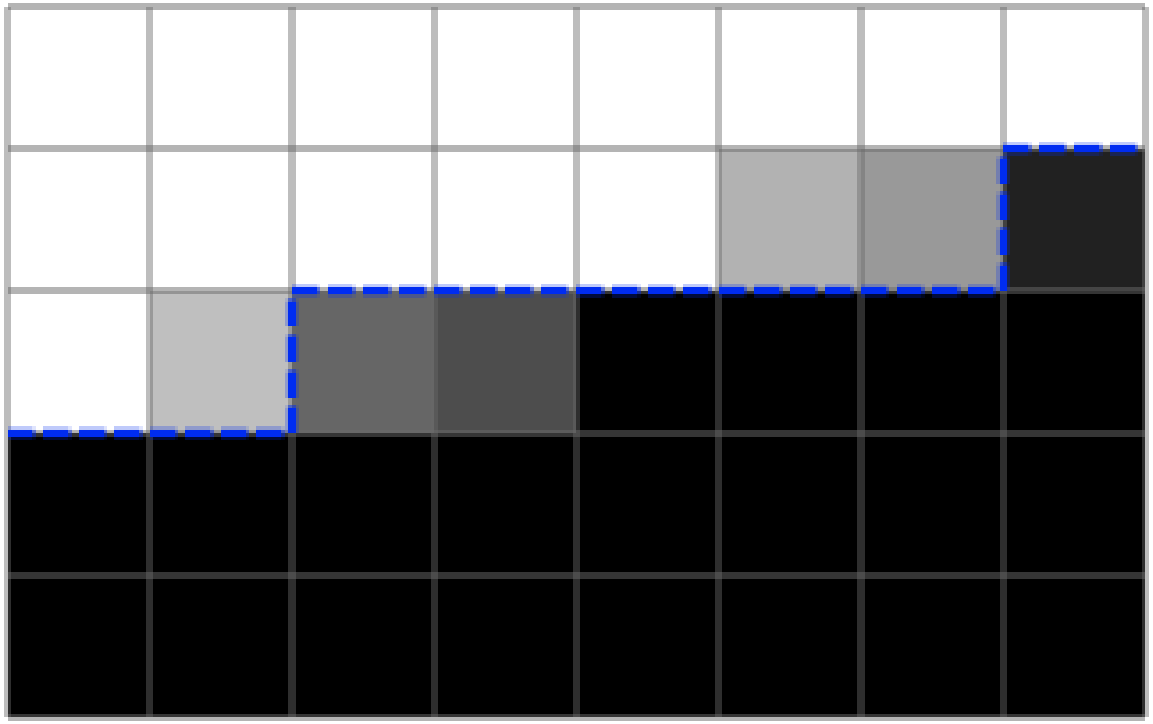
Antialiasing as a post process

... we want that



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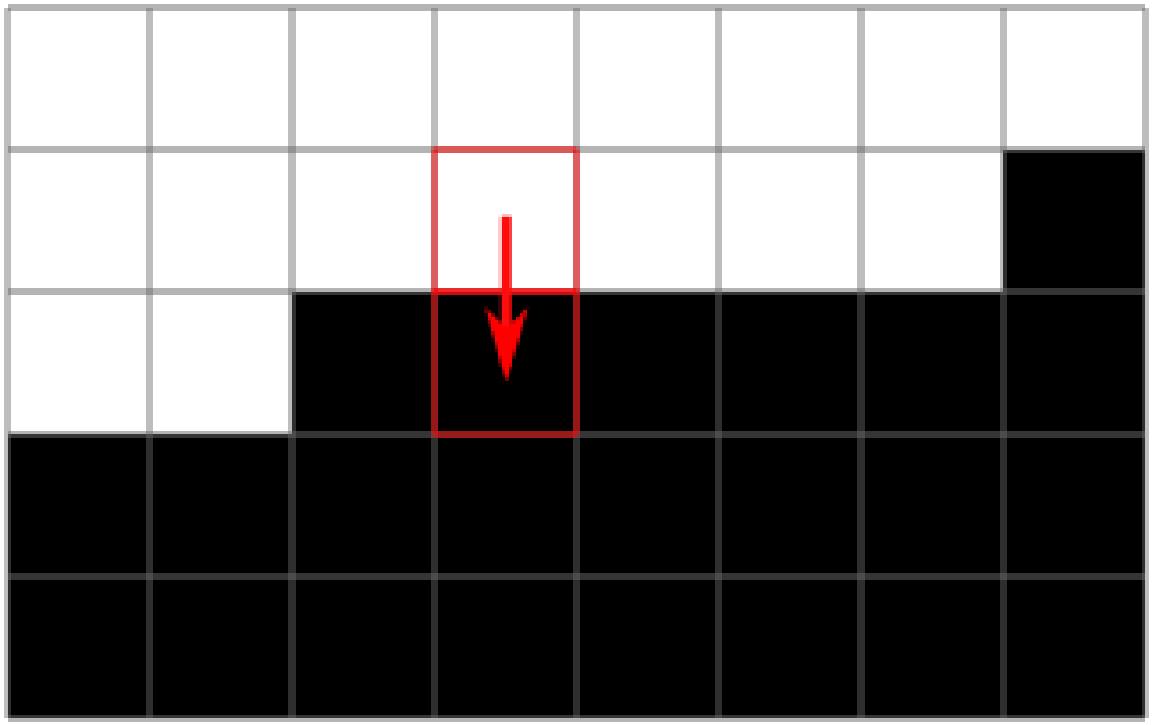
Antialiasing as a post process

Border pixels must blend with their neighbor ...



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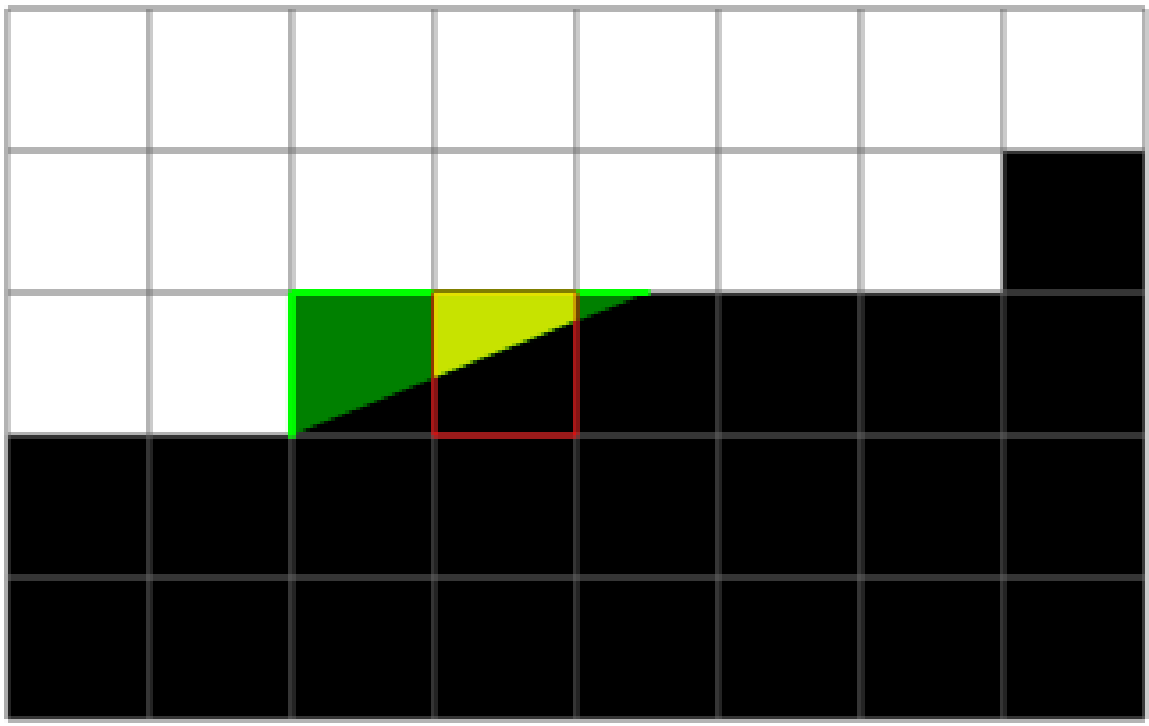
Antialiasing as a post process

... along ‘L’ shapes



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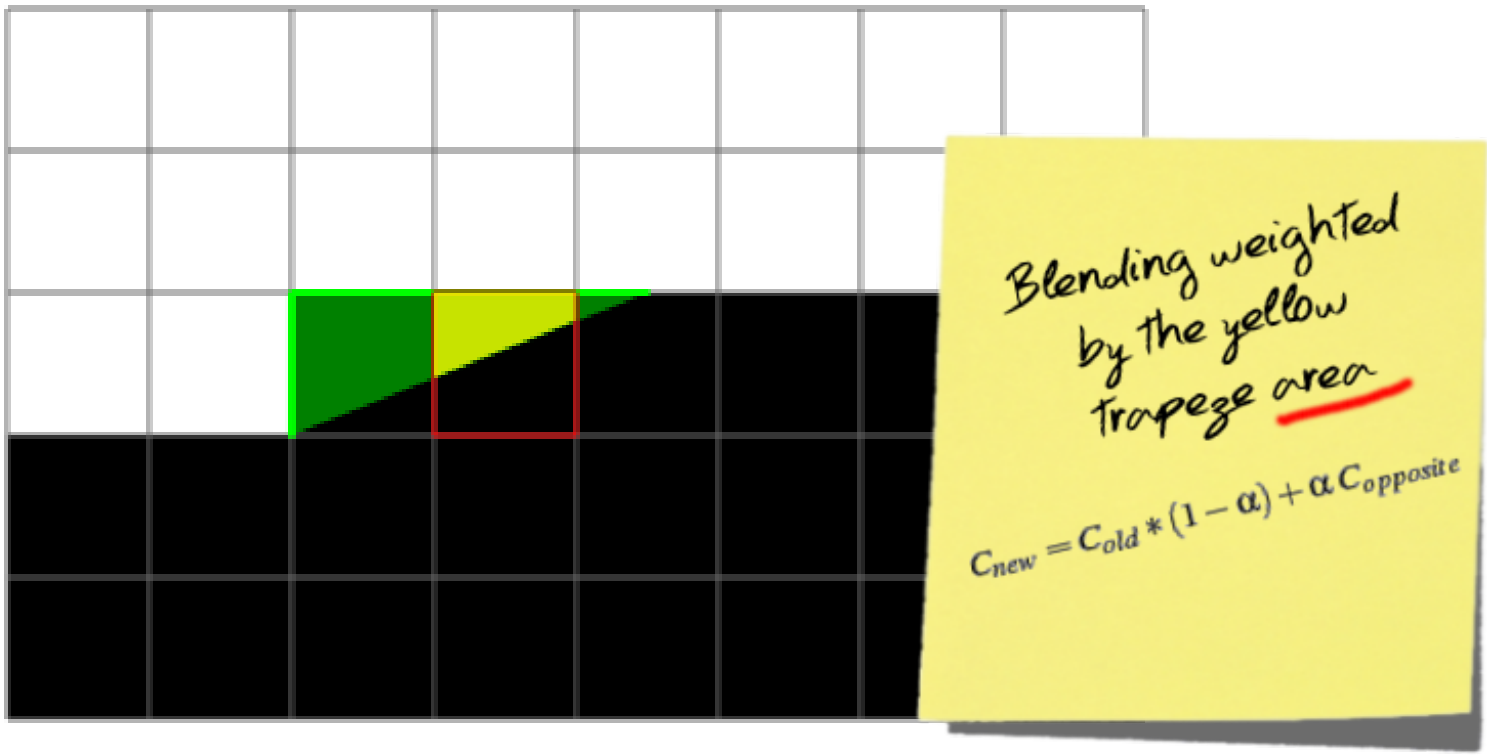

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Antialiasing as a post process

MLAA algorithm on the CPU

1. Detect antialiased lines :
   - Detect ‘L’,‘U’ and ’Z’ shapes
   - ‘U’ or ’Z’ are split into two ‘L’
2. Blend color along the ‘L’ shapes
   - Blend pixels inside the ‘L’ shape with their opposite neighbor
   - Weighted by the trapeze area

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GPU Implementation

Implementation on GPU issues

- Non linear image processing involves deep branching
- Algorithm requires sparse memory access
- GPU is limited to pixel-wise operation

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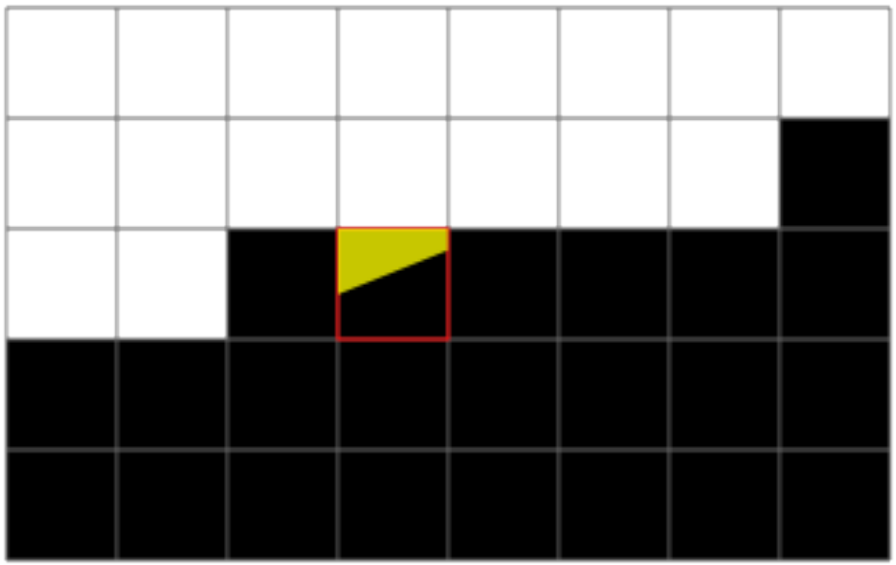

To blend the red pixel, we need to compute the yellow area

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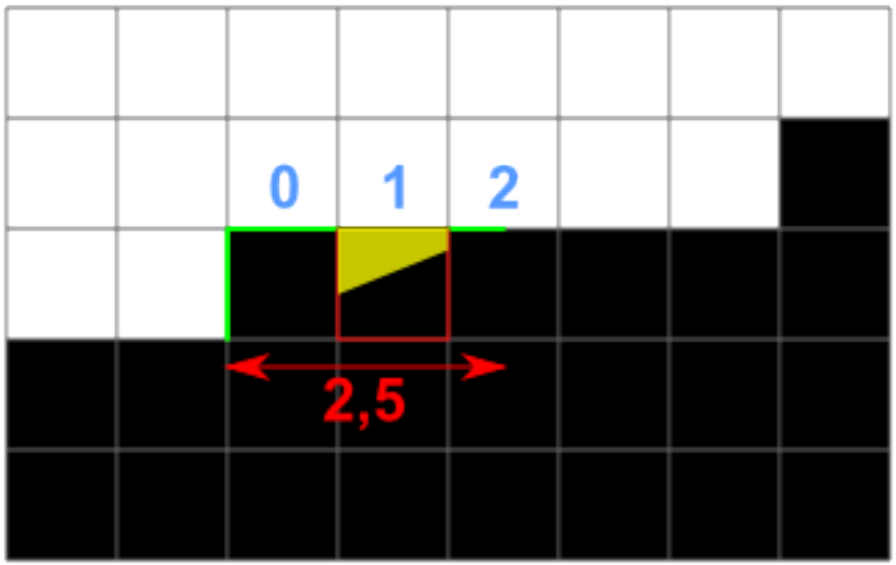
GPU Implementation



This can be obtained using the pixel's relative position p related to the L shape and its length $L/2$

$$\alpha = \left(1 + \frac{\frac{L}{2} - p - 1}{\frac{L}{2}}\right) / 4.0$$

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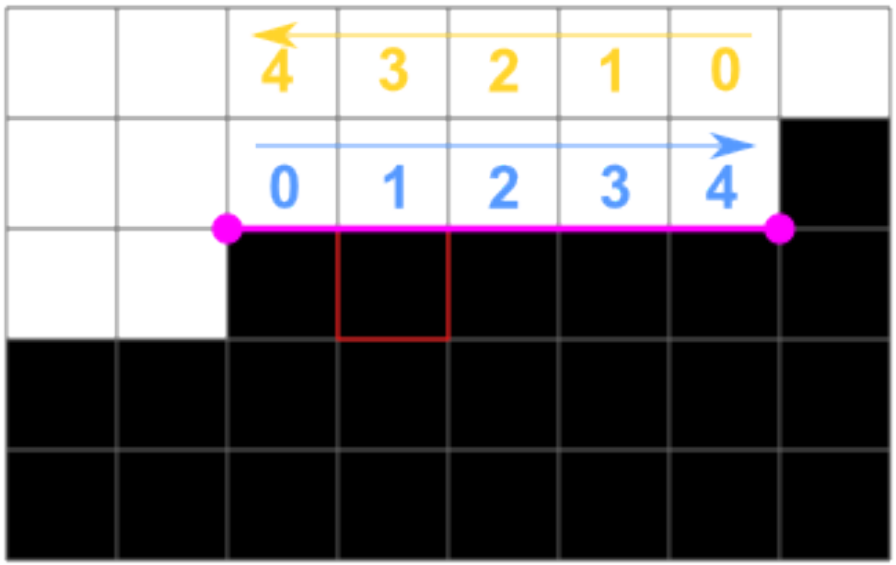
GPU Implementation



The red pixel position is the minimum of the distance to the two discontinuity line extremities

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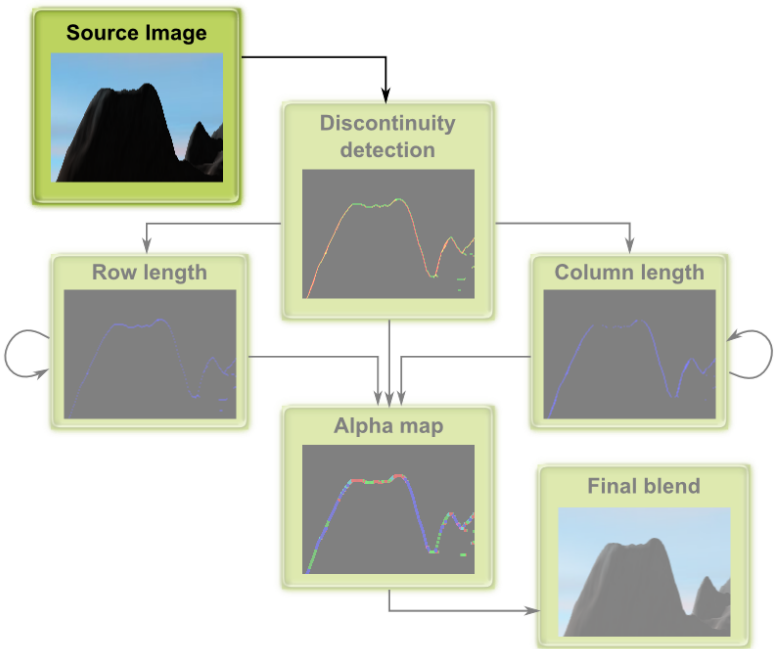
Algorithm overview



1. Detect discontinuity lines
2. Compute the positions
   - On rows and columns
   - Related to the two extremities
   - Using the “recursive doubling” algorithm
3. Compute the trapeze area for each pixel
4. Final blending

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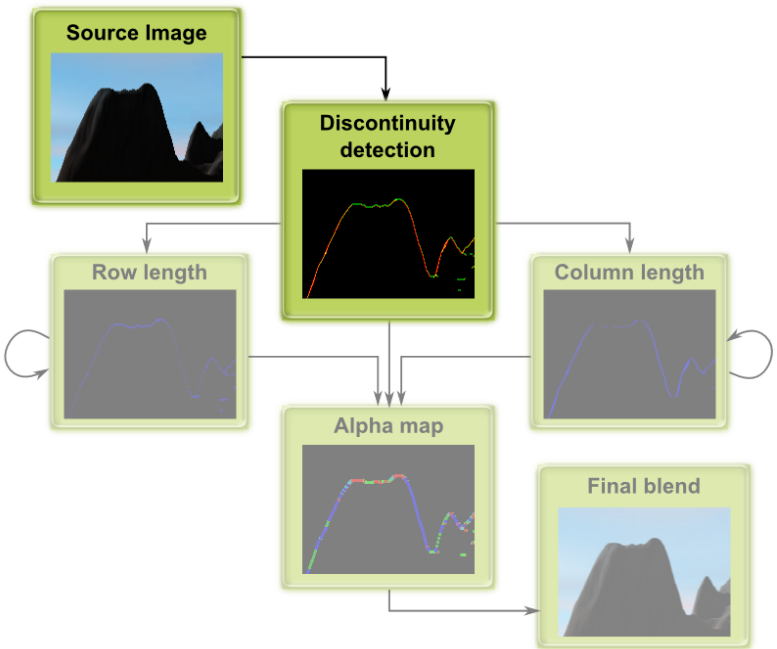

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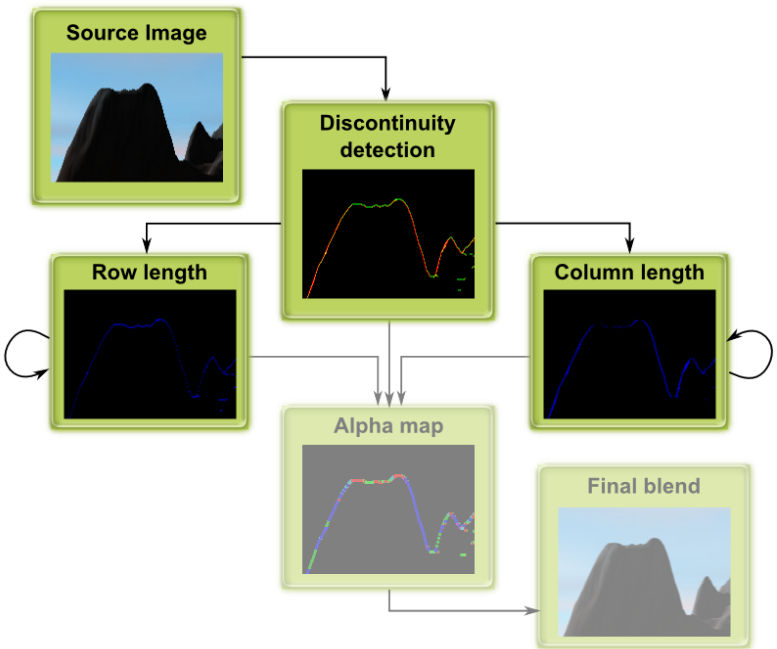

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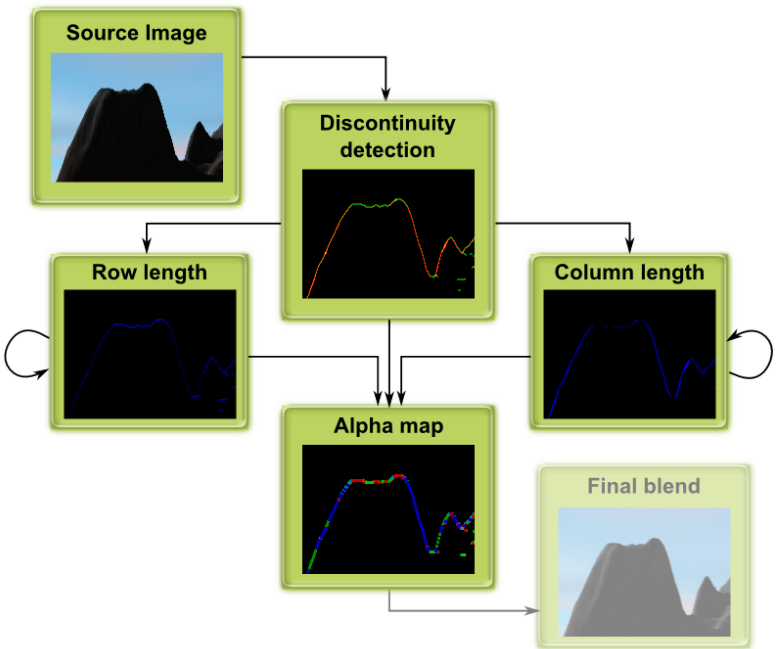

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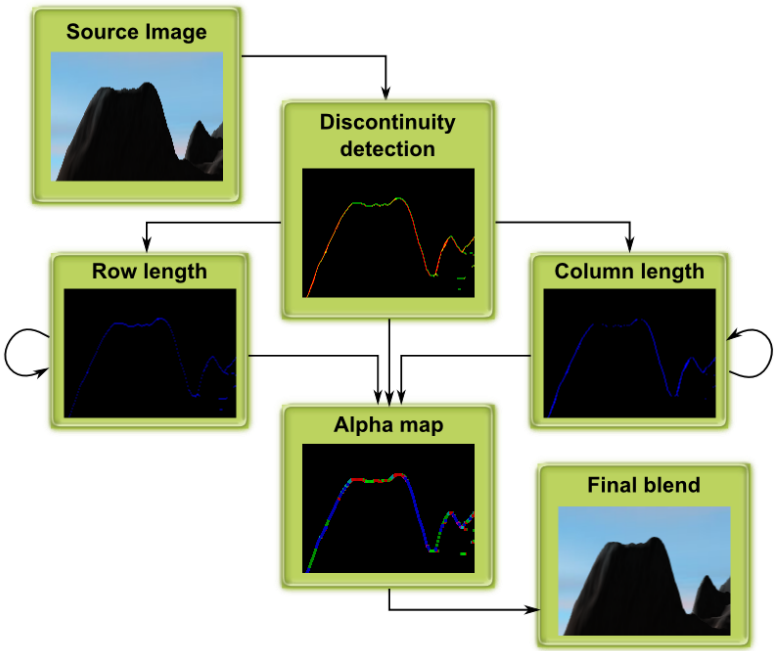

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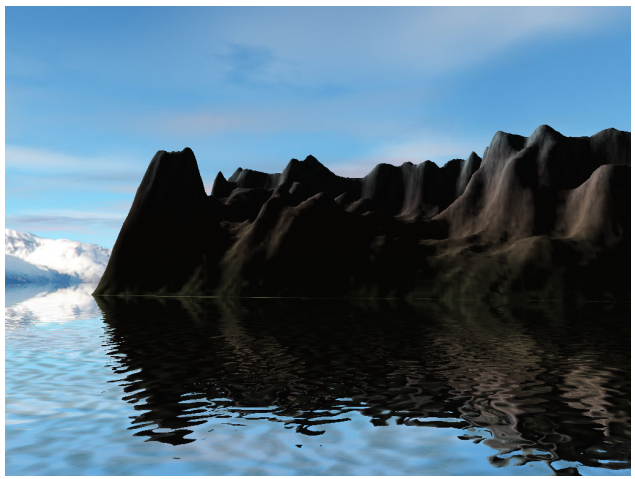
Computation of discontinuity lines

1 - Detect discontinuities of color

- Using a simple distance on $L^*a^*b^*$ color space
- Result stored in a texture



channel R : discontinuity in pixel bottom

channel G : discontinuity in pixel right

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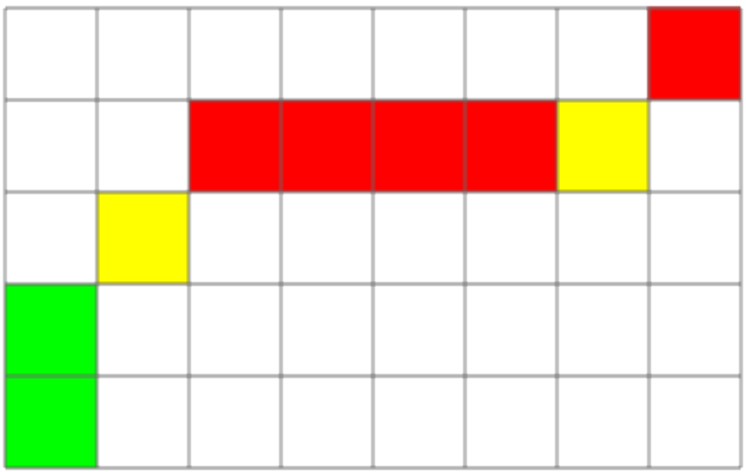

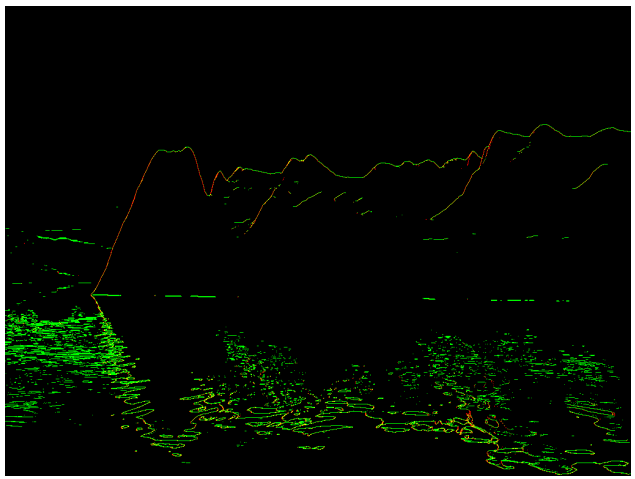

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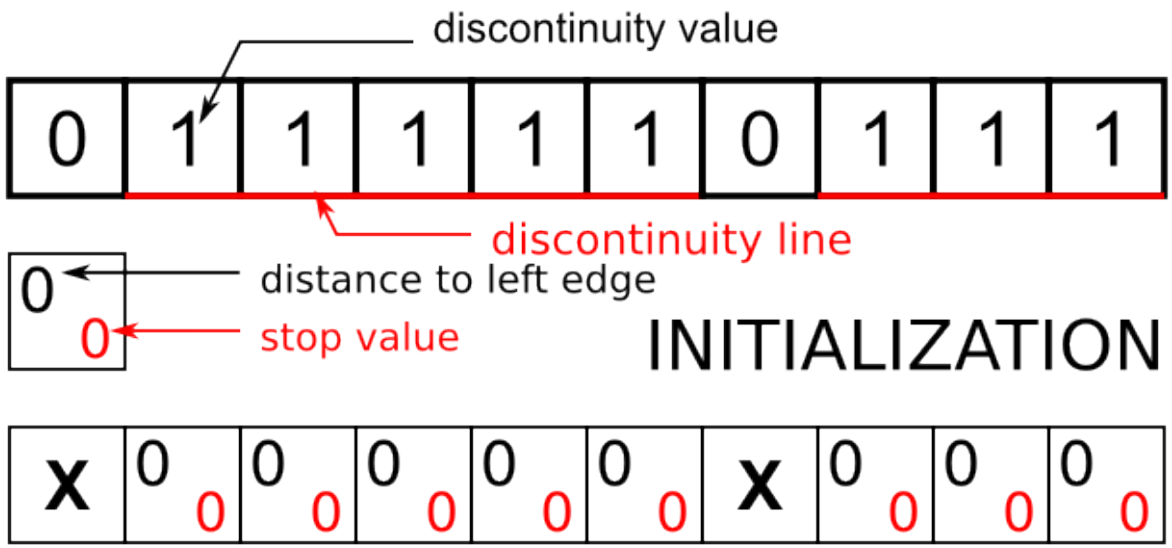
Line length computation

2 - Computation of line length and relative position

On rows and columns and in both directions, using a ‘recursive doubling’ technique.



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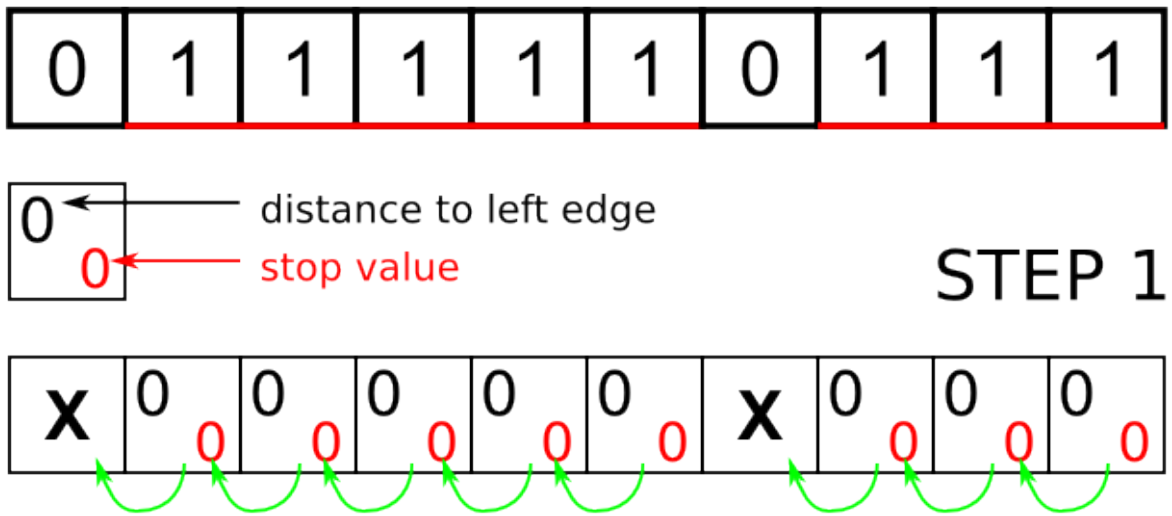

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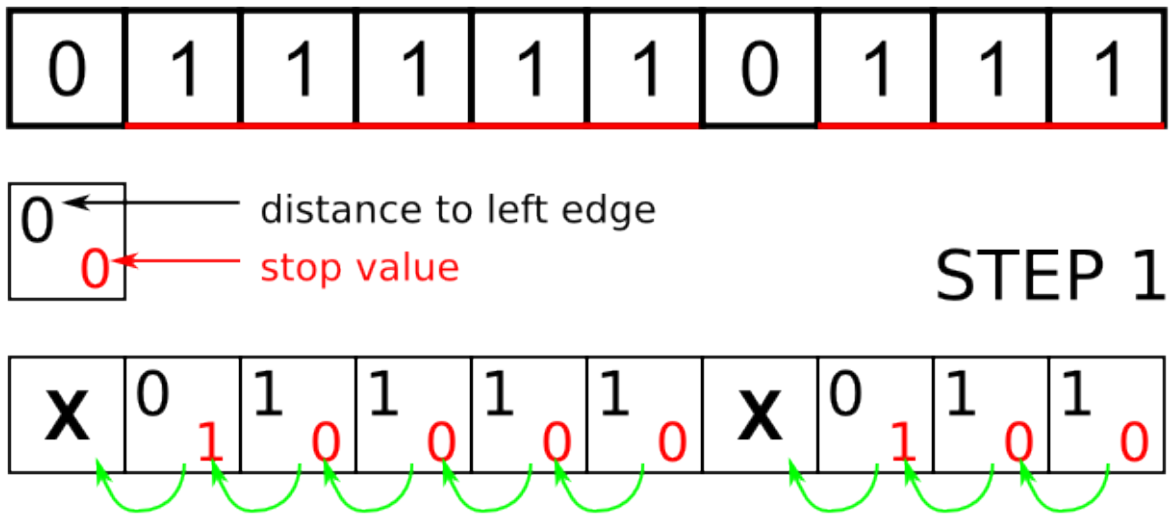

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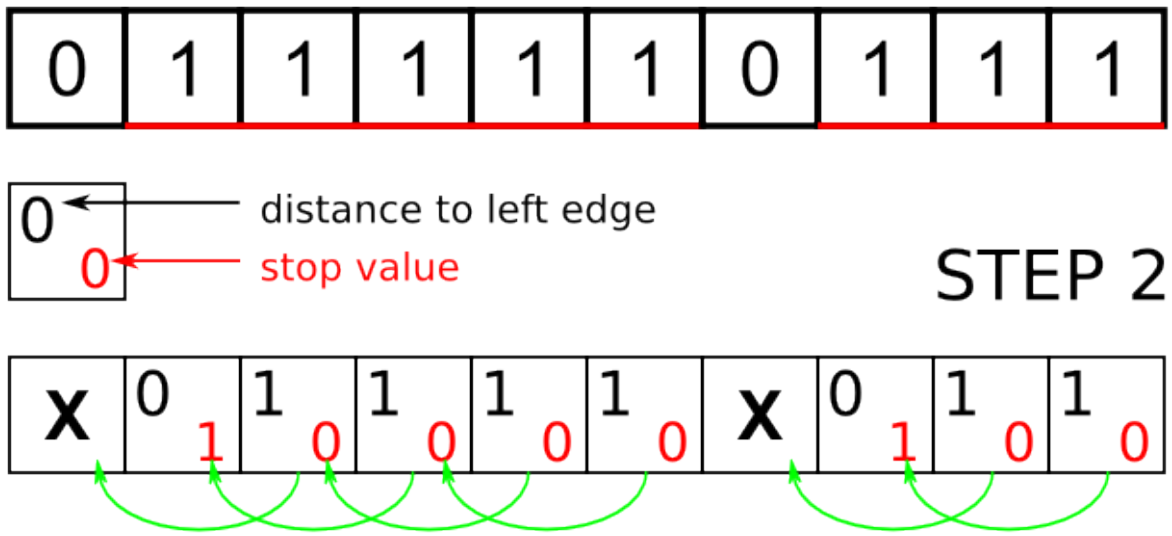

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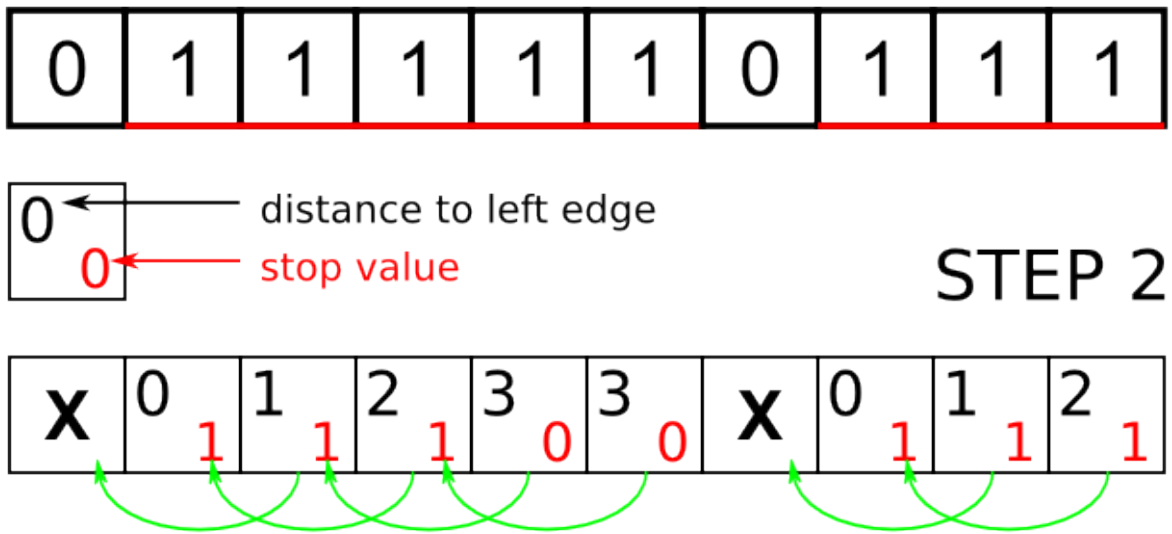

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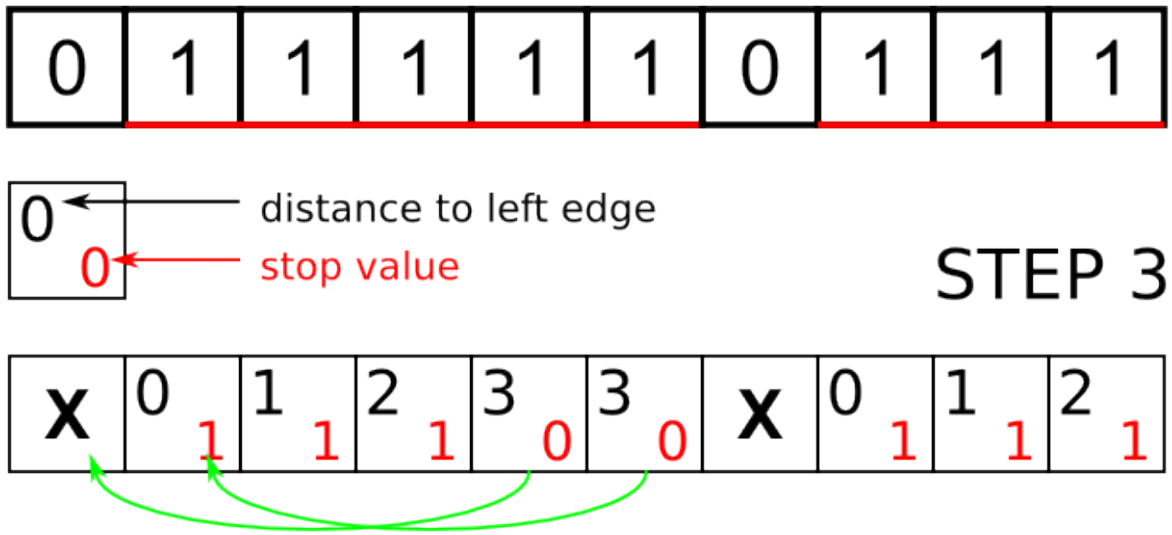

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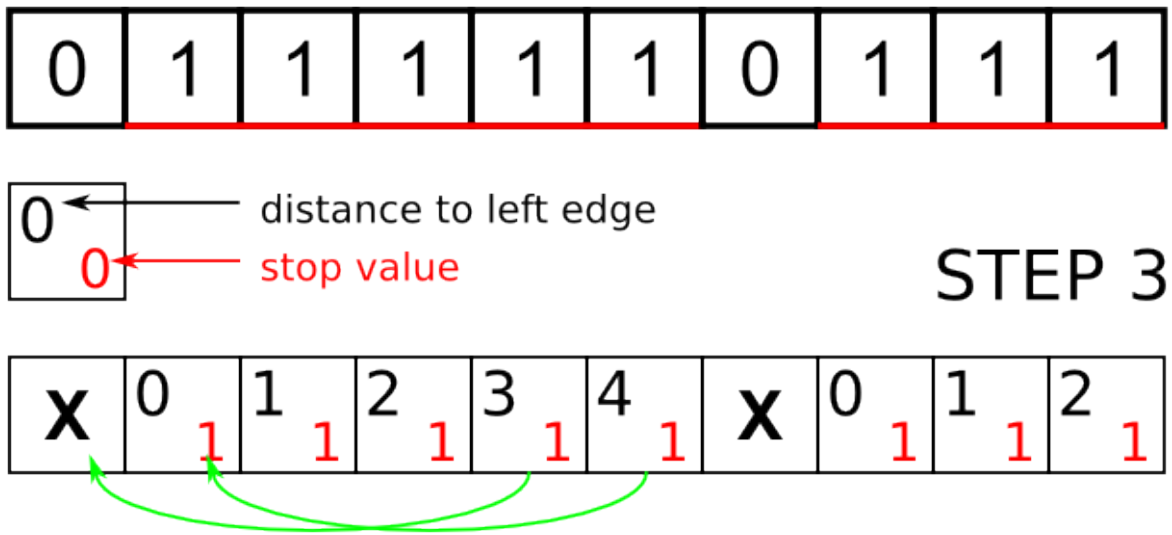

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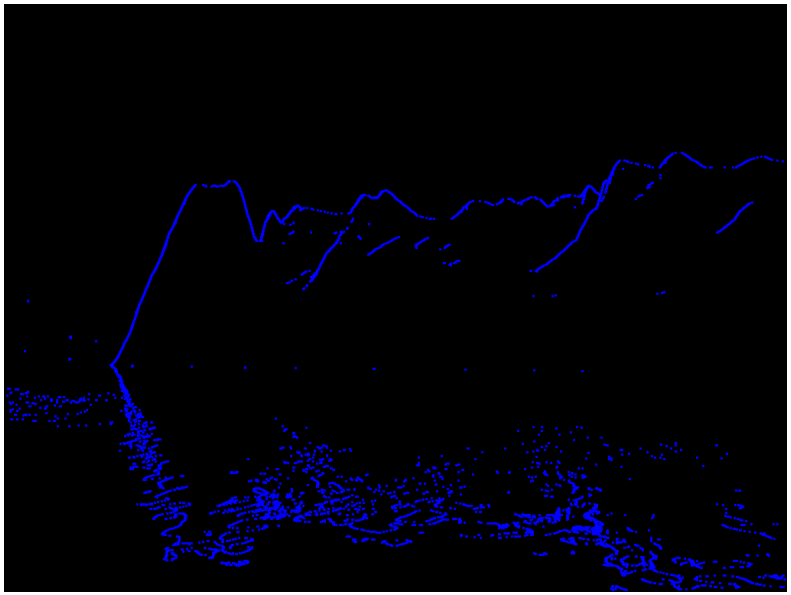
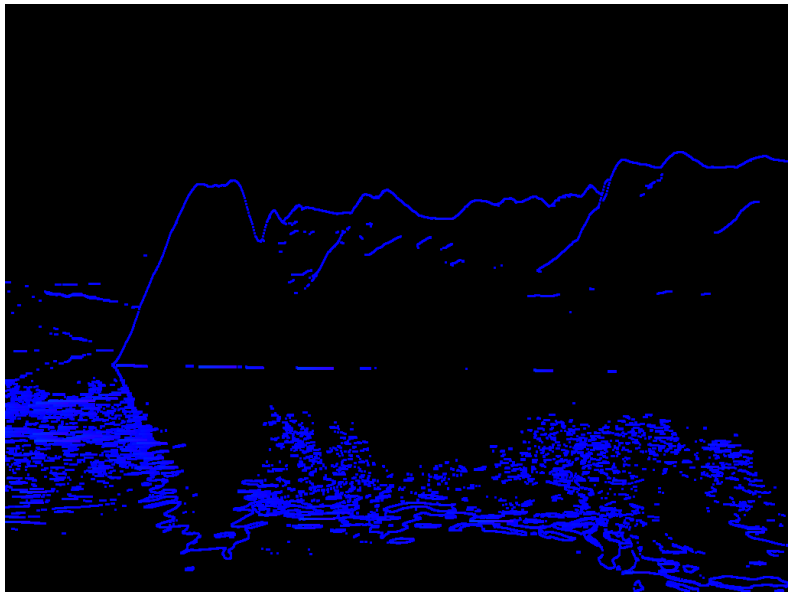
Line length computation

2 - Computation of line length and relative position

Number of iteration for row = $log_2(width)$. Number of iteration for columns = log_2(height) Results are stored in textures (one for the rows, one for the columns)





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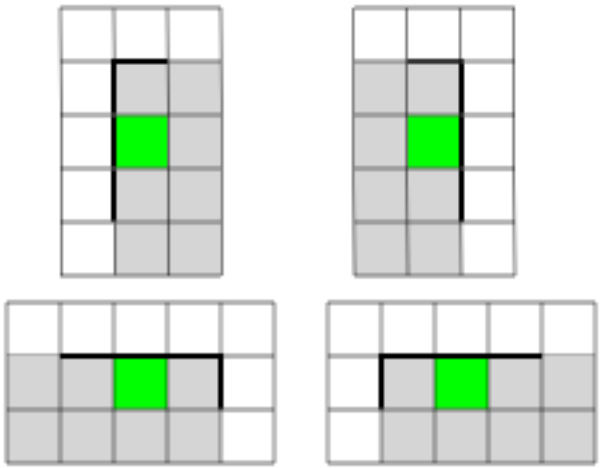
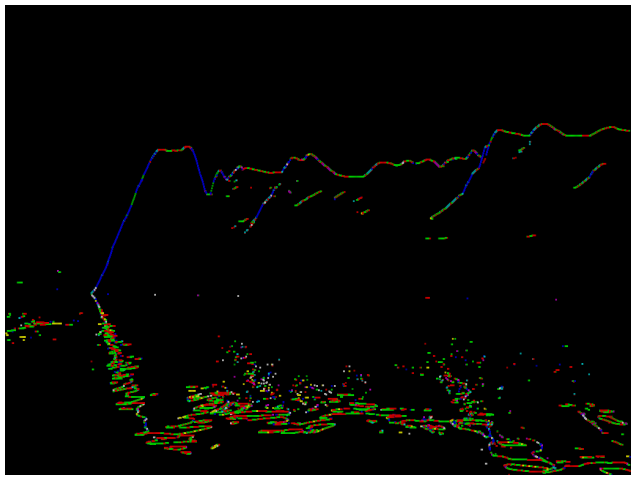
Blending map

3 - Computing the blending factors

- Select L shape type of each pixel (if any)
- For each remaining pixel, compute the trapeze area
- Results stored in an blending map, in each direction

8 cases





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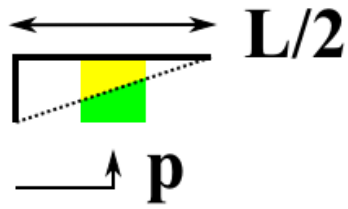
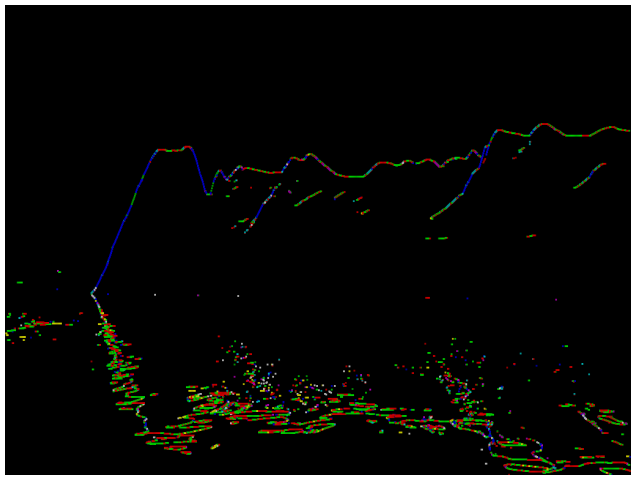


$$\alpha = \left(1 + \frac{\frac{L}{2} - p - 1}{\frac{L}{2}}\right) / 4.0$$



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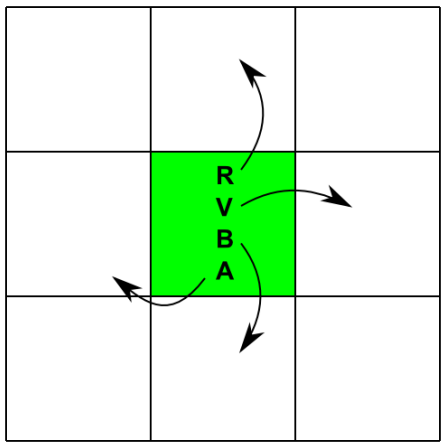

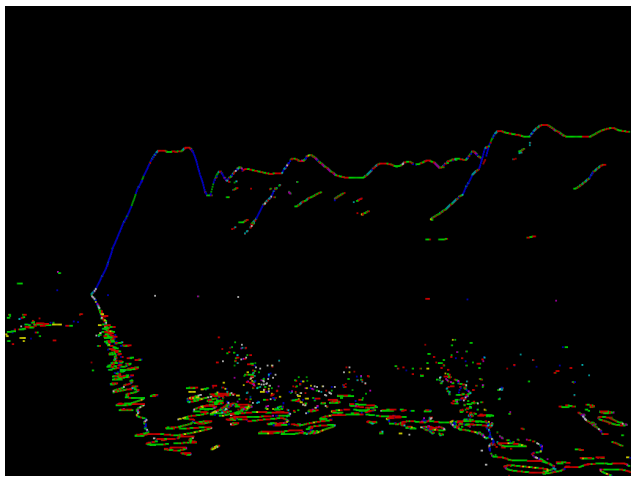

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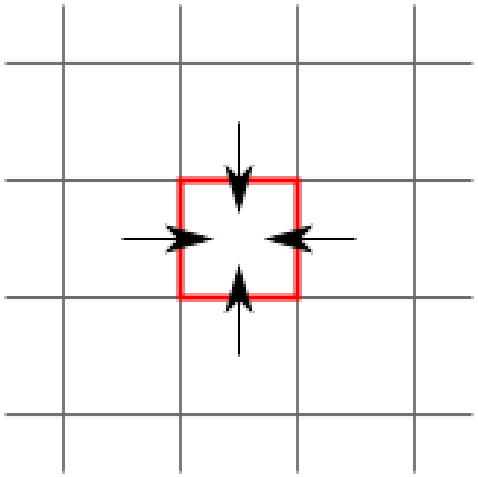
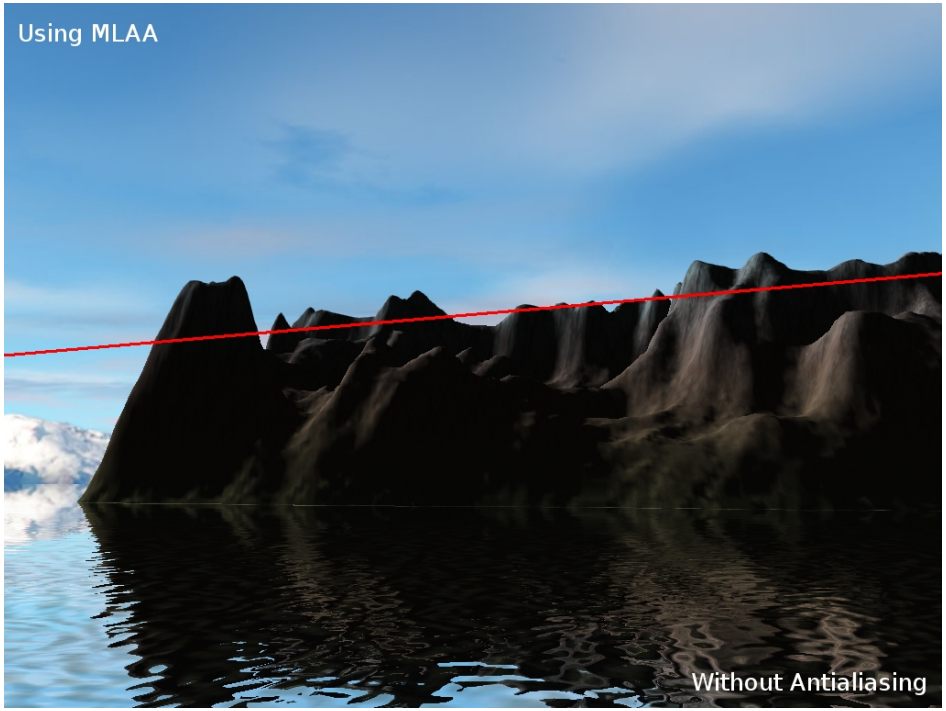
Final rendering

4 - Final blending

- We blend each pixel with its 4 neighbors
- Using previously computed blending map





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Computation times

Image size	1248x1024	1600x1200
MLAA CPU	67ms	128ms
MLAA GPU	3.49ms	5.54ms

TAB.: Algorithm cost (in ms) using a GeForce 295 GTX and a Core2Duo 2.20GHz

Step	1	2	3	4
Percent	16	64	13	7

TAB.: Detail of each step cost in the algorithm

Used with ...

... many effects like motion blur, bloom, cartoon shading, shadow mapping or parallax mapping.

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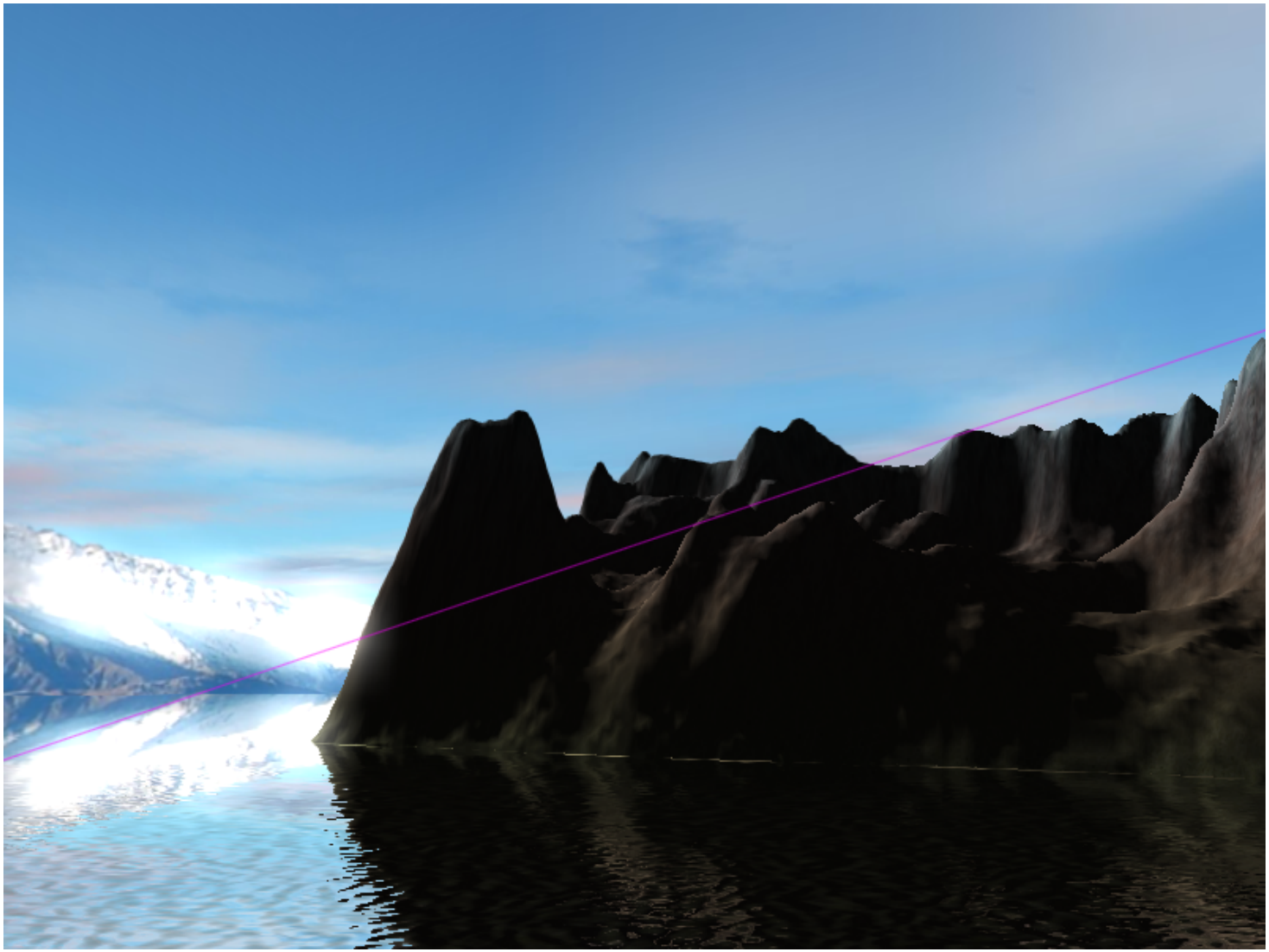
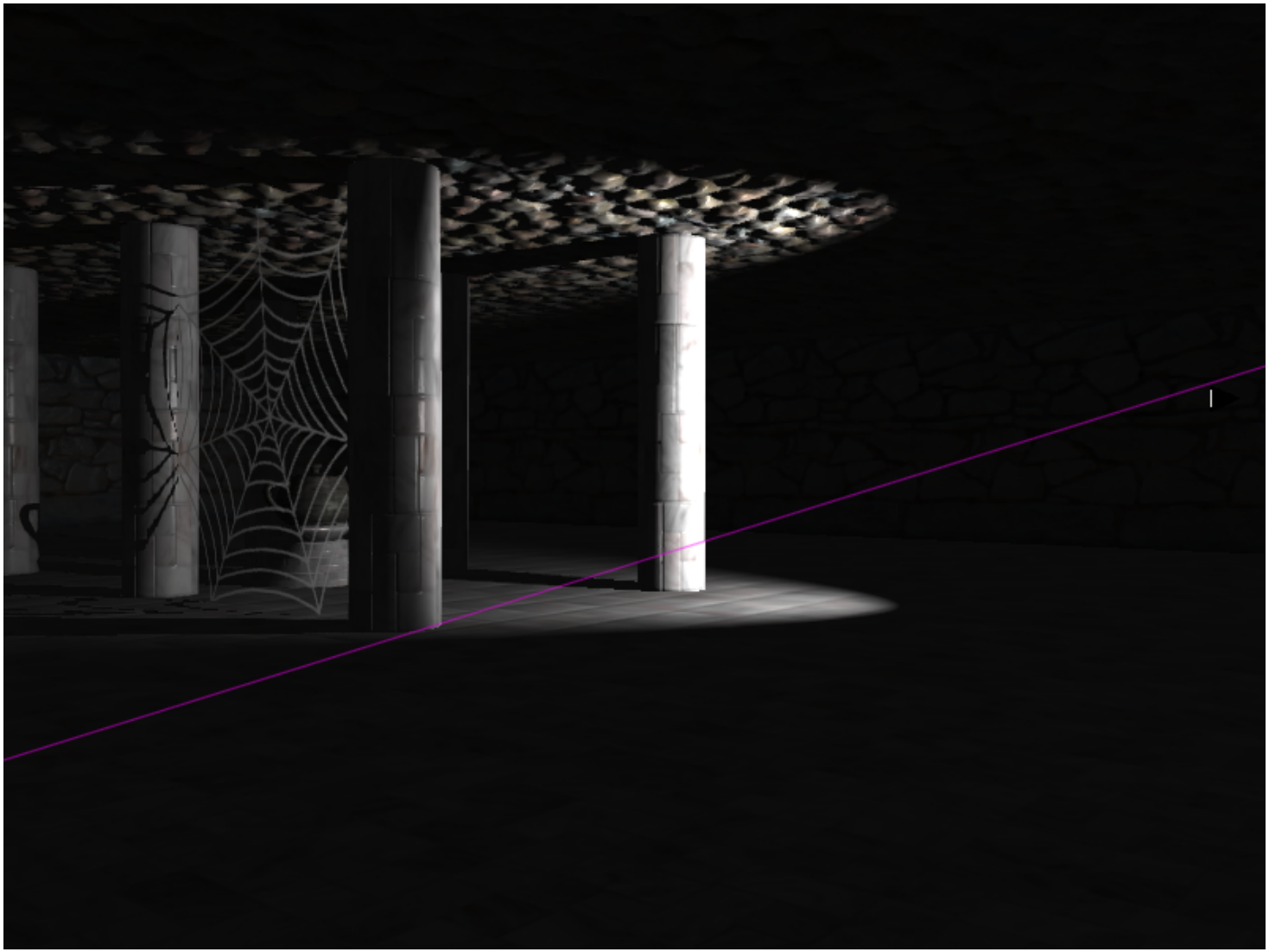
Result on bloom



Result on bloom

Result on shadow mapping



Result on shadow mapping

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Result on per pixel toonshading

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Result on per pixel toonshading

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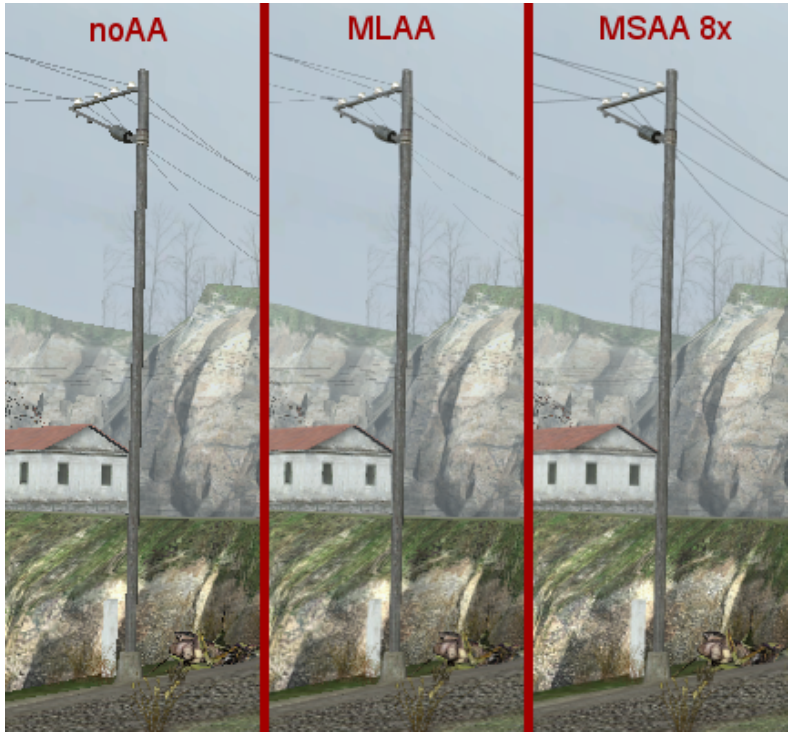
Comparison



SIGGRAPH2010

Comparison

Conclusion

Overview

- Antialiasing as a post process
- Implemented fully on the GPU, rendering engine friendly
- A new line length computation algorithm
- around 4ms overhead with a high performance graphic card

Discussion & Future works

- No subpixel antialiasing available
- Packing and profiling
- Other topological configuration than the L ?

Conclusion

Thanks

Duran Duboi R&D Team, Baptiste Malaga, Franck Letellier, Vincent Nozick, Nadine Domanget

Code available

in http ://igm.univ-mlv.fr/˜biri/mlaa-gpu/

Questions ?

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