

# LINEAR OPENINGS IN ARBITRARY ORIENTATION IN O(1) PER PIXEL

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## Introduction

**Openings** constitute one of the fundamental operators in mathematical morphology. They can be applied to a wide range of applications, including noise reduction and feature extraction and enhancement.

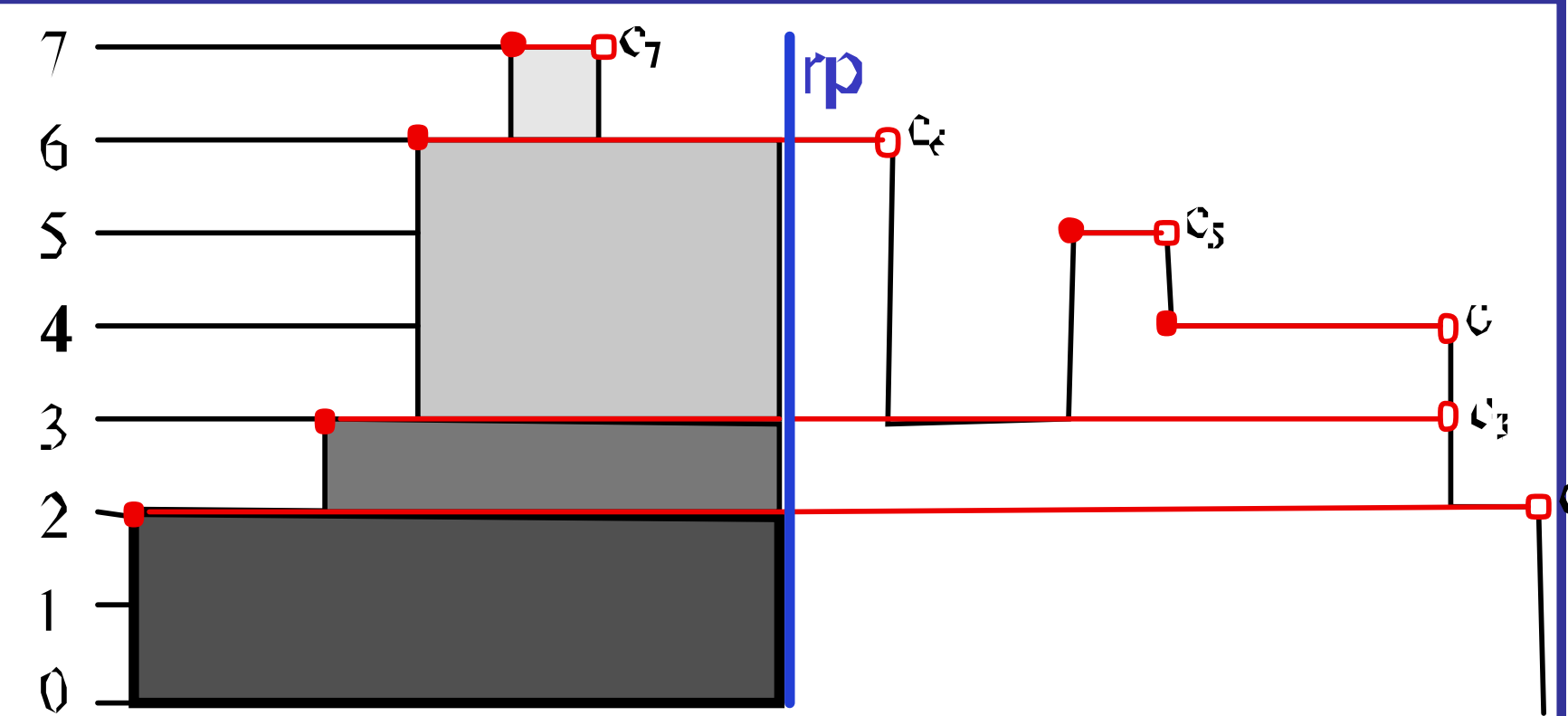
We introduce a new **efficient, adaptable** algorithm to compute one dimensional openings **along discrete lines**, in arbitrary orientation.

The complexity of this algorithm is **linear** with respect to the number of pixels of the image.

## Algorithm

➤ Raster scan

➤ The 1D signal is decomposed into **cords** :

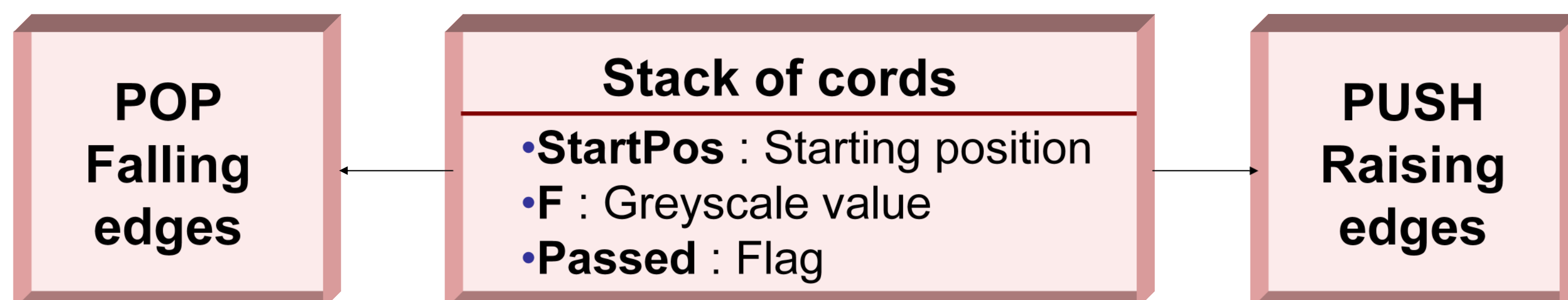


The final length of a cord is known only when the reading position reaches its end

A cord has to be processed when the reading position reaches its end.

Store the pending cords until they are processed

*With the inclusion relation between cords*

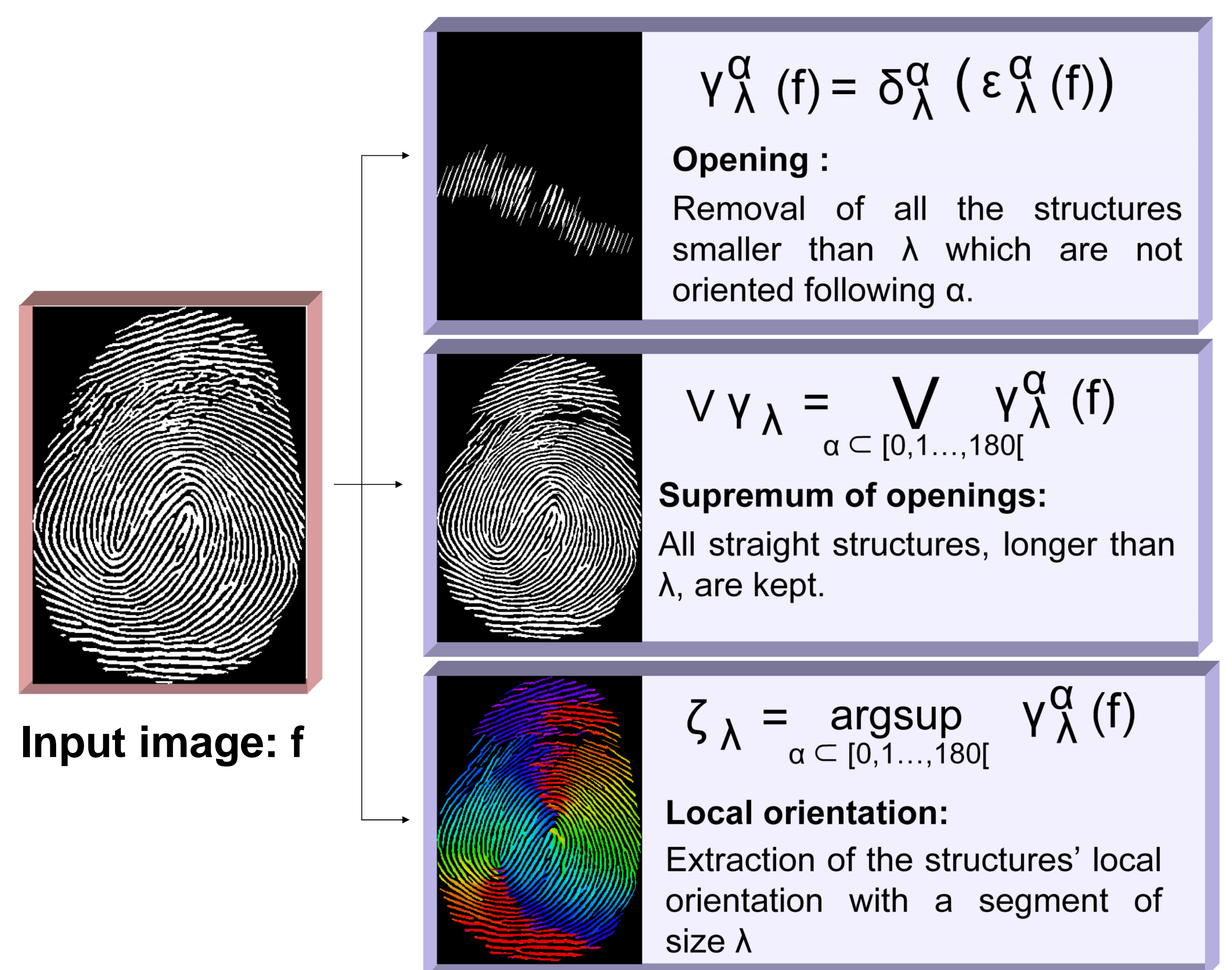


### Algorithm 1: Process\_a\_pixel(F, rp, Stack, Out)

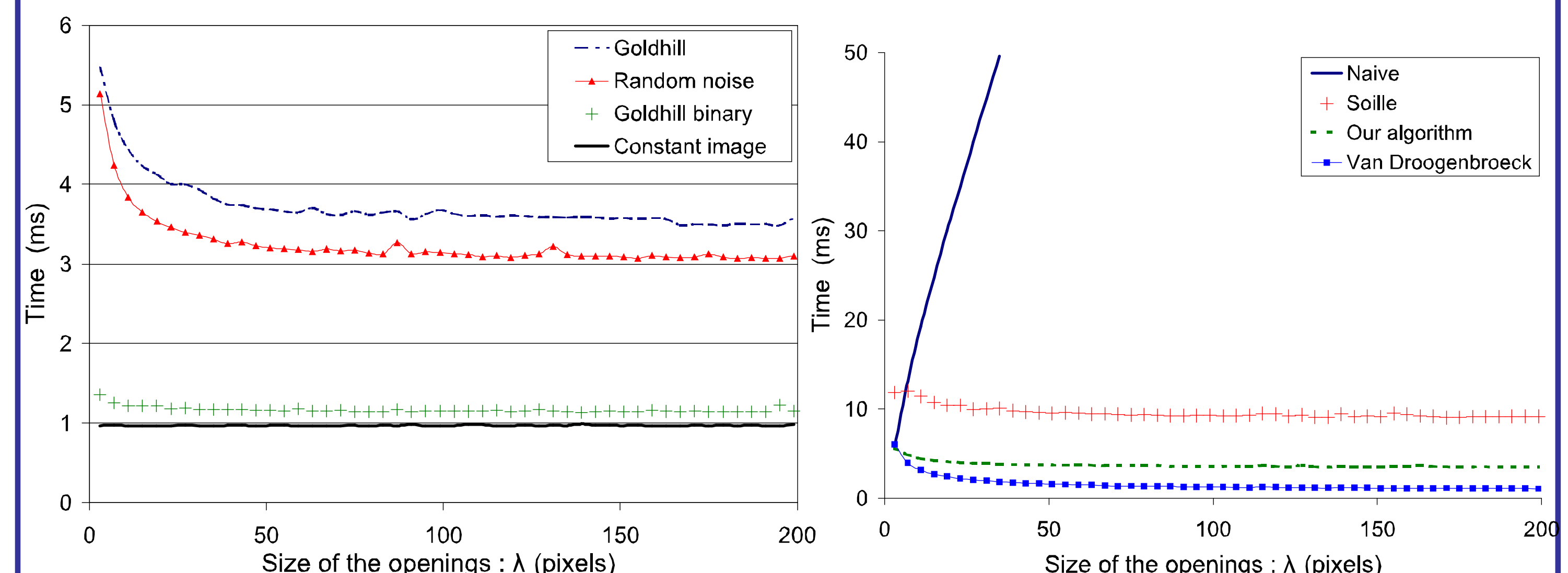
```

1: if Stack.empty() or F > Stack.top().F then
2:   Stack.push(F, rp, false)
3: else
4:   While F < Stack.top().F do
5:     cordOut = Stack.pop()
6:     if cordOut.Passed or rp-cordOut.StartPos then
7:       WriteCords(F, rp, Stack, Out, cordOut)
8:       Stack.push(F, rp, true)
9:       break
10:    else if Stack.empty() or F > Stack.top().F then
11:      Stack.push(F, cordOut.StartPos, false)
12:      break
13:    end if
14:  end while
15: end if
    
```

## Results



## Benchmarks



**On the image content**  
(Different images 512x512px)

**On existing methods**  
On Goldhill image ([1],[2],[3],[4])

## Conclusion & Perspectives

This is a **constant time** algorithm with respect to the size of the opening. It can be applied on **floating-point** data without additional computational time, as we only perform comparison operations with no histogram, which is not possible with Van Droogenbroeck's algorithm.

With some small modifications on this adaptable algorithm, we can obtain **granulometries** and the **component tree** of a signal.

This algorithm can also be extended to **paths** and we developed an approximation of the path openings defined by H. Heijmans, M.J.Buckley and H.Talbot. This approximation is several time faster than path opening with a good accuracy.

## Références

- [1] M. Van Herk, A fast algorithm for local minimum and maximum filters on rectangular and octagonal kernels, Pattern Recognition Letters, vol. 13, no. 7, pp. 517–521,(1992).
- [2] J. Gil, M. Werman, Computing 2-D Min, Median, and Max Filters, IEEE Trans. Pattern Analysis and Machine Intelligence, vol. 15, no. 5, pp. 504-507, May 1993.
- [3] P. Soille, E.J. Breen, and R. Jones, Recursive implementation of erosions and dilations along discrete lines at arbitrary angles,” IEEE Transactions on Pattern Analysis and Machine Intelligence, vol. 18, no. 5, pp. 562–567, 1996.
- [4] M. Van Droogenbroeck and MJ Buckley, Morphological erosions and openings: fast algorithms based on anchors, Journal of Mathematical Imaging and Vision, vol. 22, no. 2, pp. 121–142, 2005