Semantic annotation of urban scenes: Skyline and window detection

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Experiment

Experiment

Did you see?

- building

Did you see?

- building
- tree

Did you see?

- building
- tree
- bicycle

Did you see?

- building
- tree
- bicycle
- street light

Did you see?

- building
- tree
- bicycle
- street light
- blue car

Did you see?

- building
- tree
- bicycle
- street light
- blue car
- red car

Did you see?

- building
- tree
- bicycle
- street light
- blue car
- red car
- brand of the car?

Experiment

Q

- Why are we so good at depth recognition/object detection?

Q

- Why are we so good at depth recognition/object detection?
- How can we apply this to a computer system?

Q

- Why are we so good at depth recognition/object detection?
- How can we apply this to a computer system?
  - *Computer Vision*

Outline

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What is my research about?

- Semantic annotation of urban scenes

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- Describe the scene on a higher level

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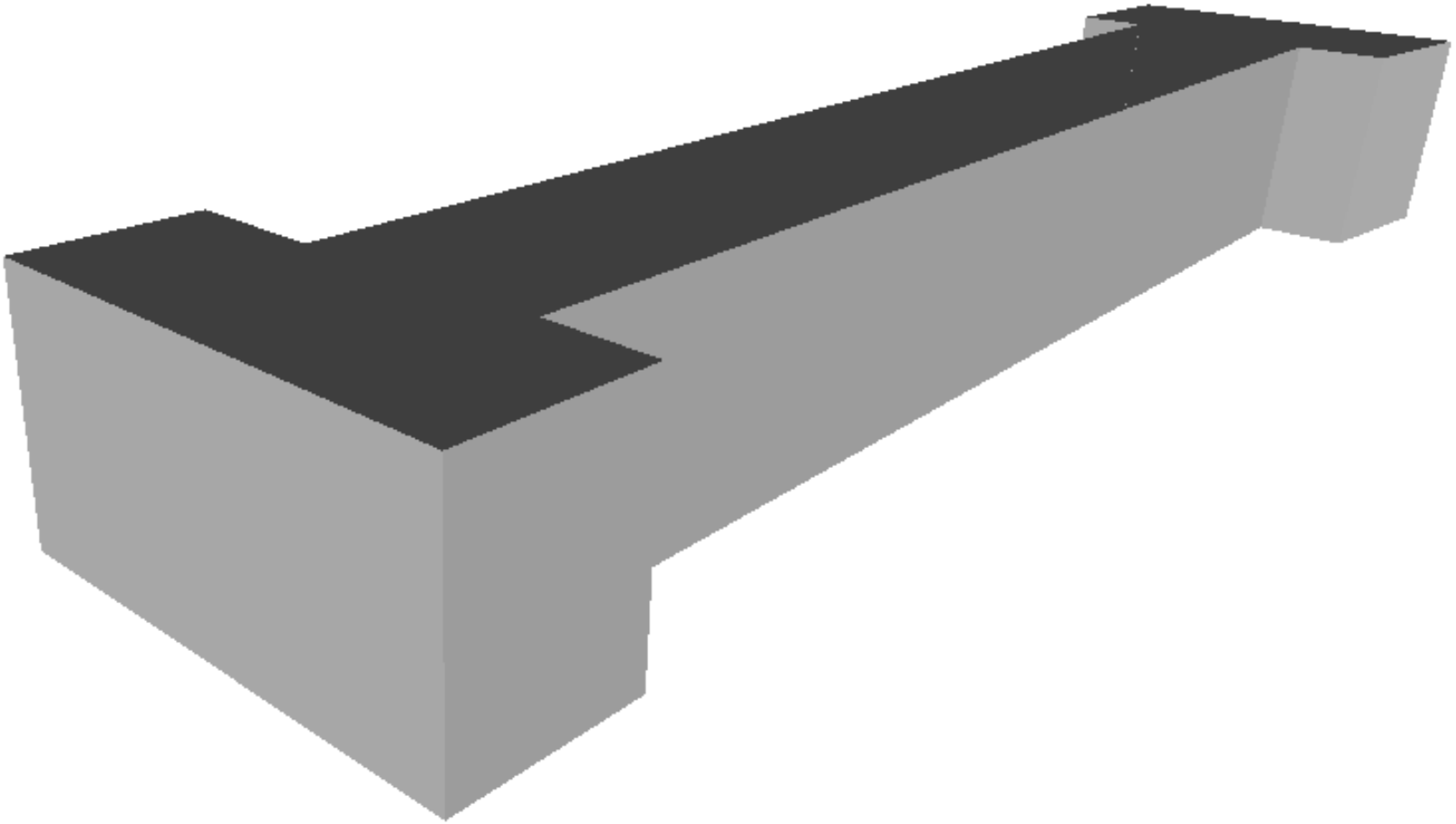

Where is my research about?

- Semantic annotation of urban scenes
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- Based on 2D input images of different views
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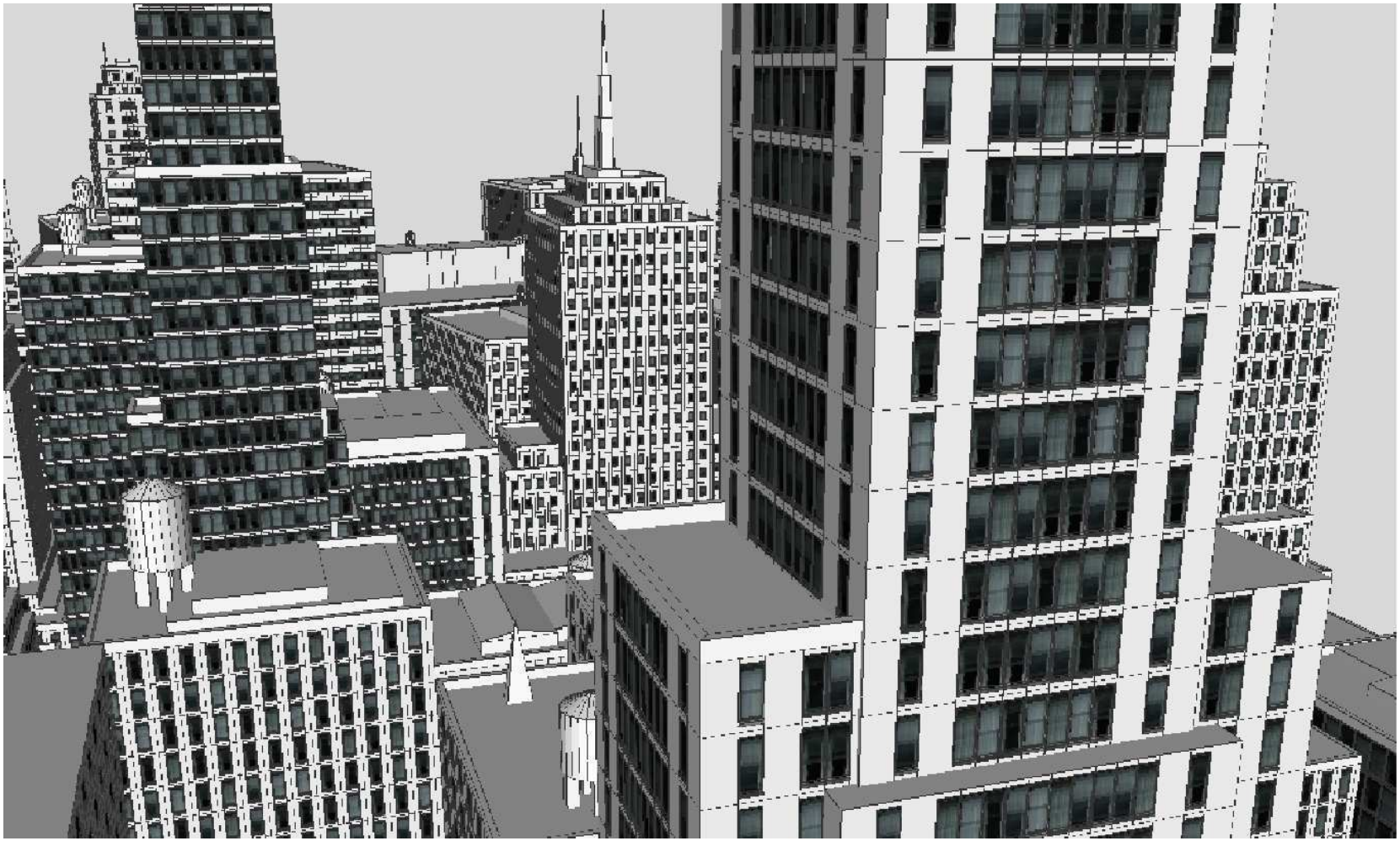
  - 3D building reconstruction
  - Window detection

Application examples of semantic annotation of urban scenes

- 3D city models



Application examples of annotation of urban scenes

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- Driving simulation

Application examples of annotation of urban scenes

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Application examples of annotation of urban scenes

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- Augmented reality


vodafone
funda
Funda: Zoek woningen
1.3
10km
Prins Hendrikkade
80/K
EUR 349000 K.K.,
Woonopervlak: 165 m2
Afstand: 1323m
Makelaarskantoor Babs Persoons B.V.
menu


DEM DEUTSCHEN VOLKE

Application examples of annotation of urban scenes

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- Building recognition
- Augmented reality
- Analysis building deformation

Application examples of annotation of urban scenes

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  - 'noord-zuidlijn'

Outline

Skyline detection application example

- Horizon detection for Unmanned Air Vehicles

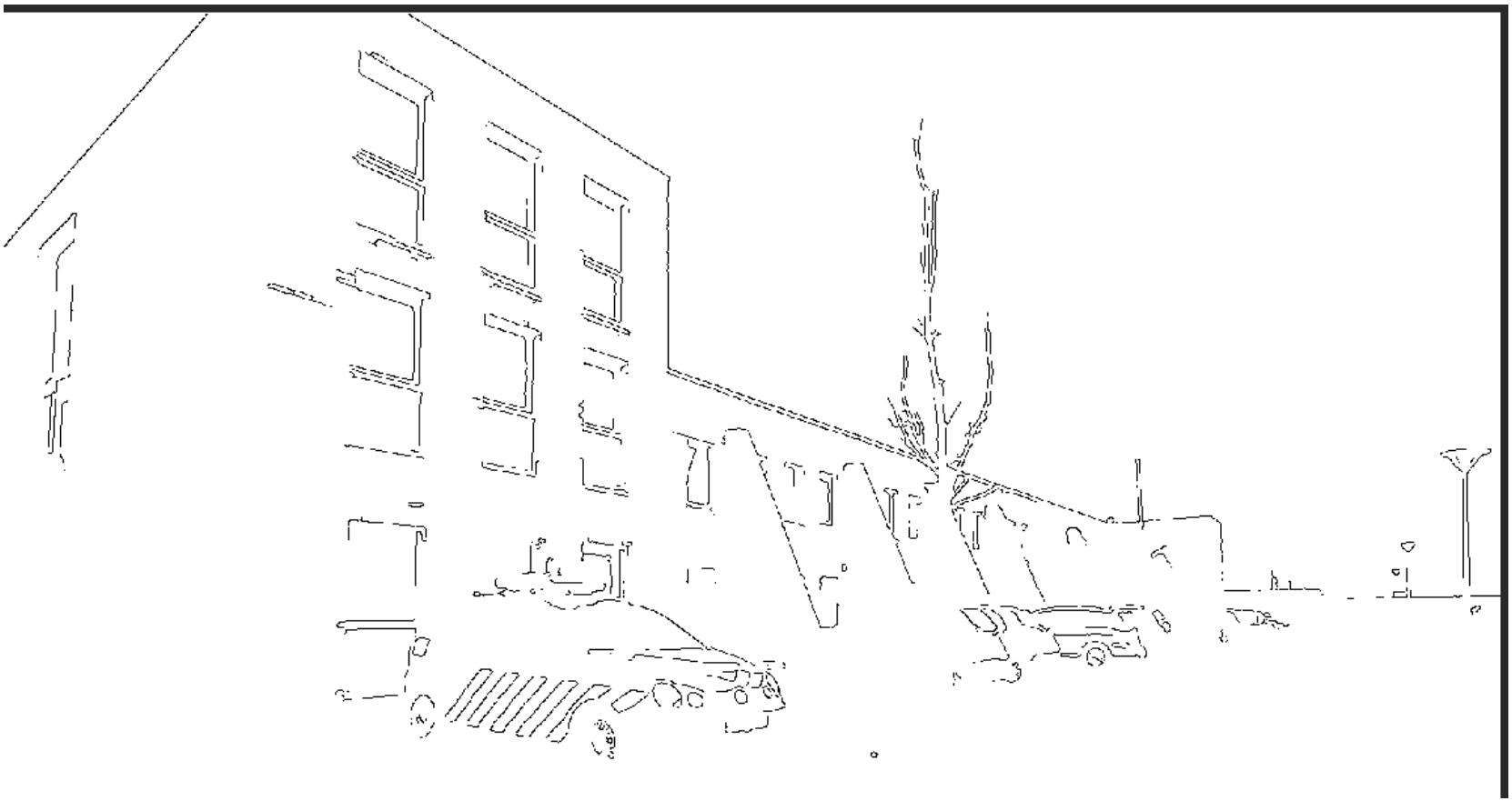
Skyline detection in urban scenes

Skyline detection in urban scenes

- Canny edge detection (based on intensity change)

Skyline detection in urban scenes

- Canny edge detection (based on intensity change)
- Result: binary image (edge or no edge)



Skyline detection algorithm

- Which edge represents the building contour?

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  "The first sharp edge (seen from top to bottom) in the image represents the skyline."

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- Algorithm:
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  - The image is sliced in #w pixel columns
  - Each column present #h binary edge values (edge or no edge)
  - y-location of the most upper edge value is stored

Skyline detection result

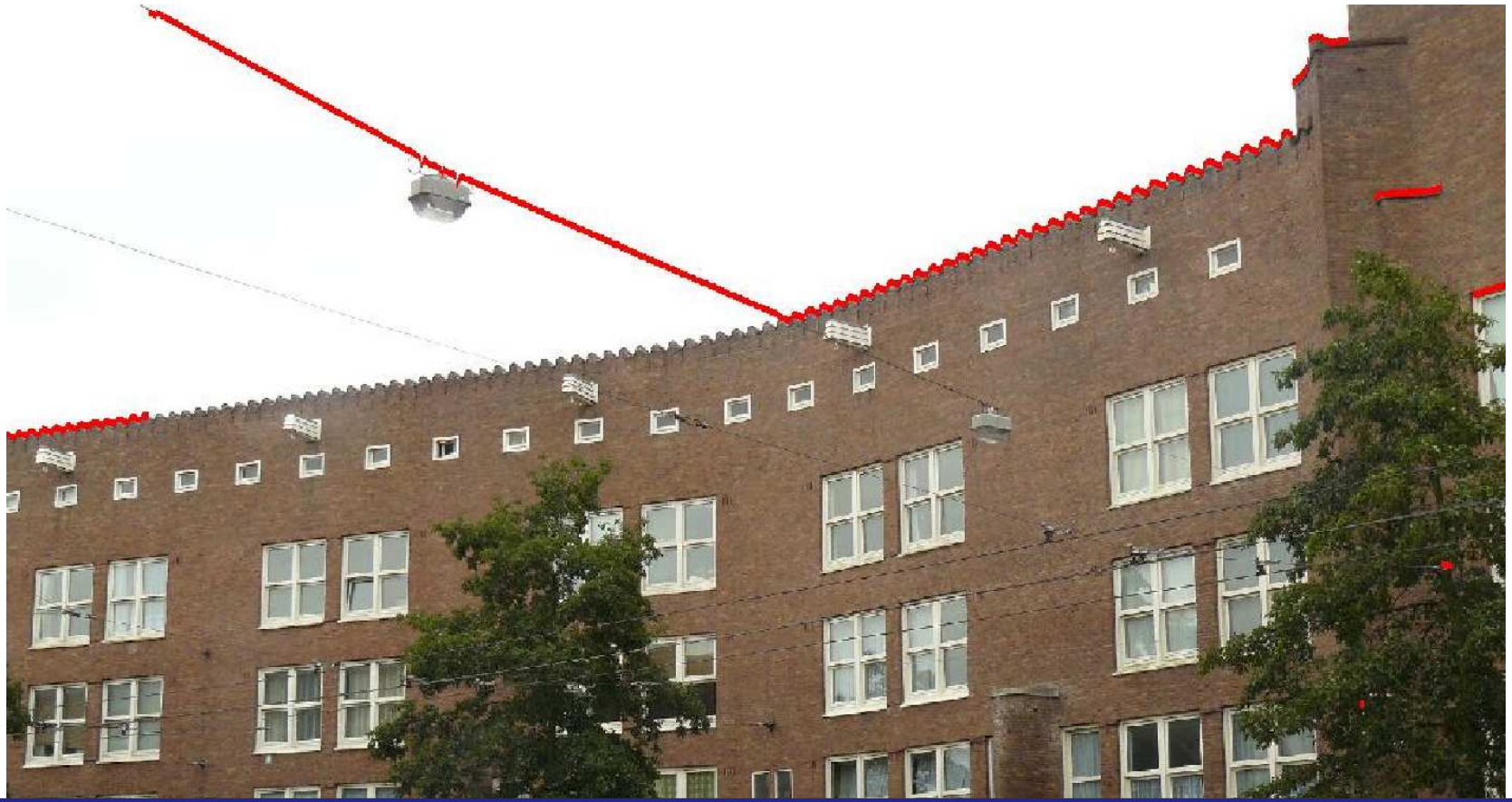
Skyline detection result

Future research

Hypothesis based skyline detection, assumption

"The first sharp edge (seen from top to bottom) in the image represents the skyline."

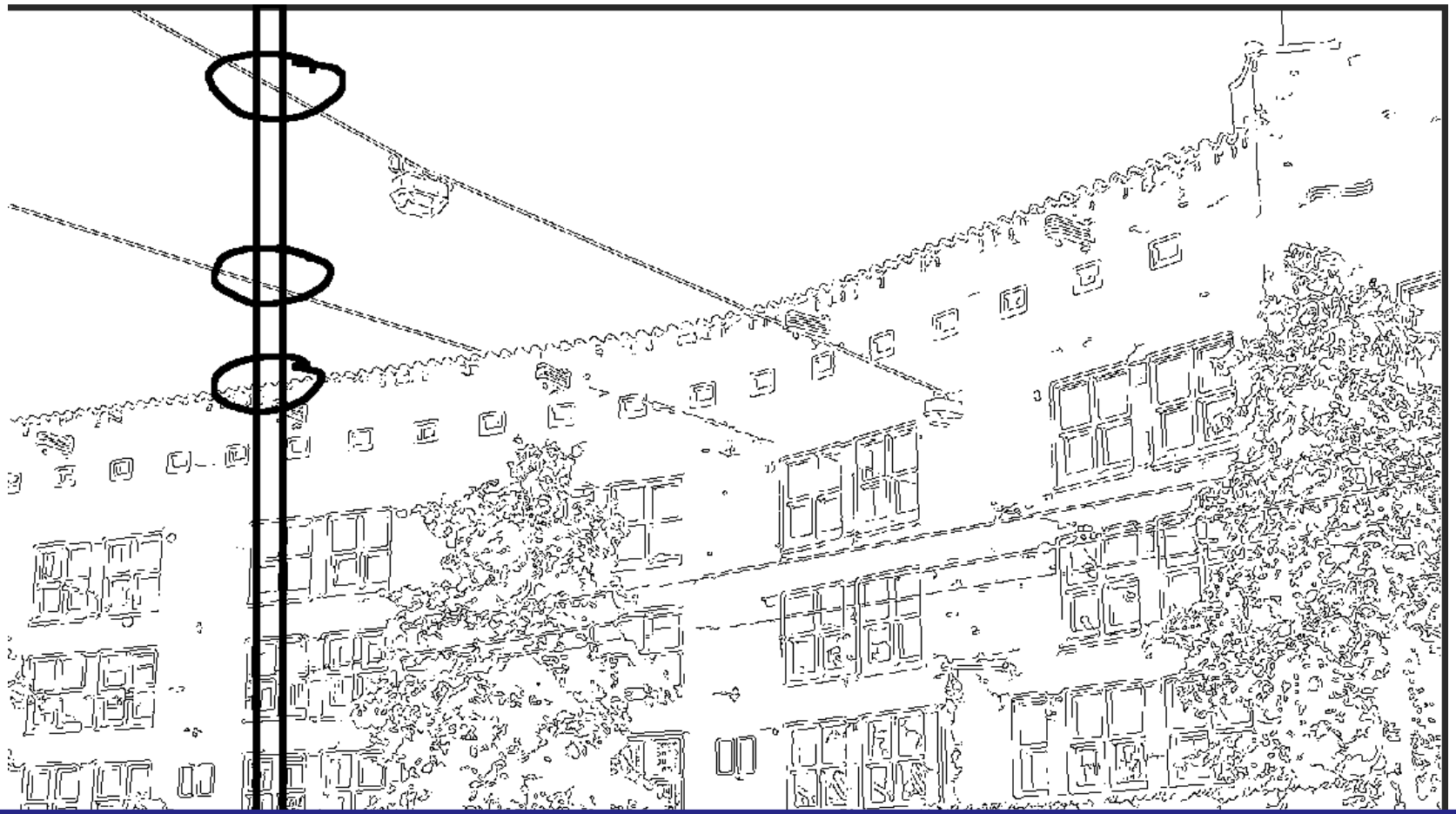
- Example of a scene where this assumption is violated



Hypothesis based skyline detection, assumption

- Change of assumption

"The skyline is part of the first n sharp edges (e.g. $n = 3$)



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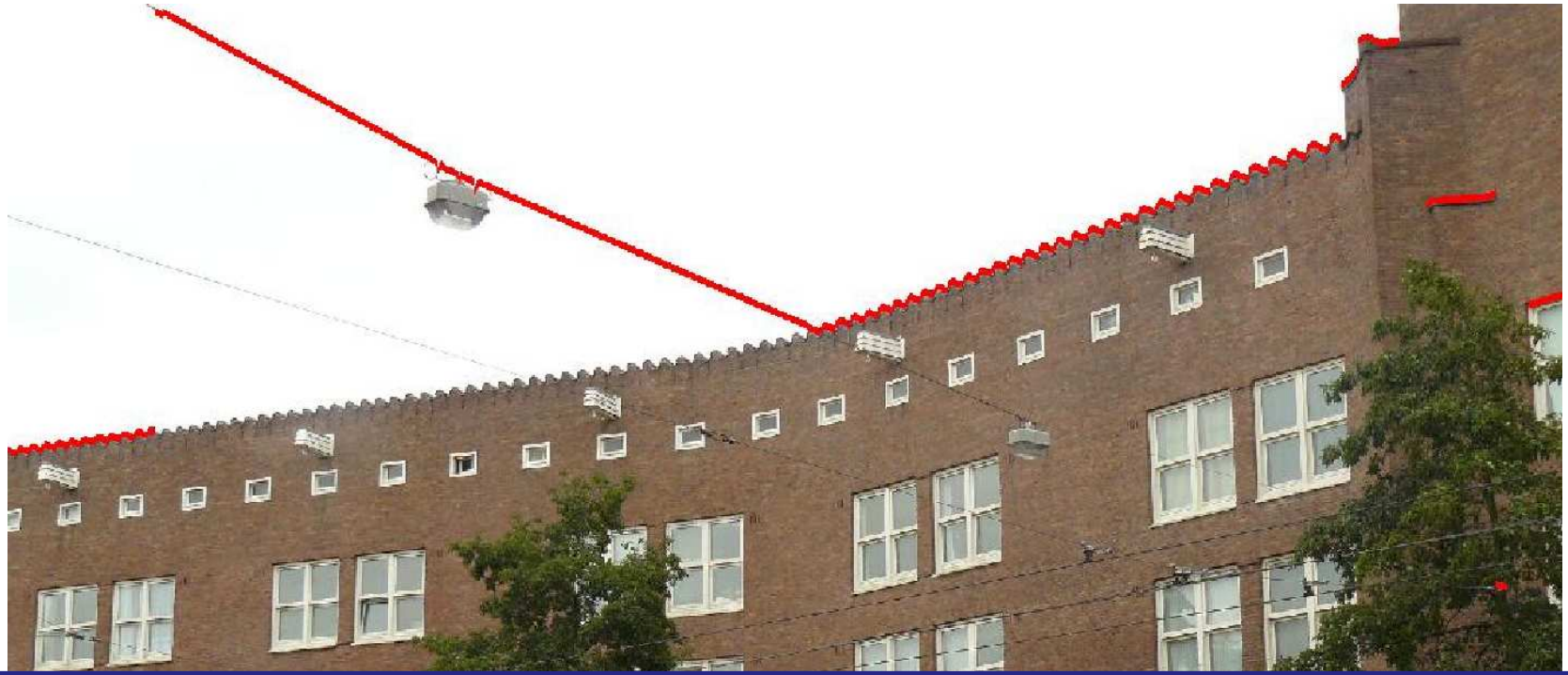
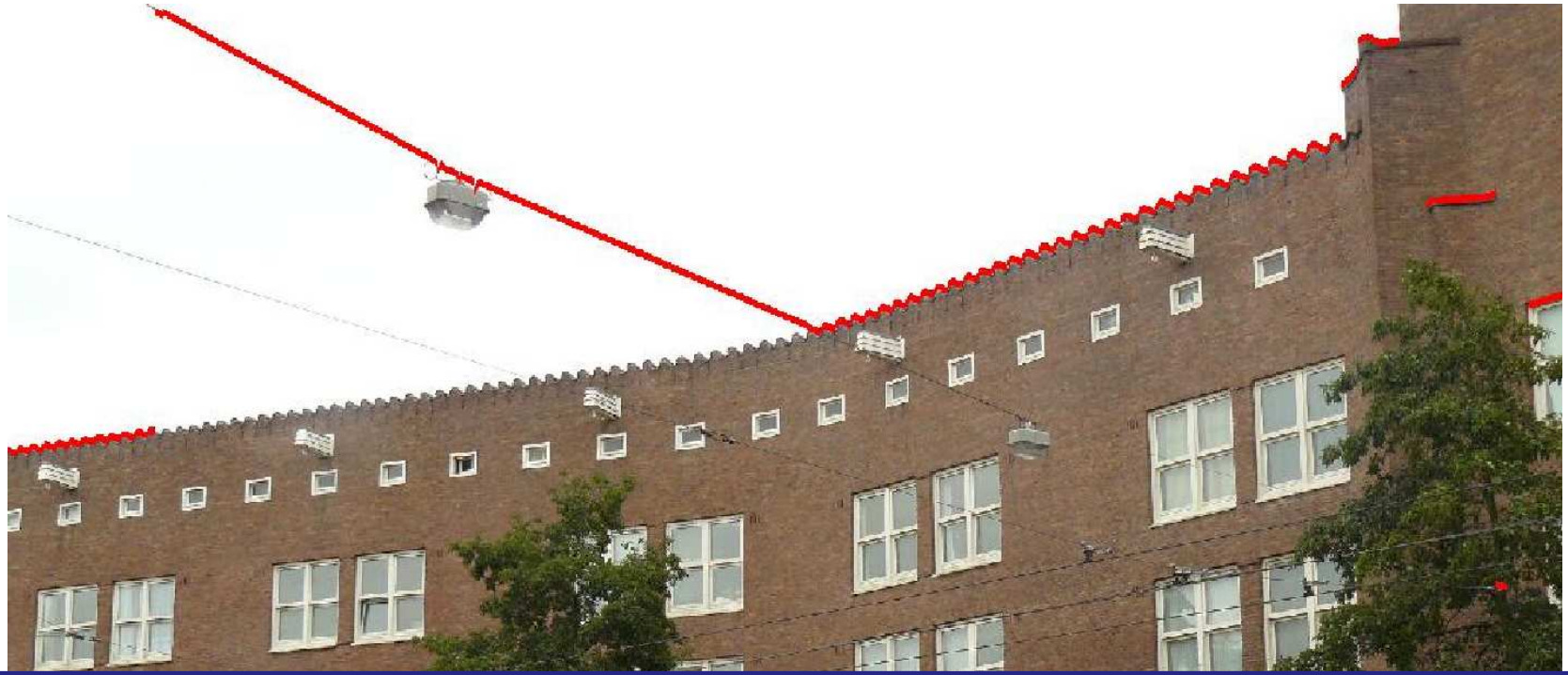


Hypothesis based skyline detection, algorithm

- Generate *n* hypothesis
- Classify hypothesis with additional info
  - texture



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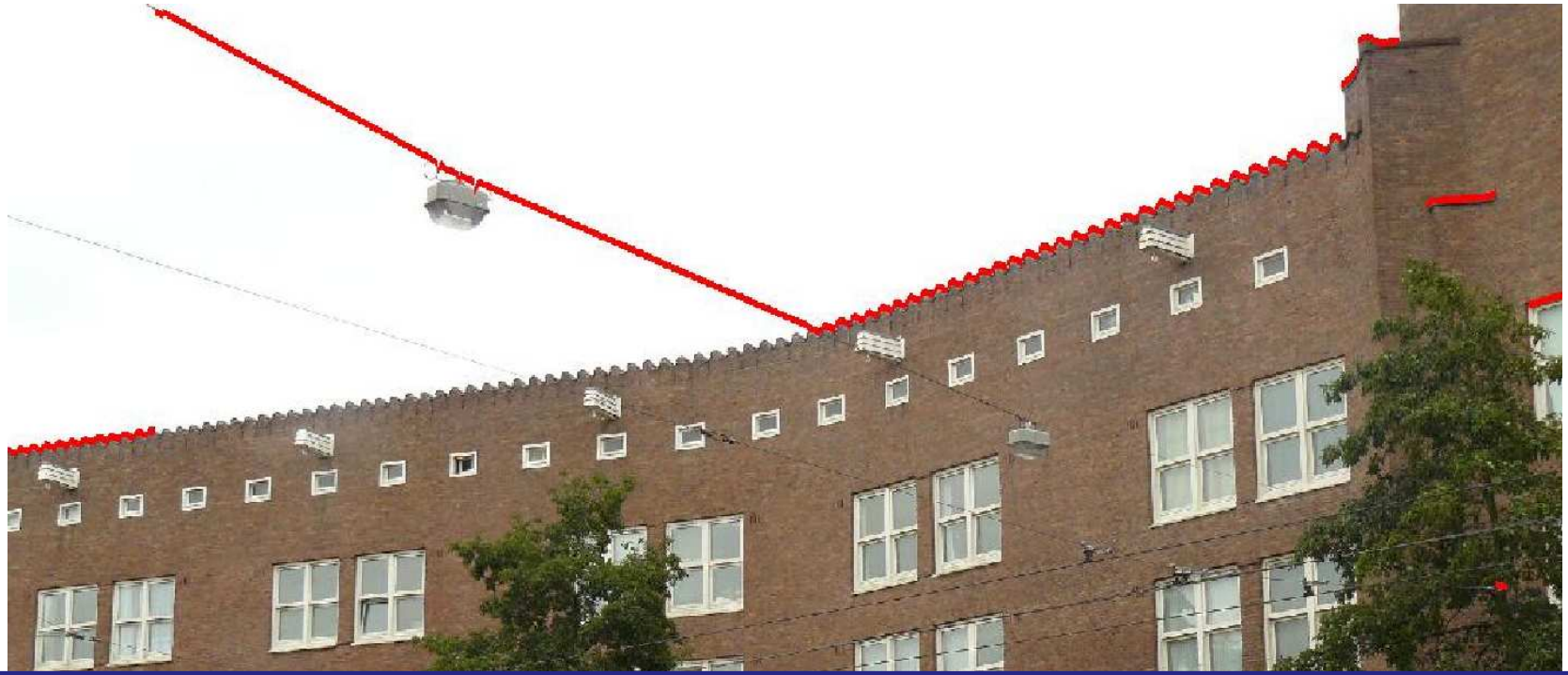
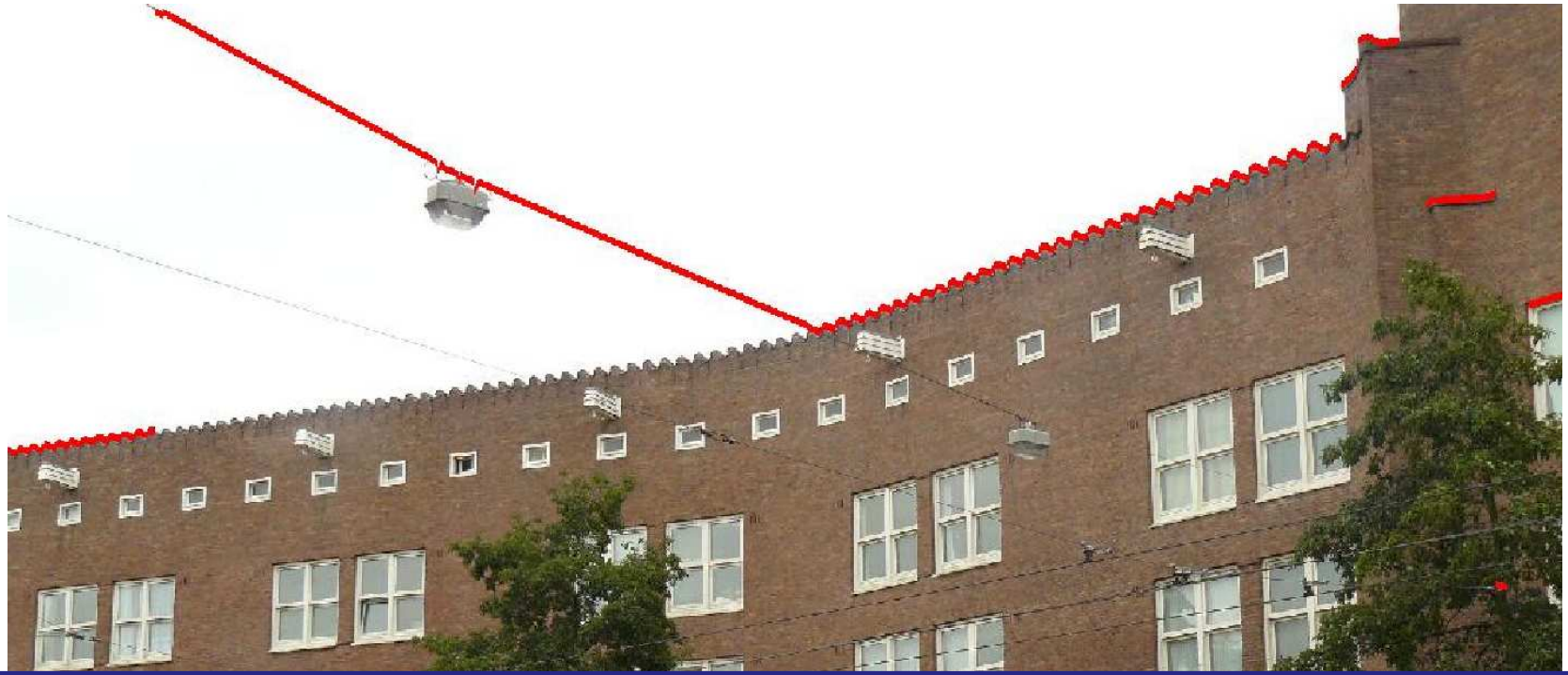
  - color



Hypothesis based skyline detection, algorithm

- Generate *n* hypothesis
- Classify hypothesis with additional info
  - texture
  - color
  - height variation



Expected result on hypothesis classification based on color

Expected result classification based on height variation

Expected result classification based on height variation

Conclusion

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Conclusion

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  - works well under the assumption skyline is upper edge
  - needs future research
    - can provide a set of hypothesis which should be evaluated using additional features (e.g. color and height variation)

Outline

Overview

- Create (top view) 2D model of the scene using *Openstreetmap*

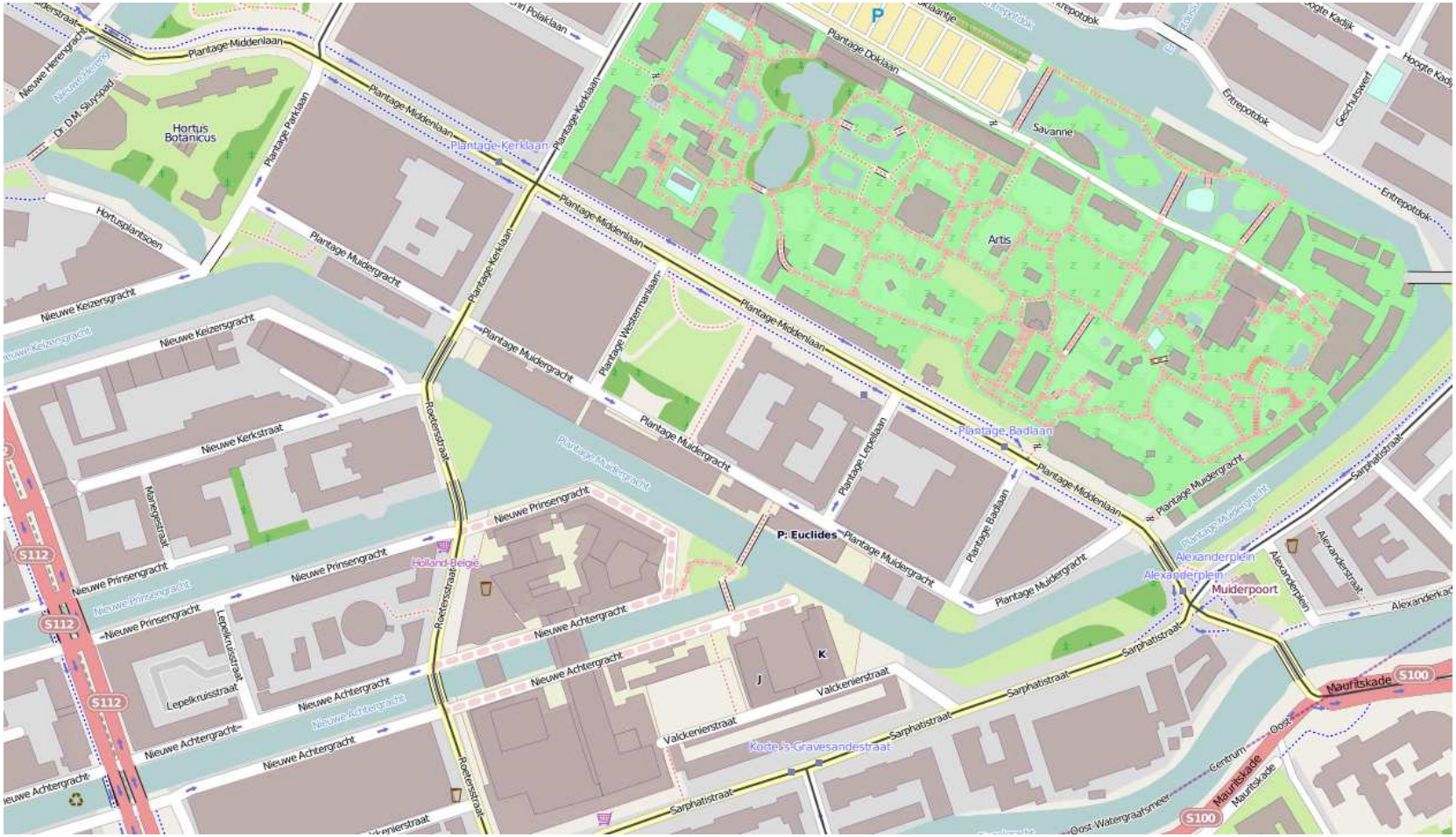
Overview

- Create (top view) 2D model of the scene using *Openstreetmap*
- Align 2D model with the scene

Overview

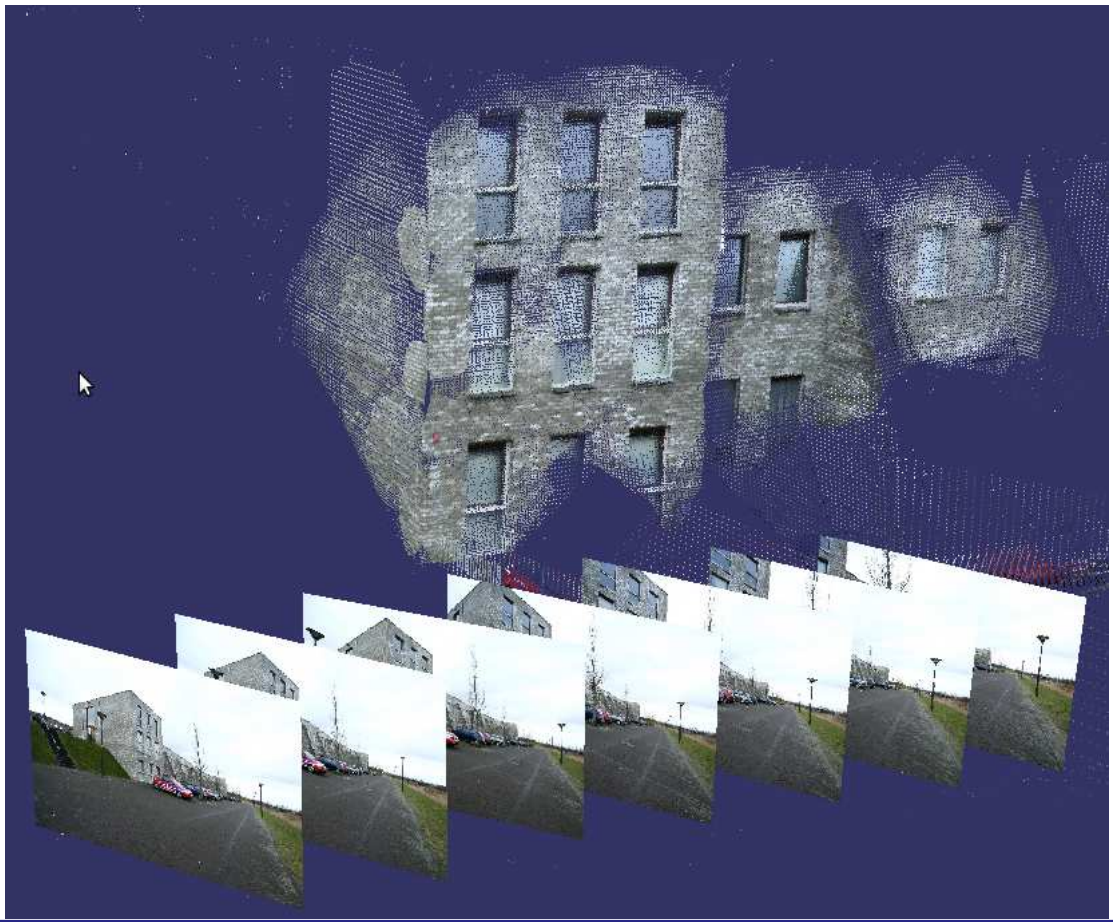
- Create (top view) 2D model of the scene using *Openstreetmap*
- Align 2D model with the scene
- Transform the 2D model to a 3D model by extending the walls

Extract 2D model



Align 2D model

- Isaac Esteban's *FIT3D toolbox*



Align 2D model

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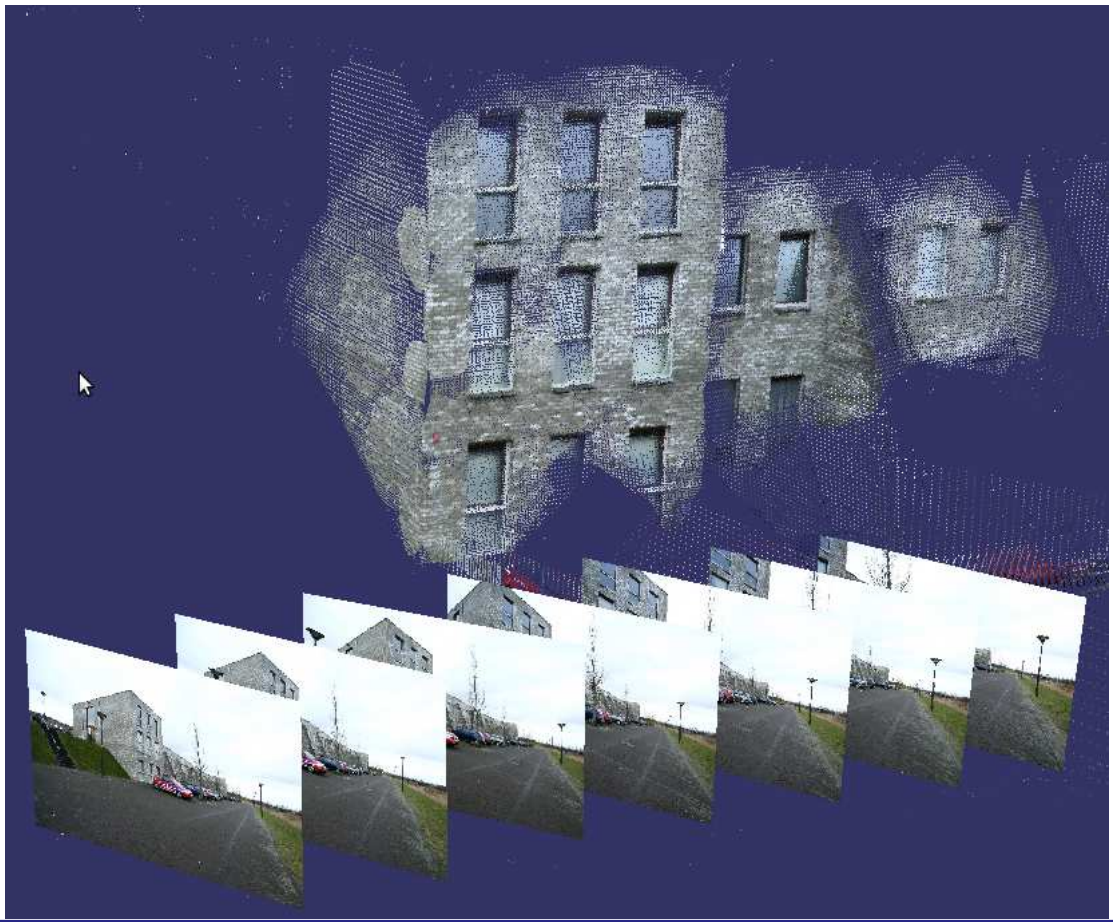
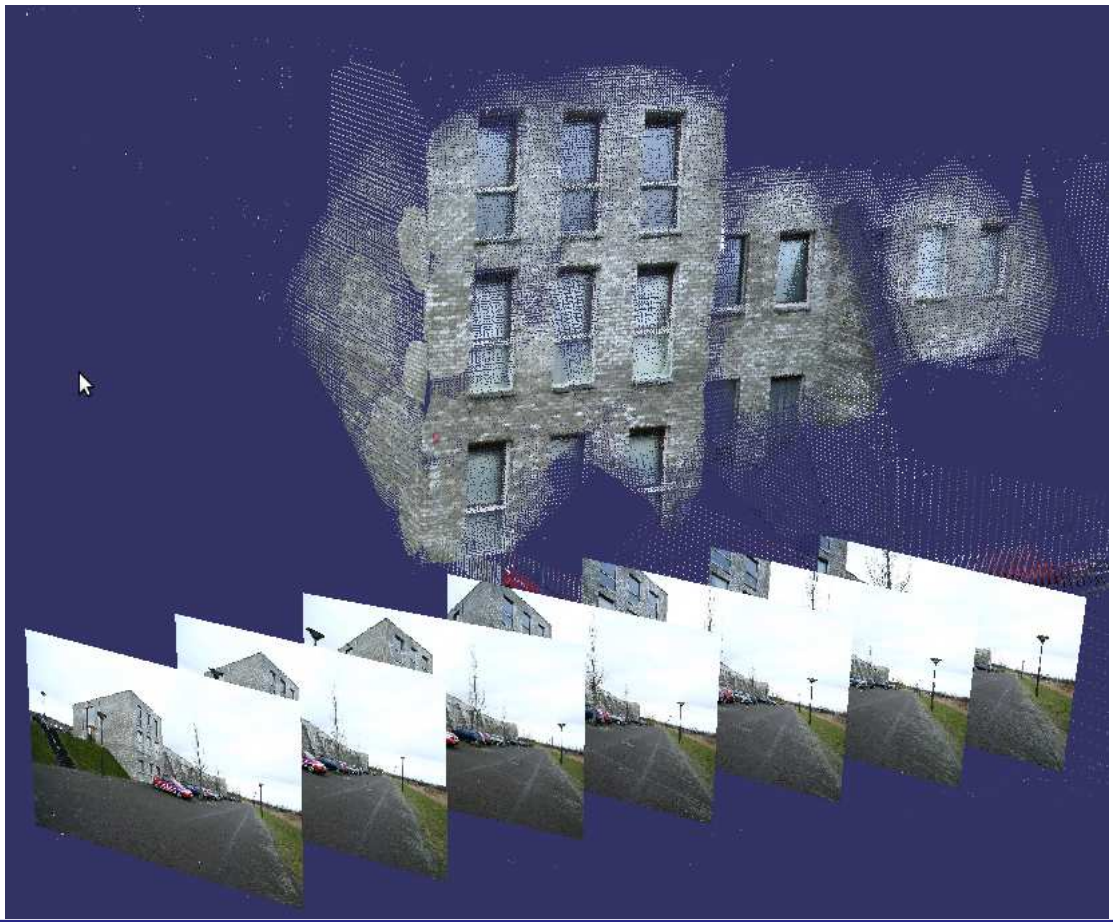
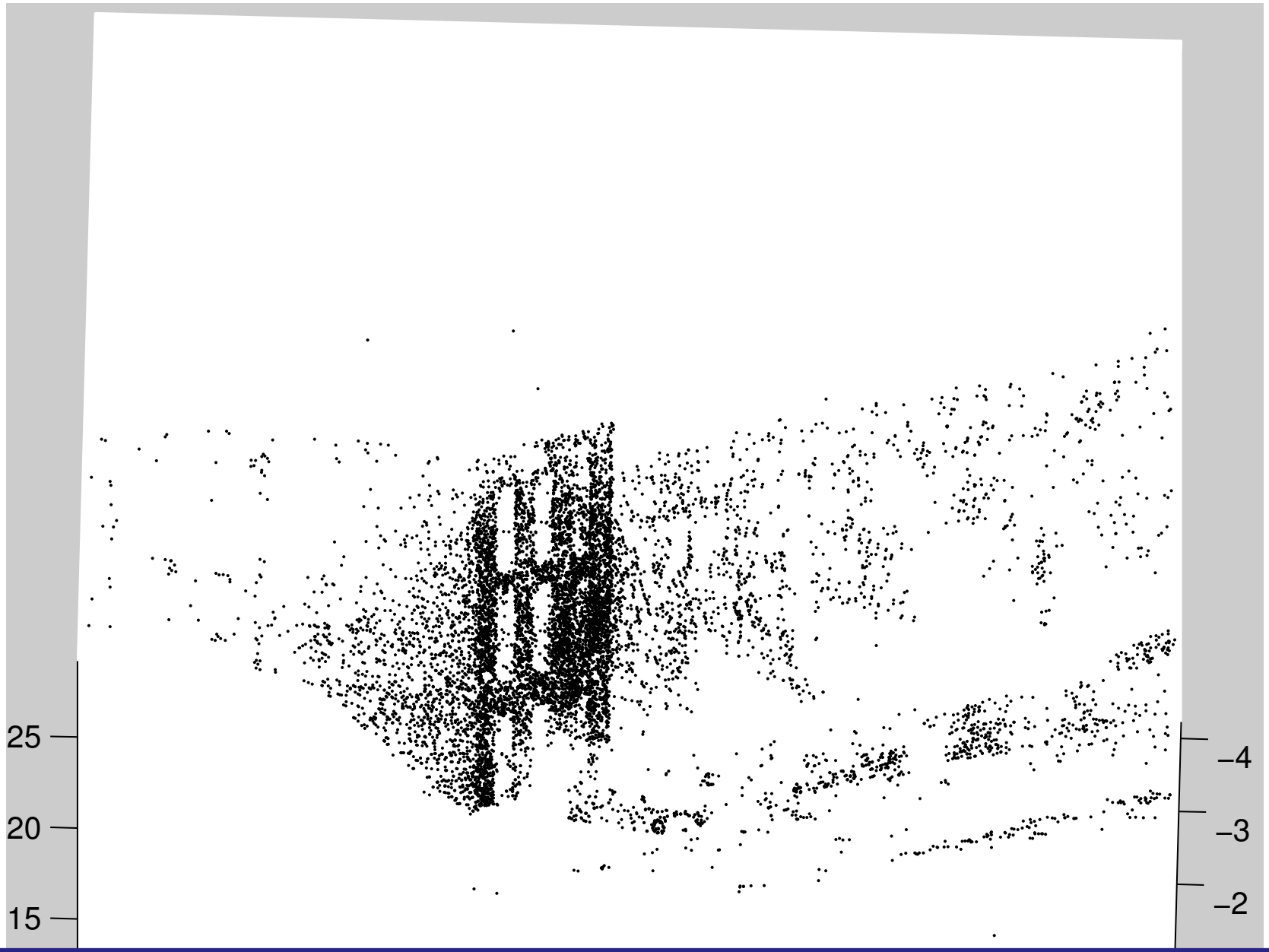
  - Input: sequence of images (different views of the building)



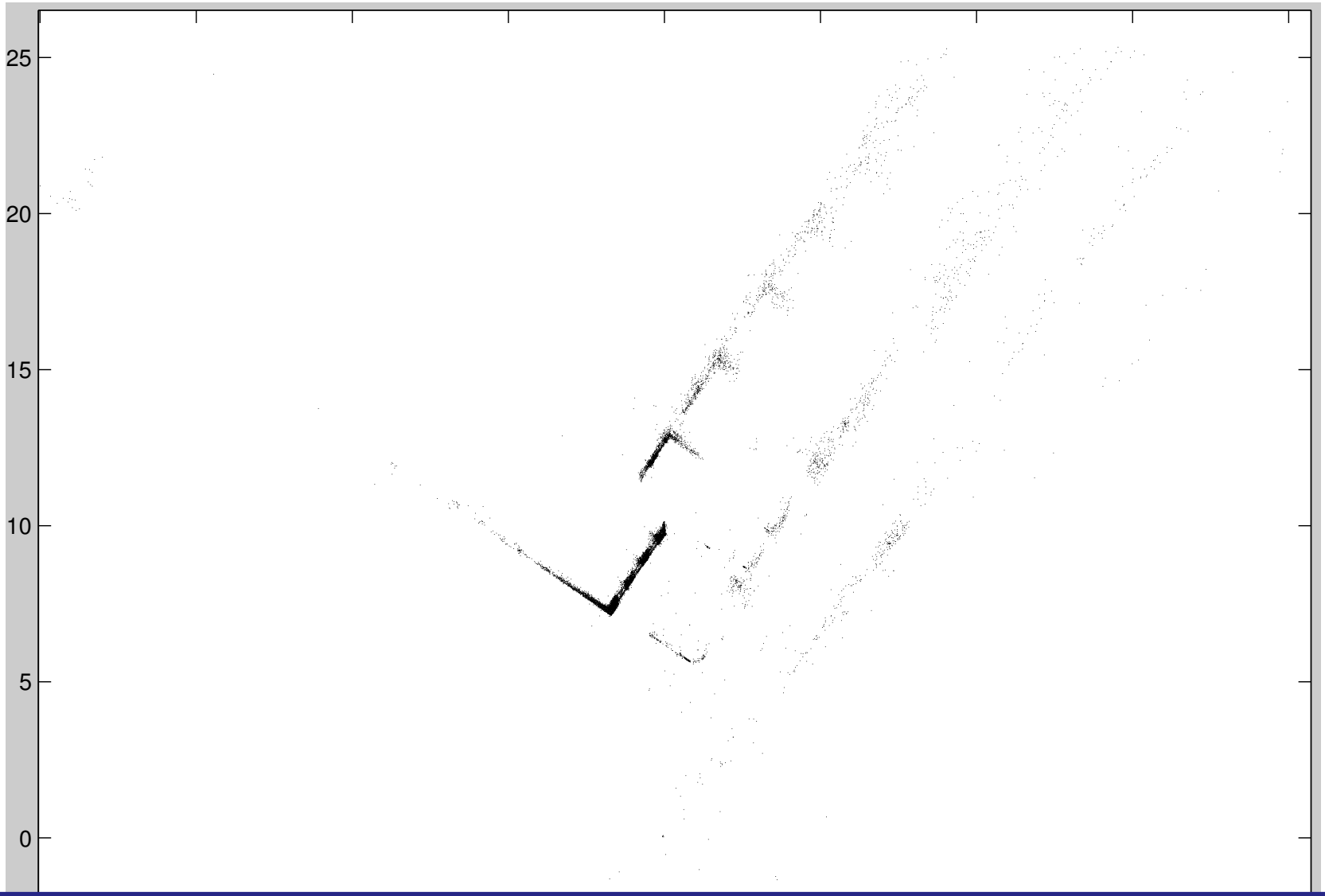
Align 2D model

- Isaac Esteban's *FIT3D toolbox*
  - Input: sequence of images (different views of the building)
  - Output: a 3D point cloud of the building




25
20
15
−4
−3
−2

Align 2D model



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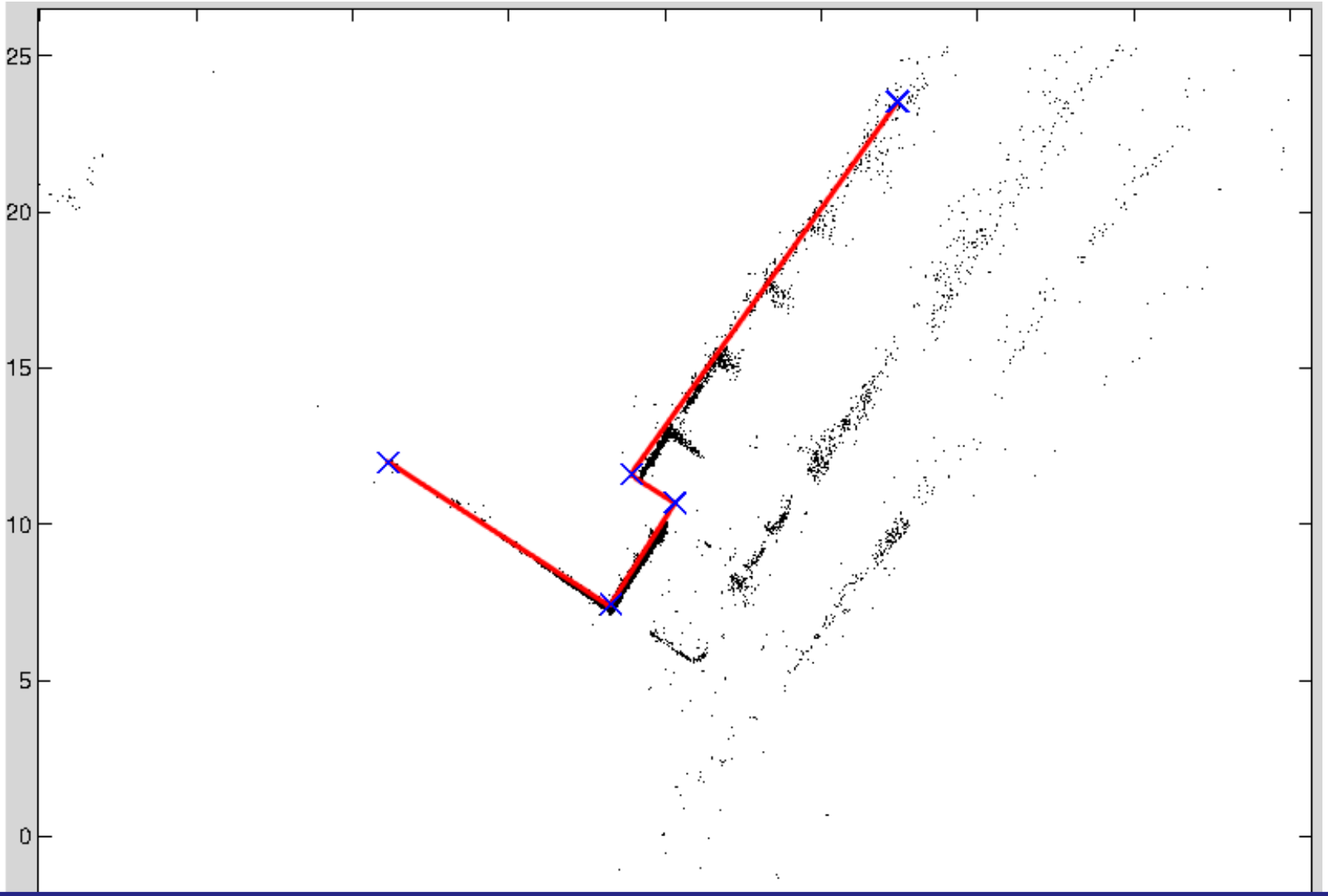

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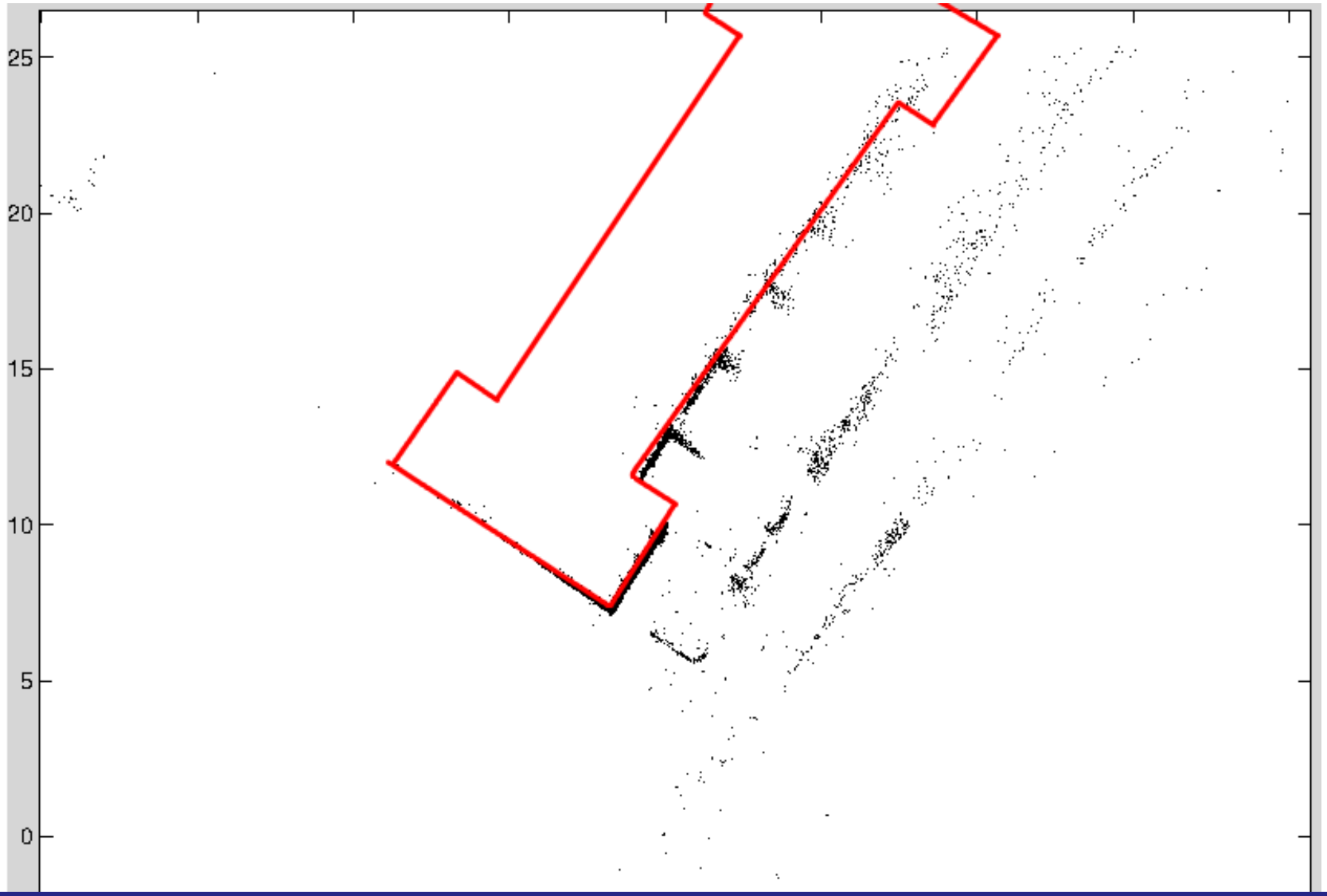
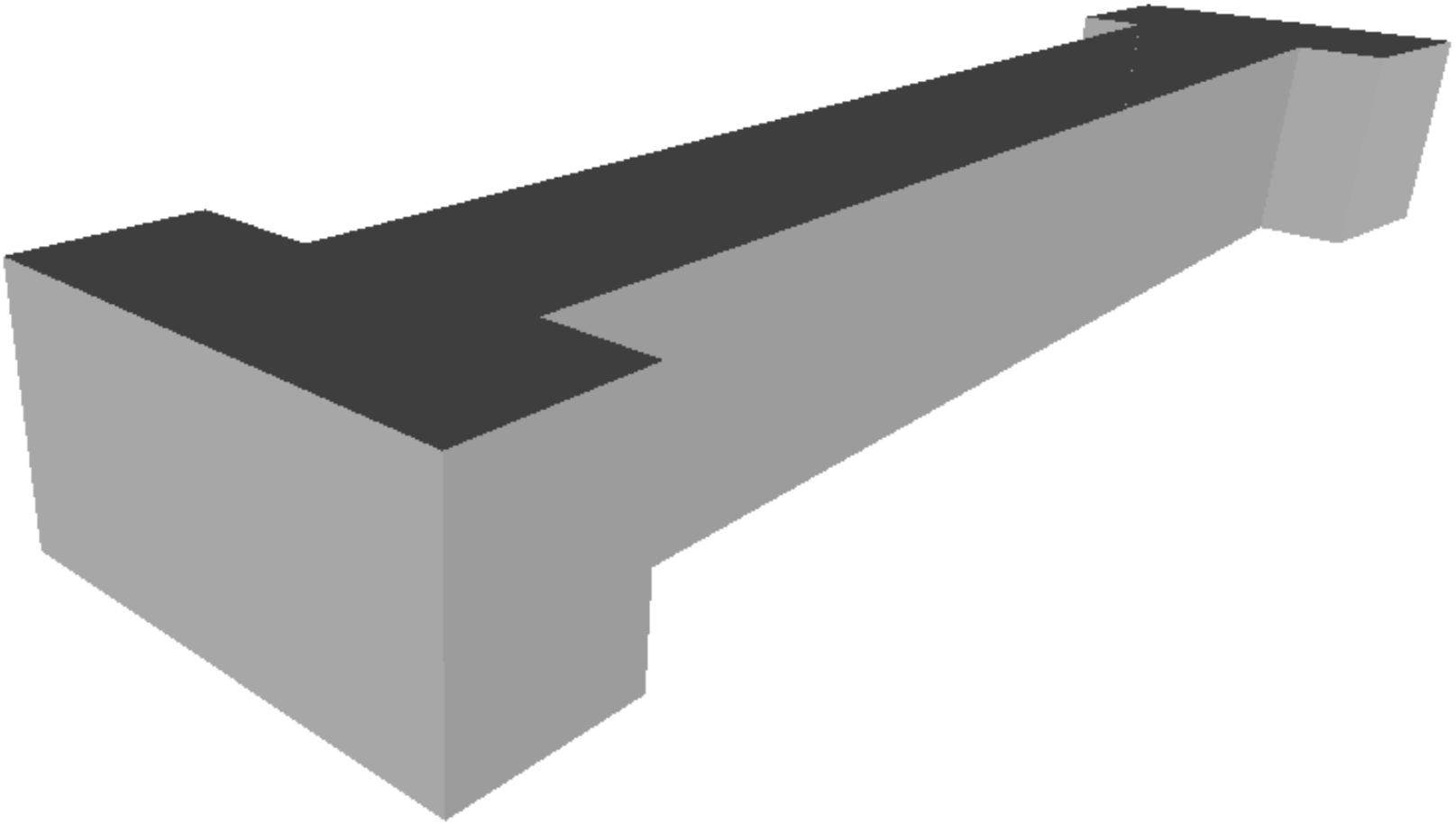


Results



Wall height estimation

- Wall heights of 3D model are not accurate

Wall height estimation

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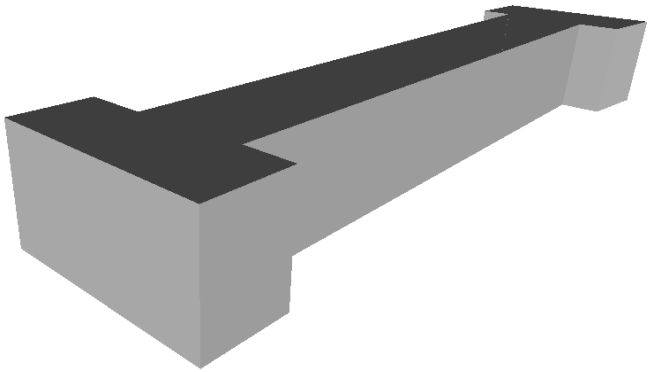
- Improve the 3D model by wall height estimation



(c)

(d)

Skyline detection for wall height estimation

- Straight lines assumption:

Skyline detection for wall height estimation

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  - *Straight lines in the skyline are likely to come from the building contour*

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- Flat roof assumption:

Skyline detection for wall height estimation

- Straight lines assumption:
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- Flat roof assumption:
  - *building contour is equal to upper side of building walls*

Extracting line segments

- Output of skyline detector

Extracting line segments

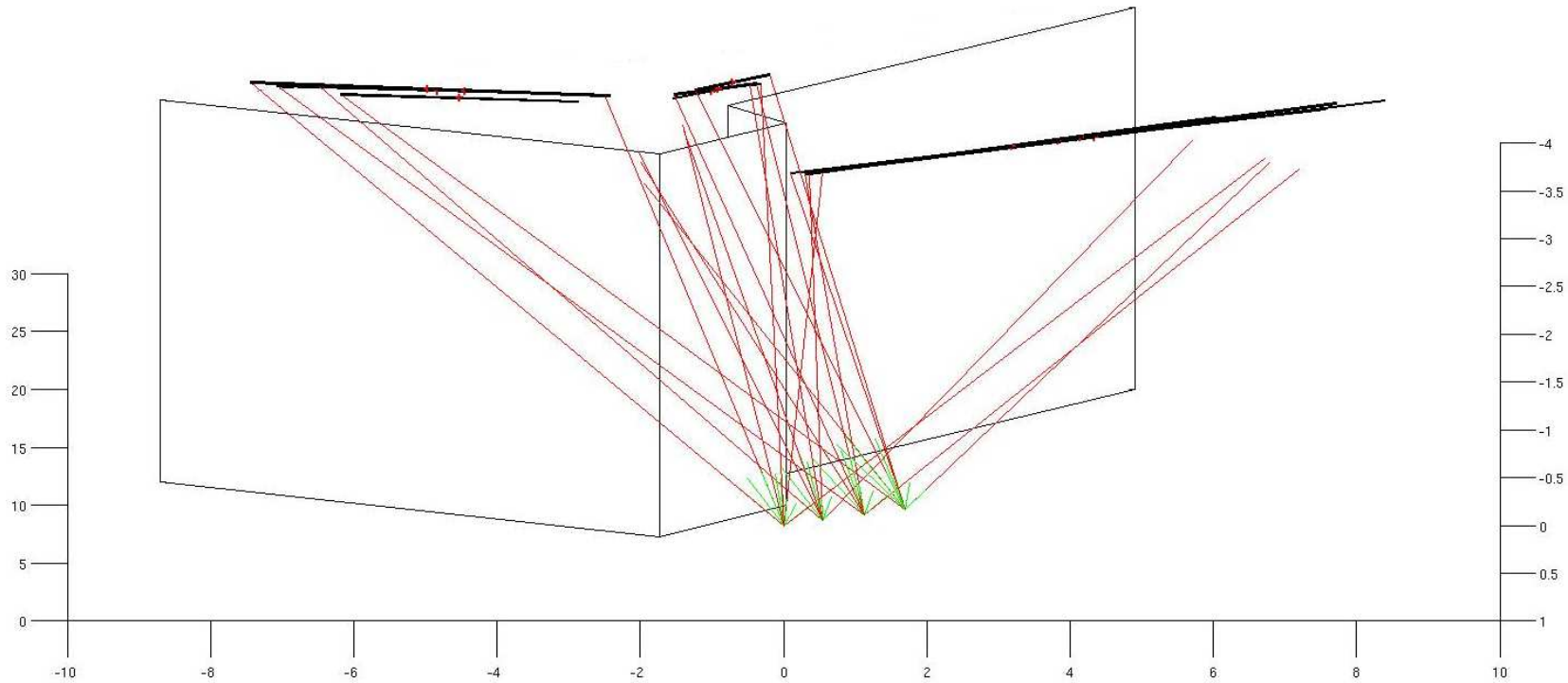
- Output of skyline detector
- Hough transform

Project to the 3D model

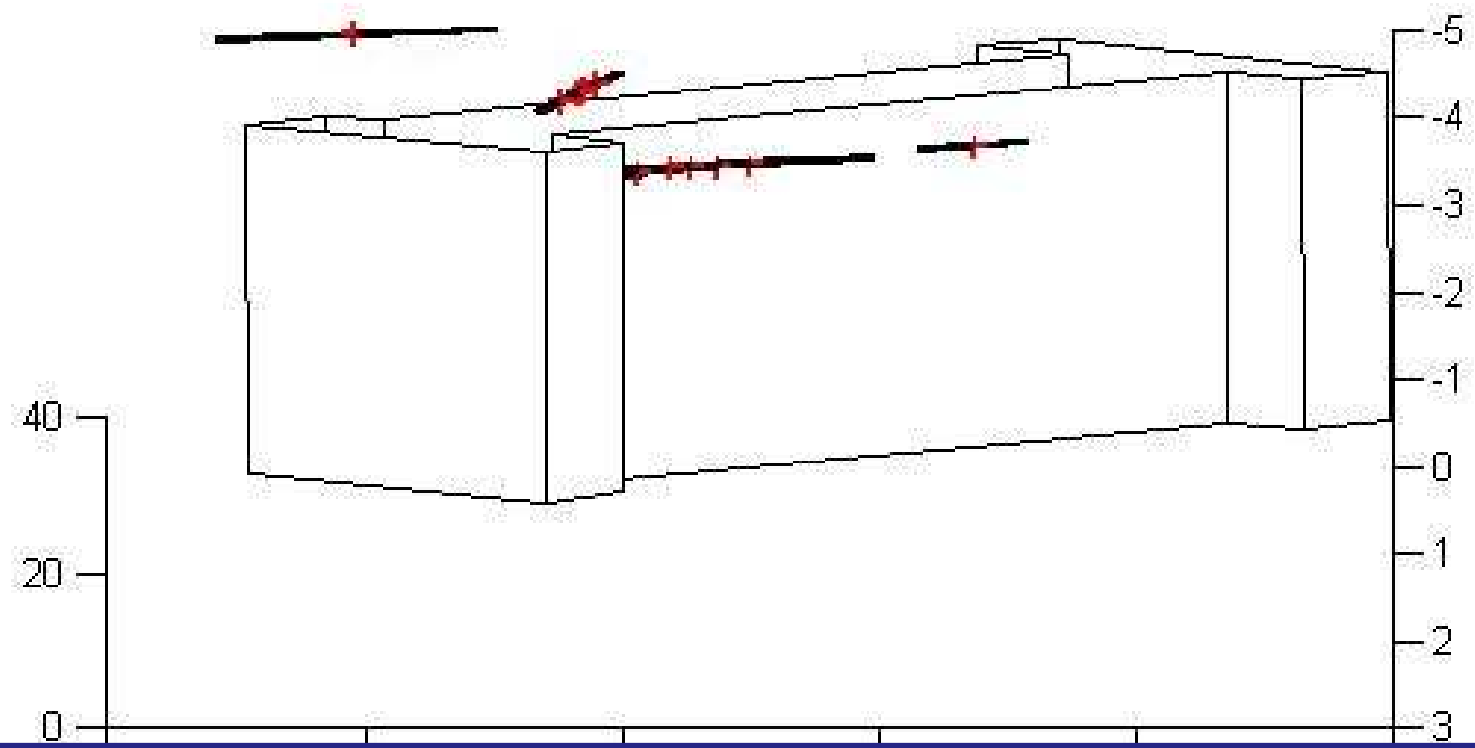
- Estimate wall heights

Project to the 3D model

- Estimate wall heights
- Project line segments to specific walls of 3D model



Results



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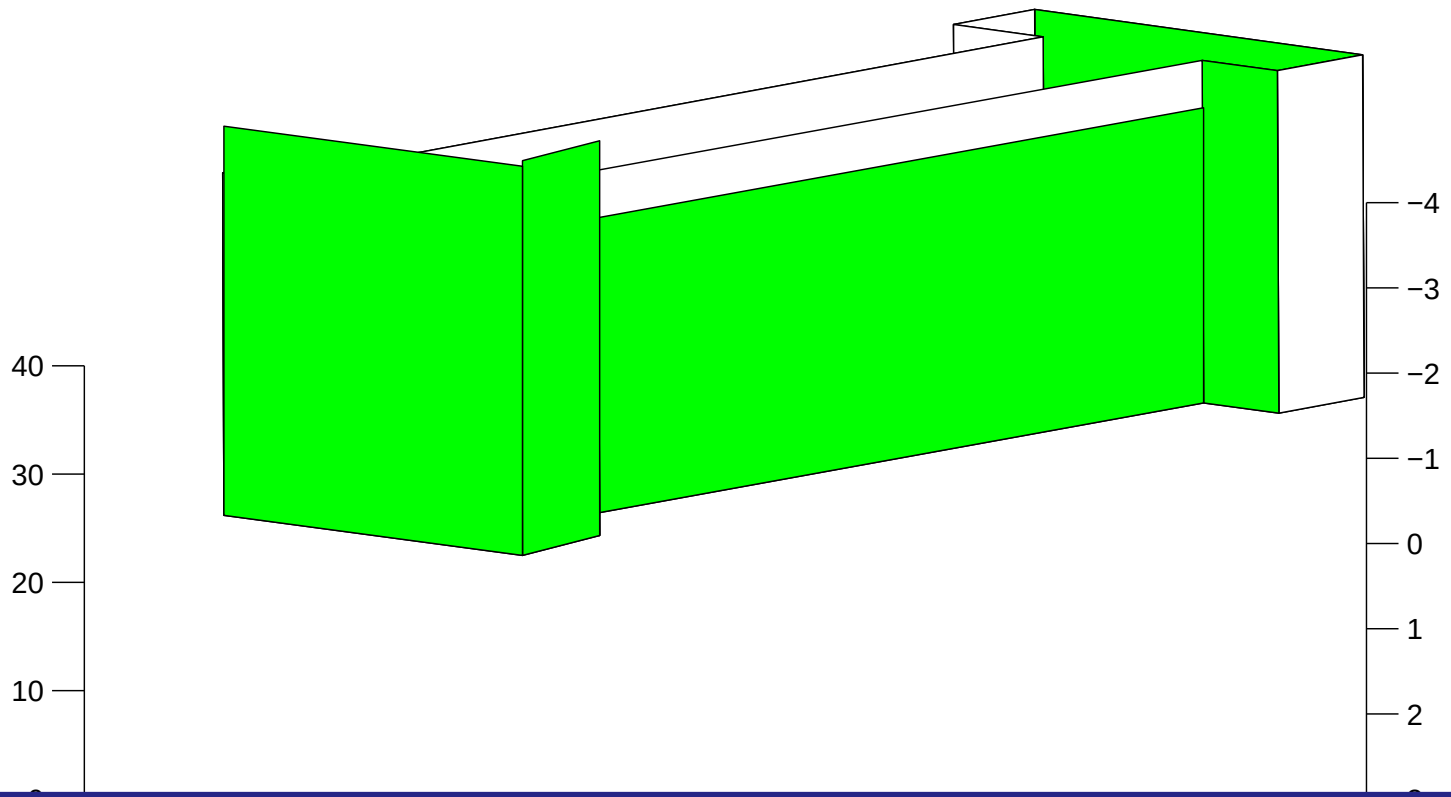
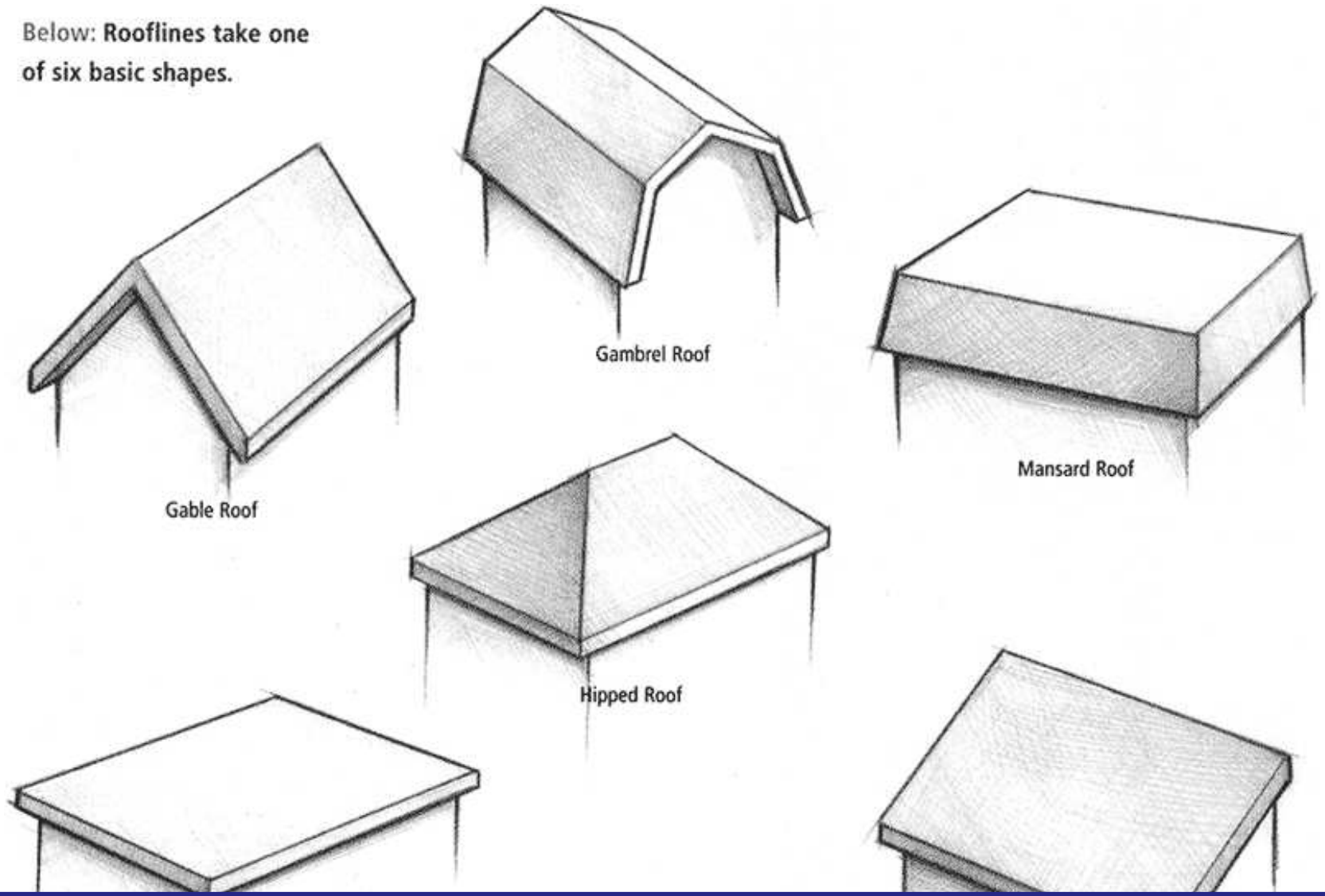


Future research



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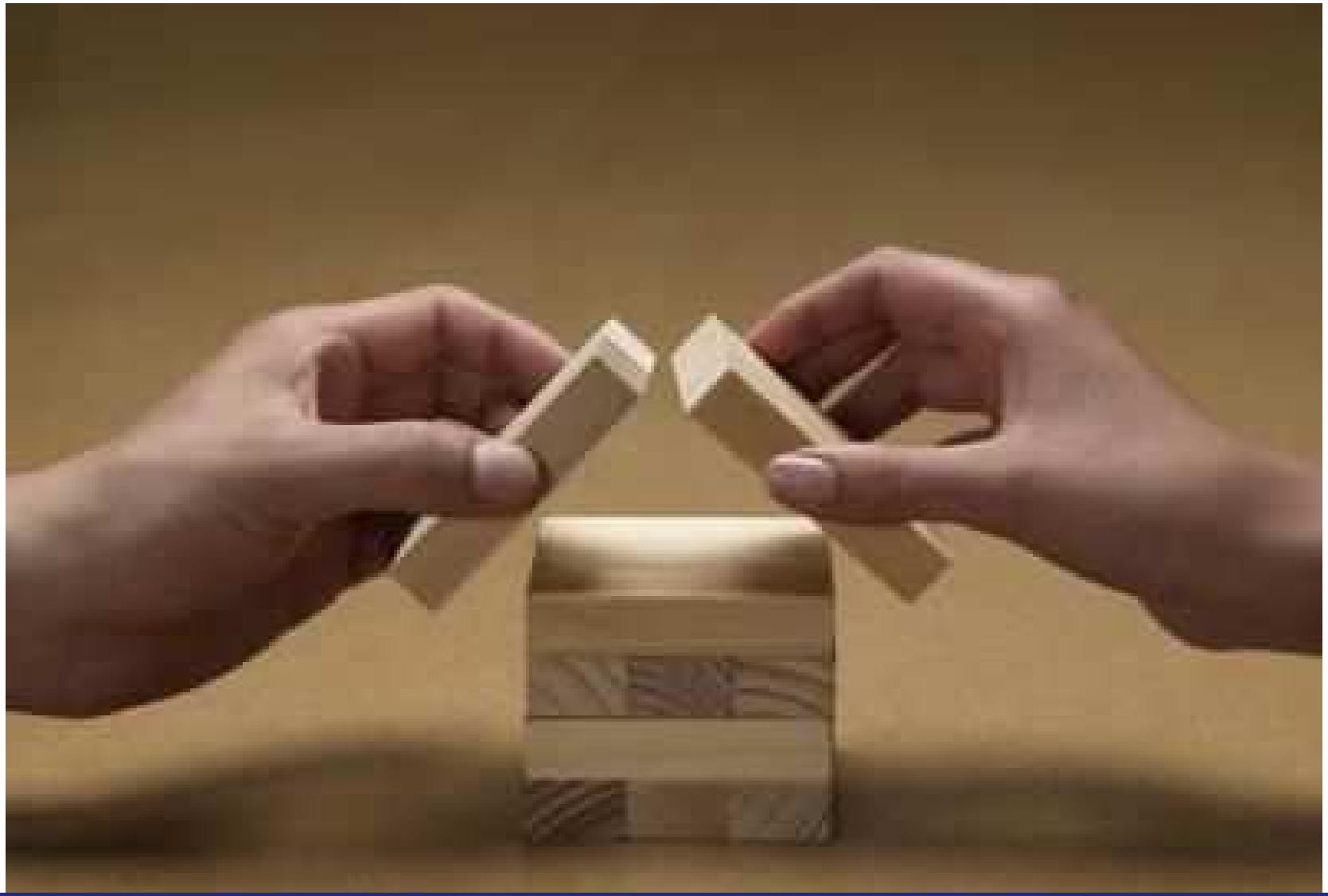

Outline

(e)

(f)

Outline window detection

- Method I: Connected corner approach
  - invariant to viewing direction
- Facade rectification
- Method II: Histogram based approach
  - frontal view only
  - uses histograms of Houghlines

Method I: Connected corner approach

Situation

- Window = frame + glass (+ sub windows)

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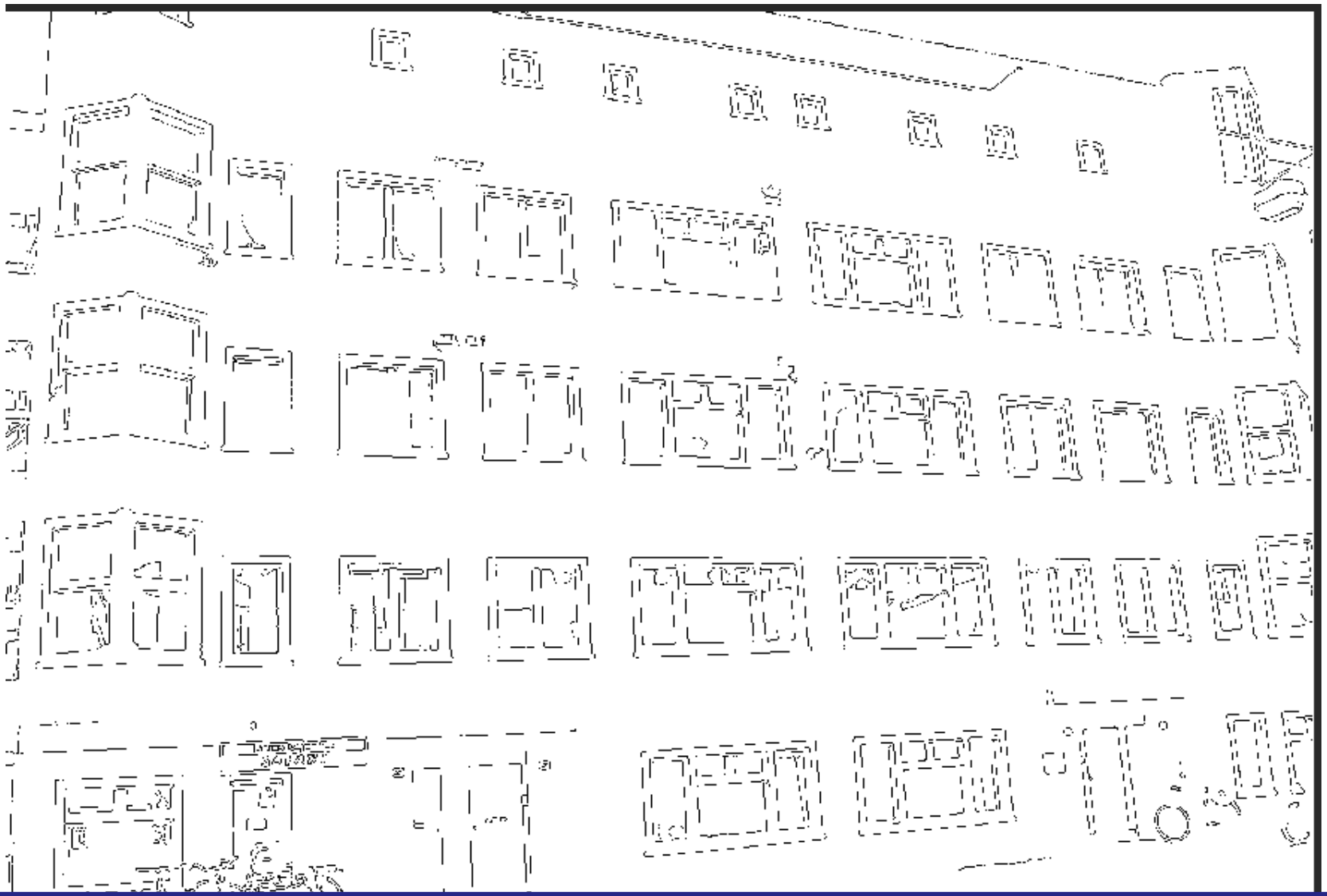
Situation

- Window = frame + glass (+ sub windows)
- Color difference, frame, glass
- Produce edges in horizontal and vertical direction

Original

Edge detection



The idea

- *"horizontal and vertical edges that come from the same (sub)window frame share a corner"*

Edge detection and Houghline extraction

- Two groups of straight lines (Houghlines)
  - θ-constraint

Edge detection and Houghline extraction

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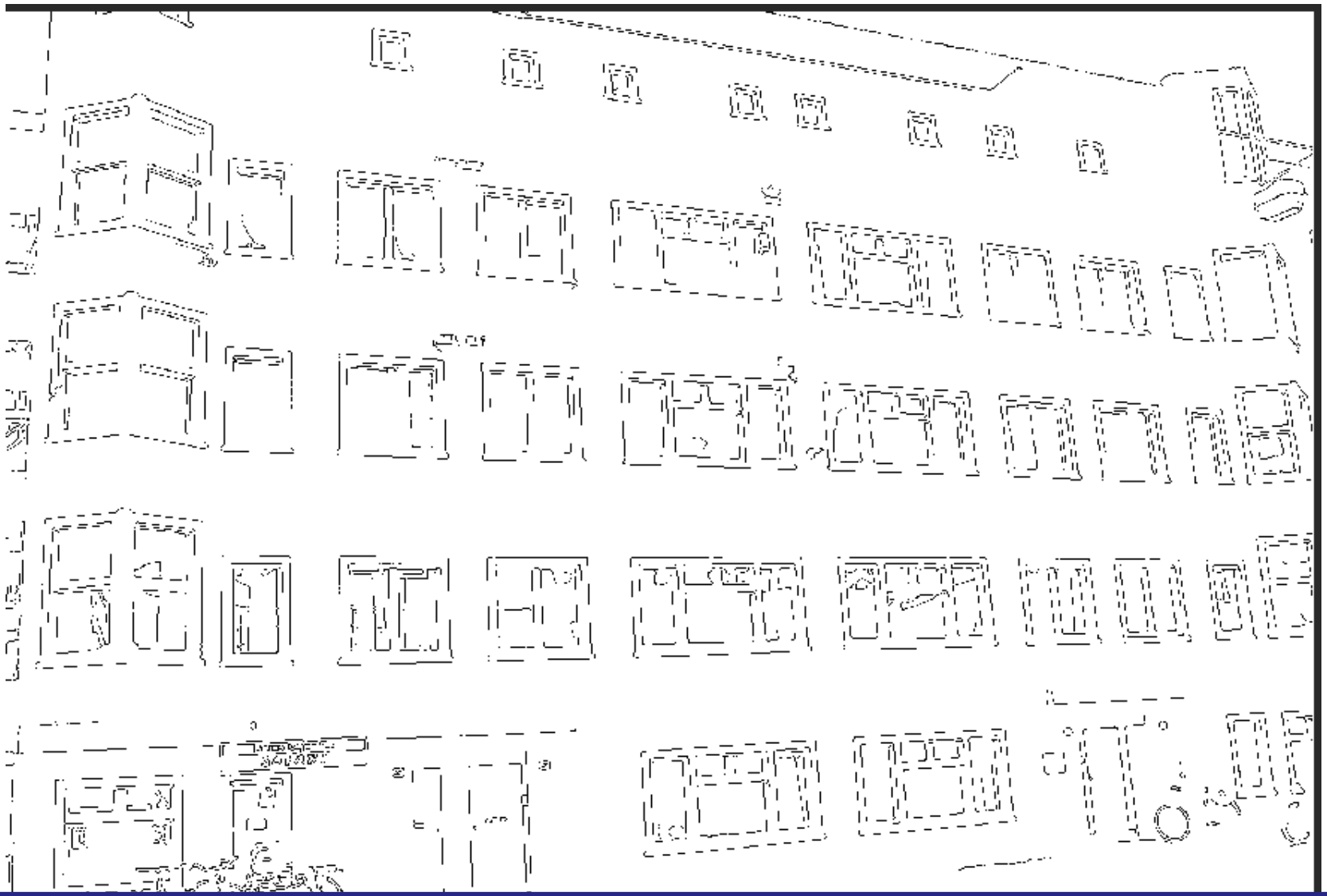
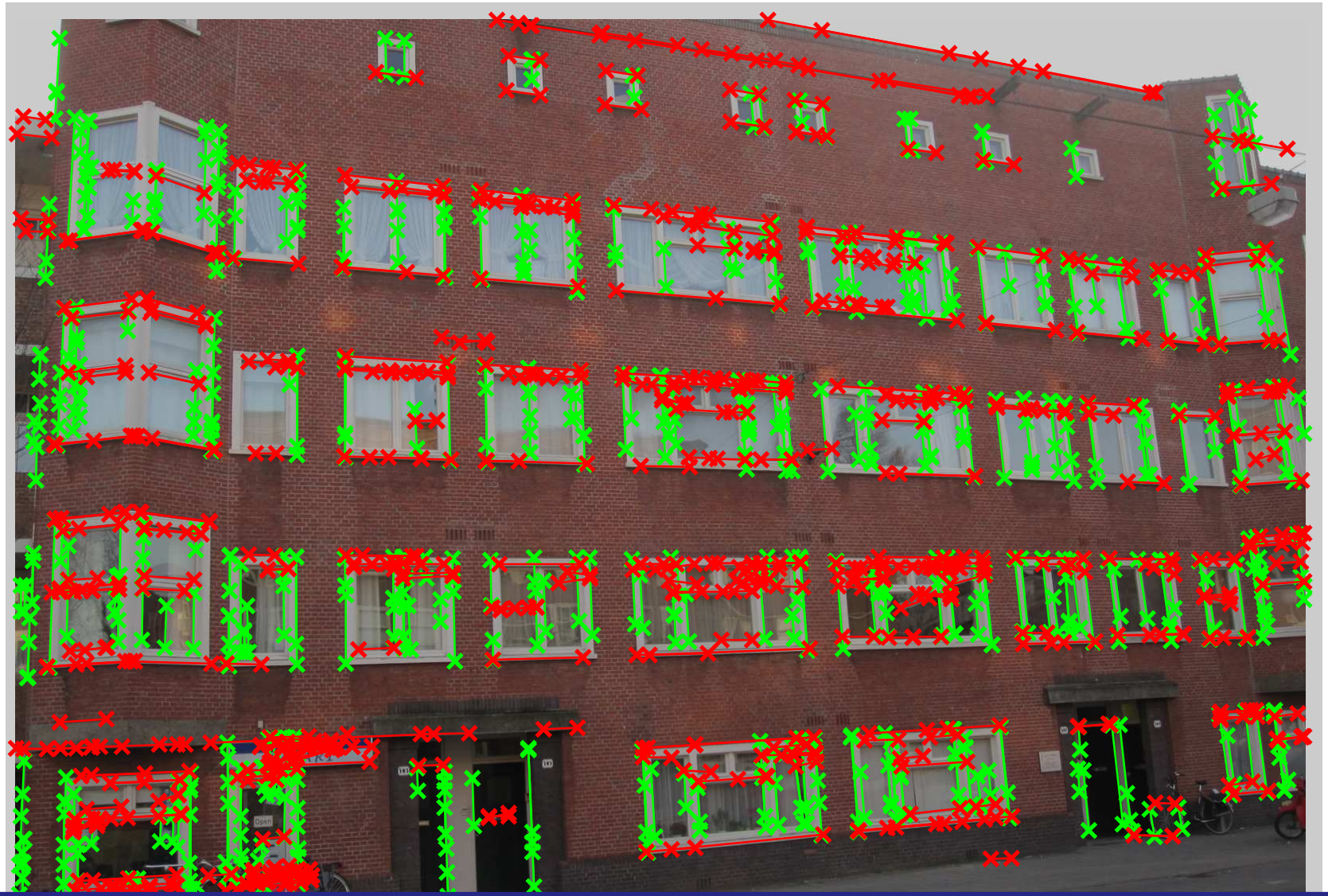
  - Camera not exactly upright
  - Facade view contains an angle, perspective distortion

Original

Edge detection



Result of θ constrained Hough transform



Connected corner

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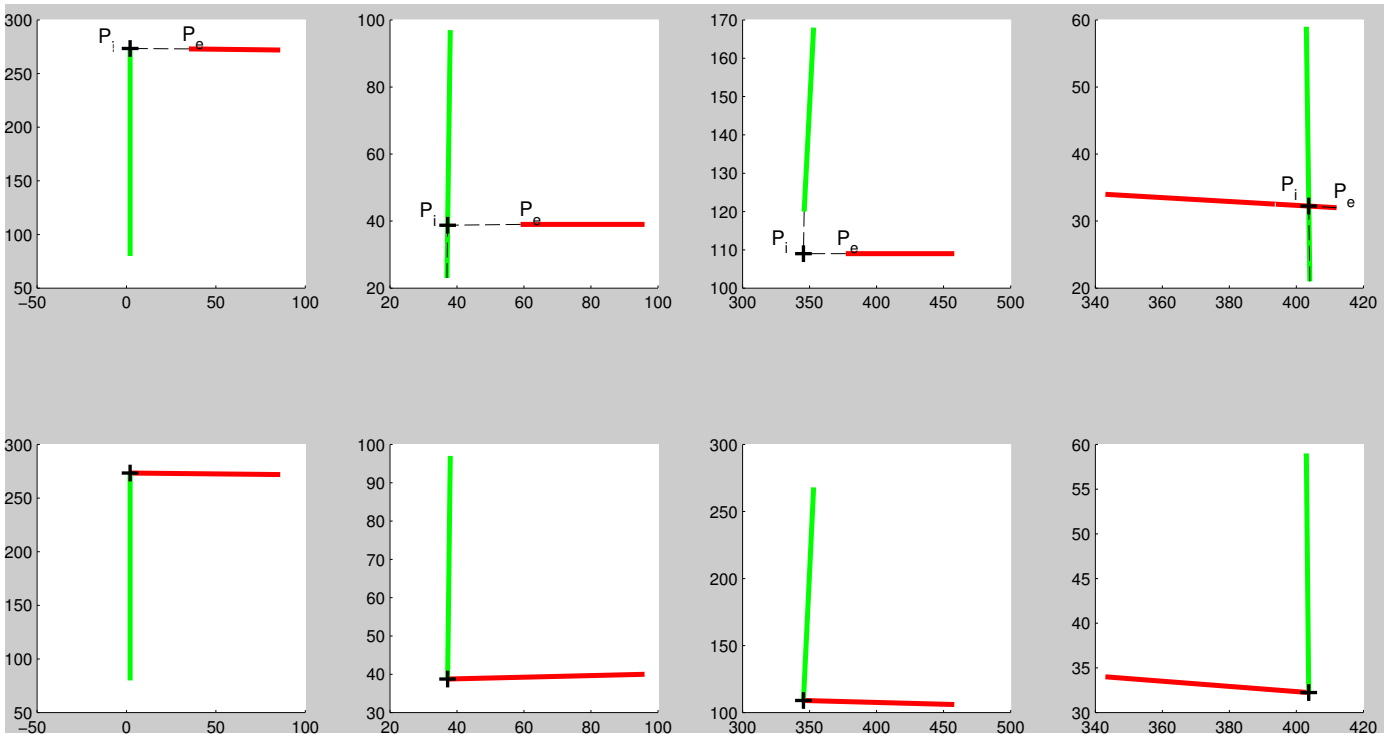
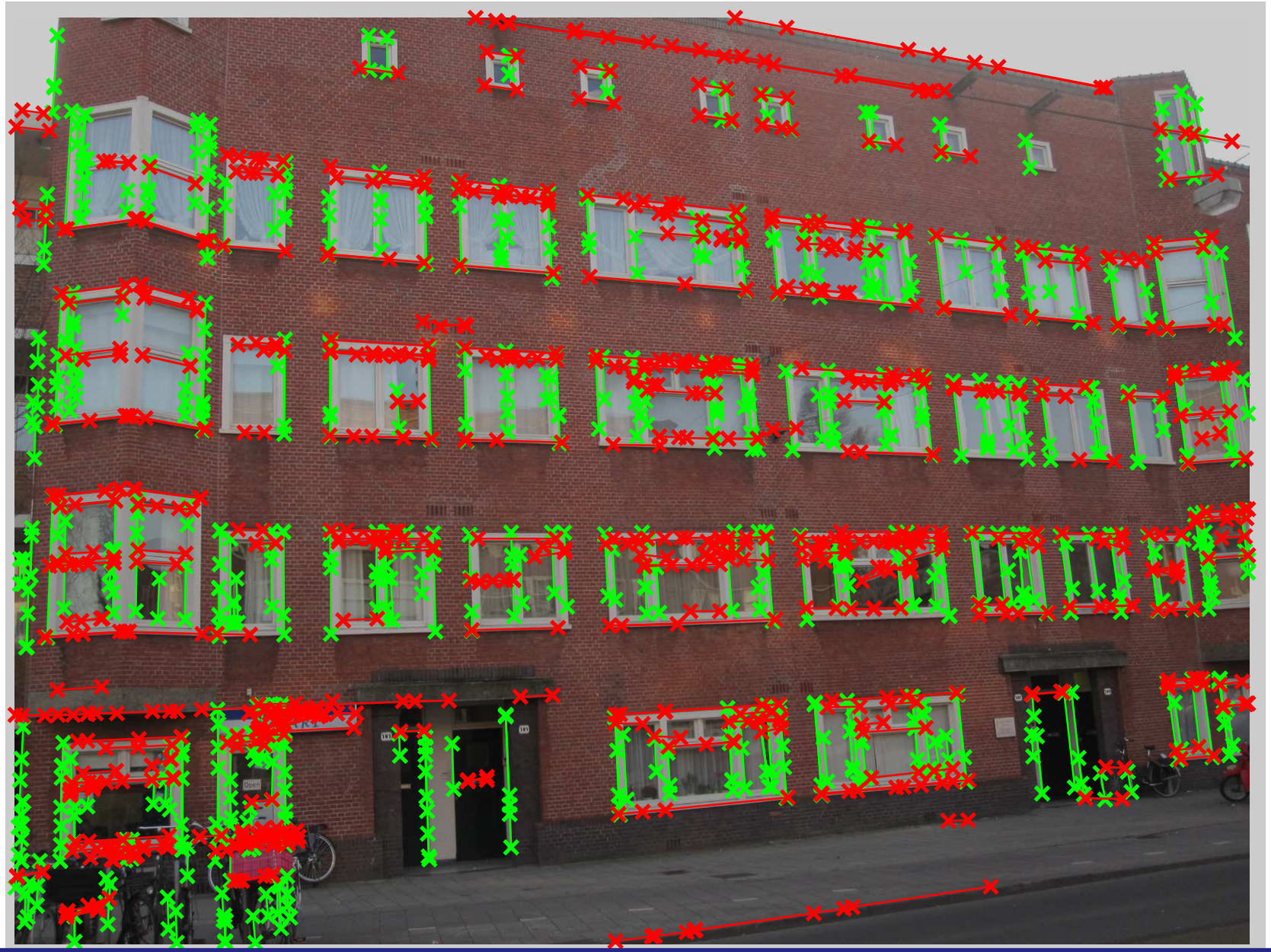
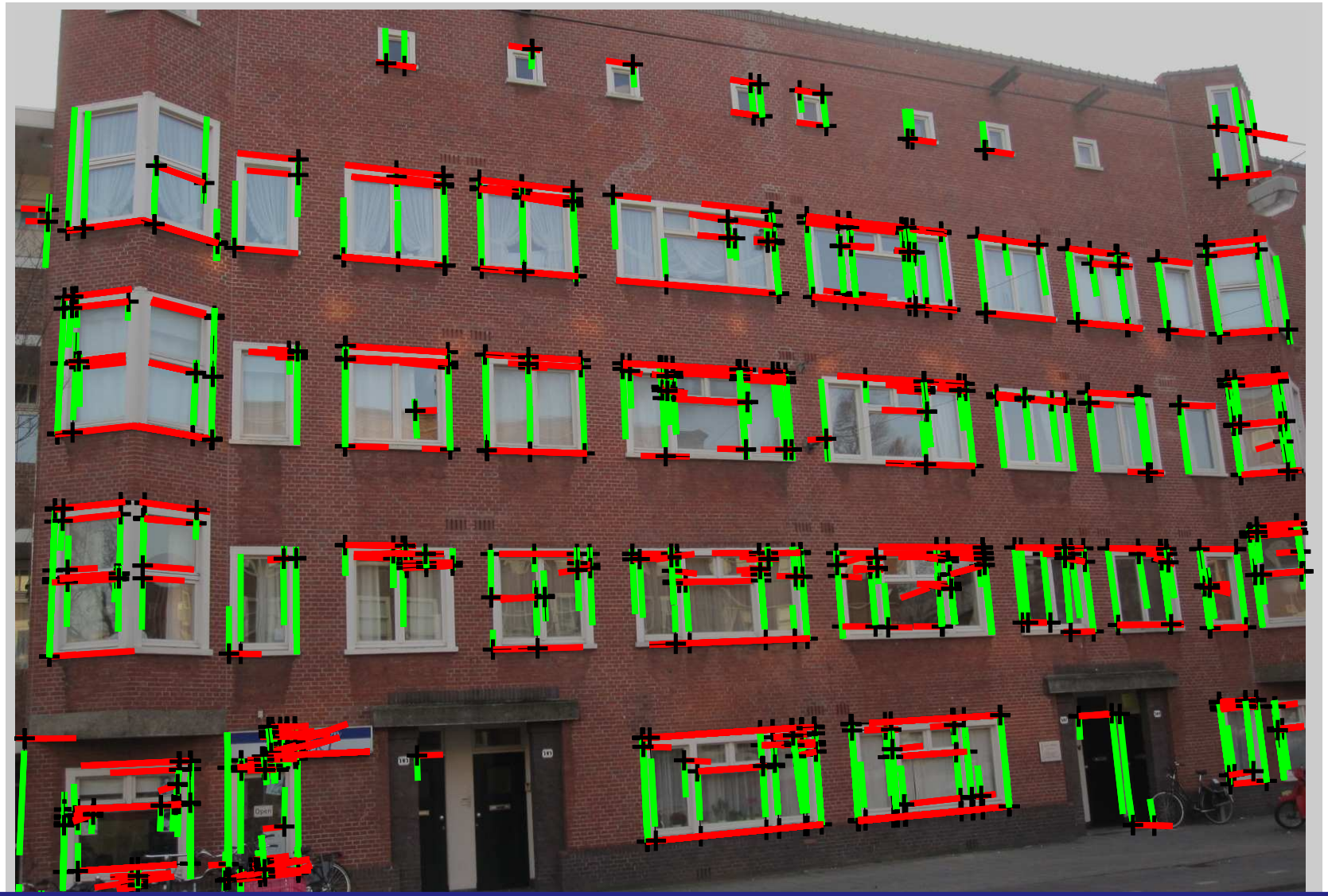
- Tolerate gab or extension





Connected Corners



Window area extraction

- How to extract the window areas?

Window area extraction

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- Mirror from diagonal through endpoints

Window area extraction

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- L-shapes becomes quadrangle shaped window areas

Results

Future research

- L-shapes, U-shapes

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- Analysis of substructure of windows

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- L-shapes, U-shapes
- Analysis of substructure of windows
  - Cluster connected corner on location and length
  - Close connected corners of same size will be grouped
  - Maximum inter-cluster distance correlates with size sub window
  - Assume nr of sub windows to estimate
    - max and min size of window
    - number of clusters
    - max inter-cluster distance

Method II: window detection

- Assumes that the windows are

Method II: window detection

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  - orthogonal

Method II: window detection

- Assumes that the windows are
  - orthogonal
  - aligned

Aligned but not orthogonal

Facade rectification

- 3D model of building gives plane that corresponds to wall

Facade rectification

- 3D model of building gives plane that corresponds to wall
- plane's normal vector: b

Facade rectification

- 3D model of building gives plane that corresponds to wall
- plane's normal vector: b
- (FIT3D) Camera's heading: a

Facade rectification

- 3D model of building gives plane that corresponds to wall
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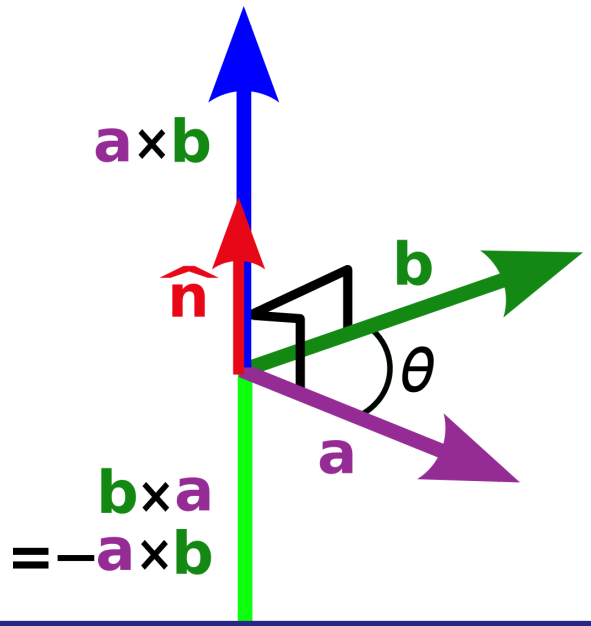

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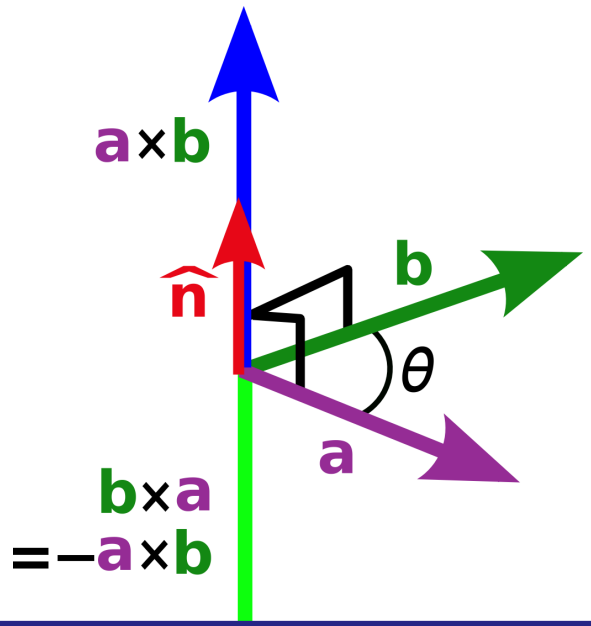

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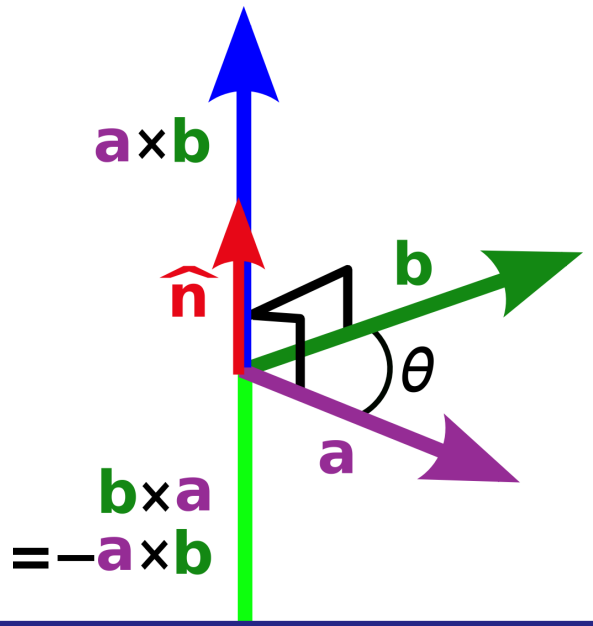

Unrectified facade

Rectified facade


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Extracting the window alignment

- Window alignment line
  - *"A horizontal or vertical line that aligns multiple windows"*

Extracting the window alignment

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Extracting the window alignment

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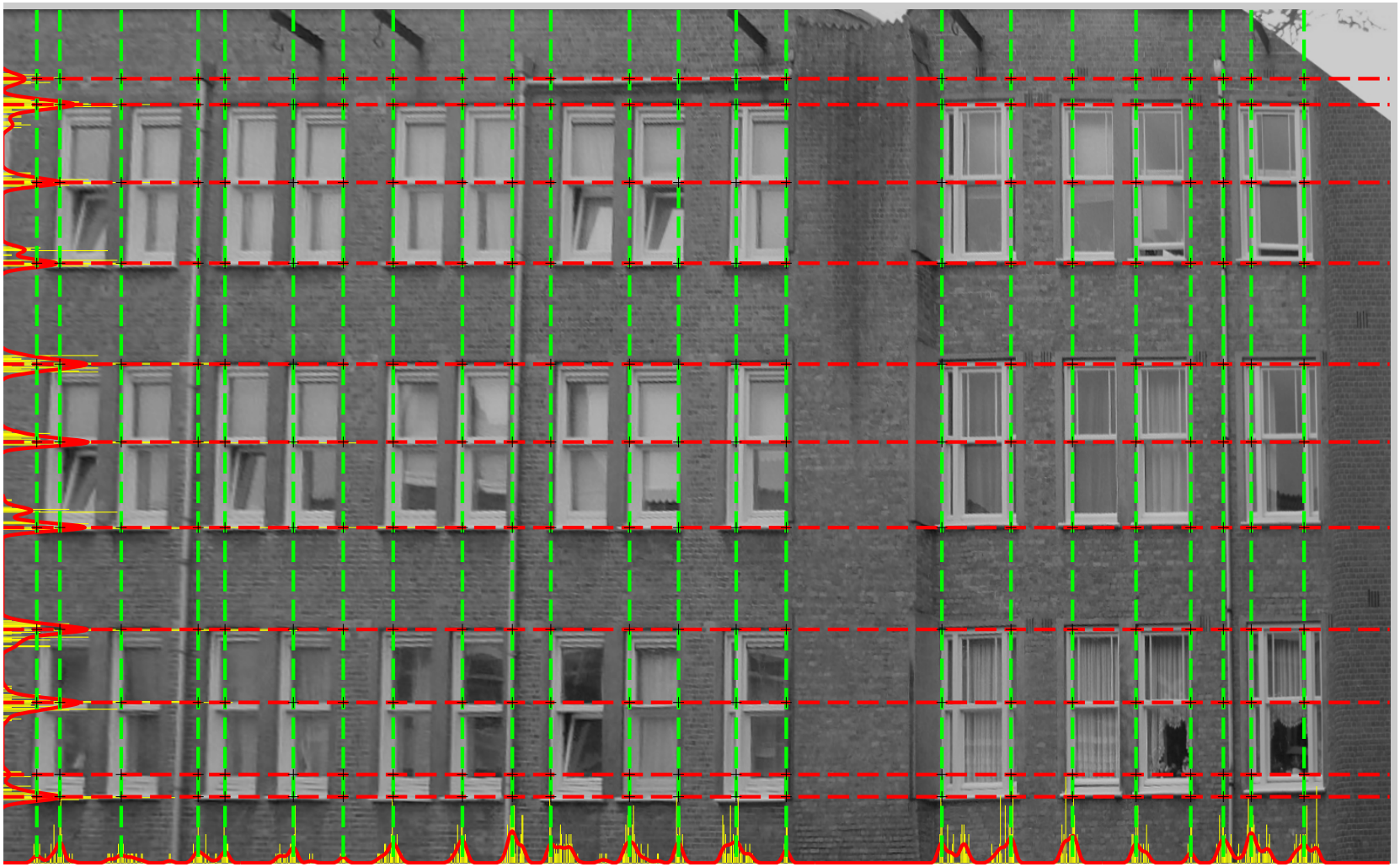
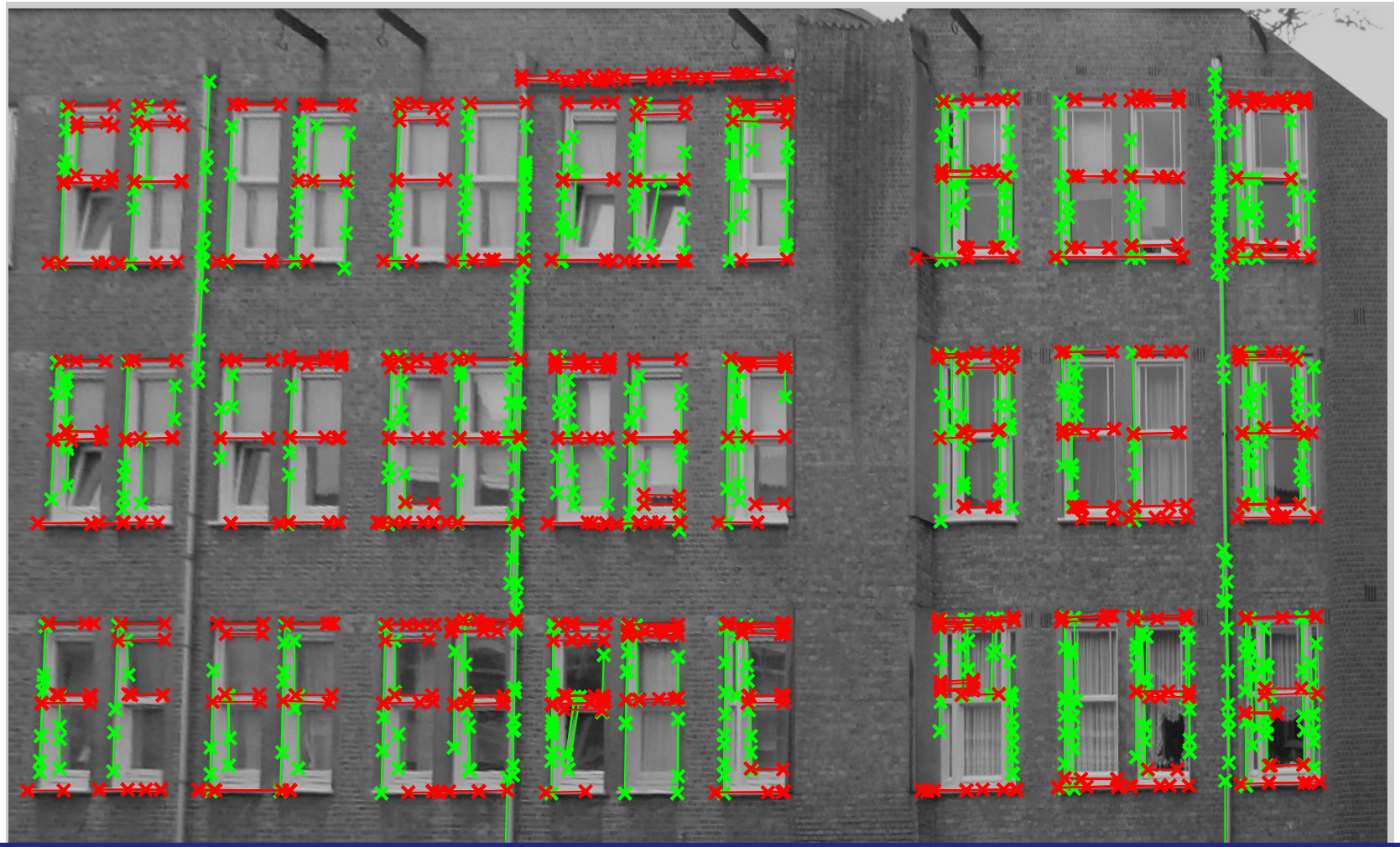
- Alignment lines provide grid of blocks
- Window, non-window areas

Window alignment lines example



The idea

- Amount of Houghlines high at window locations



The algorithm for vertical alignment (columns)

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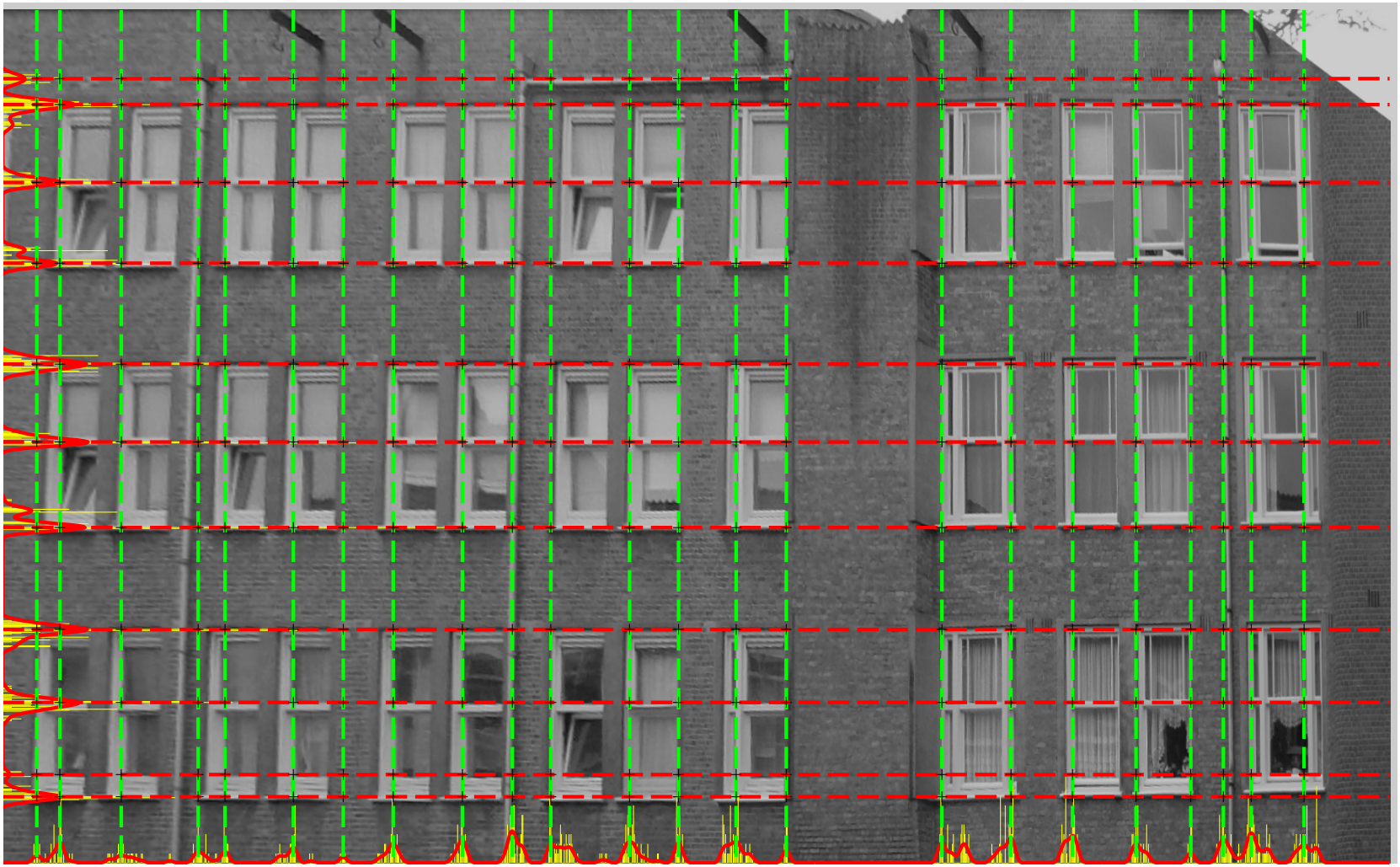
- Create histogram: count number of values on each x-position

Window alignment lines



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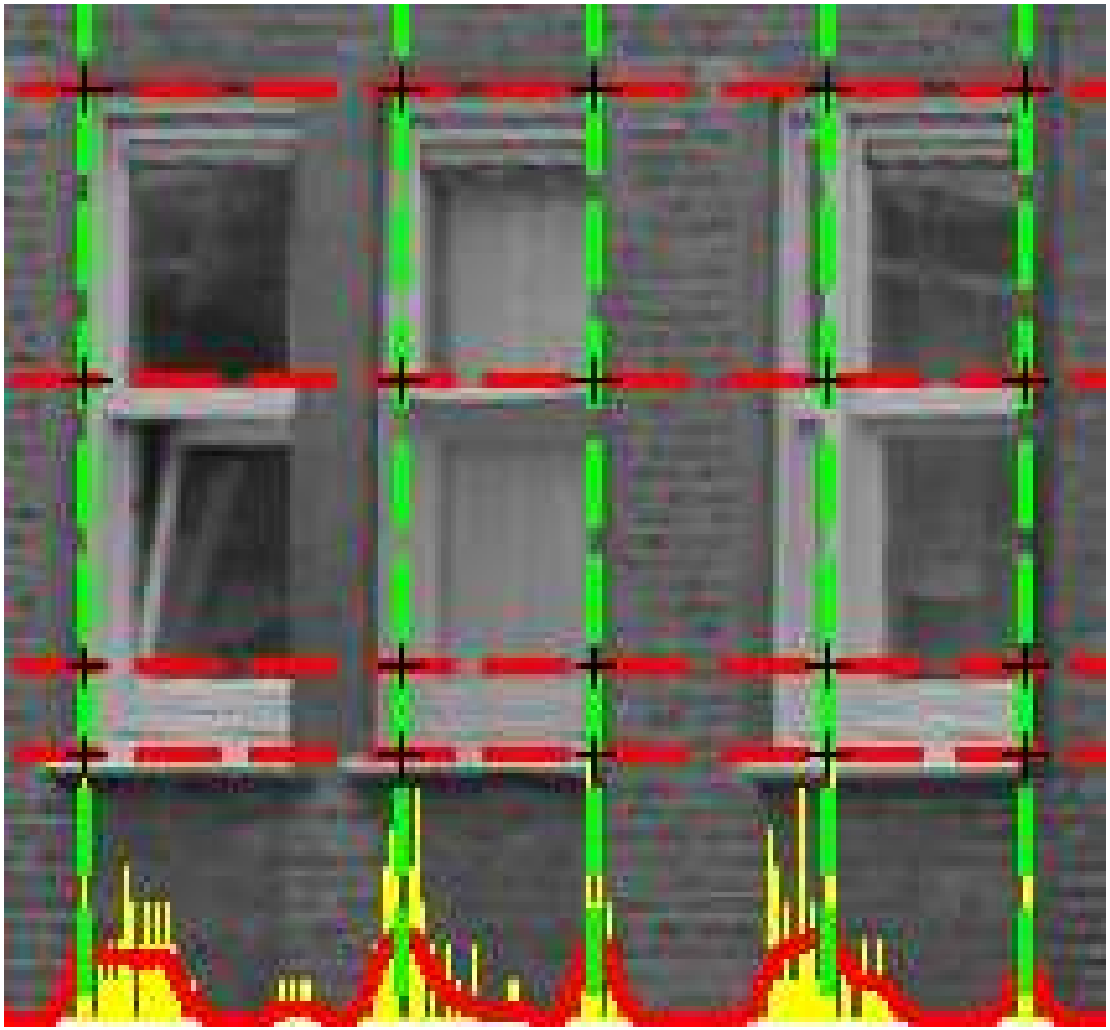
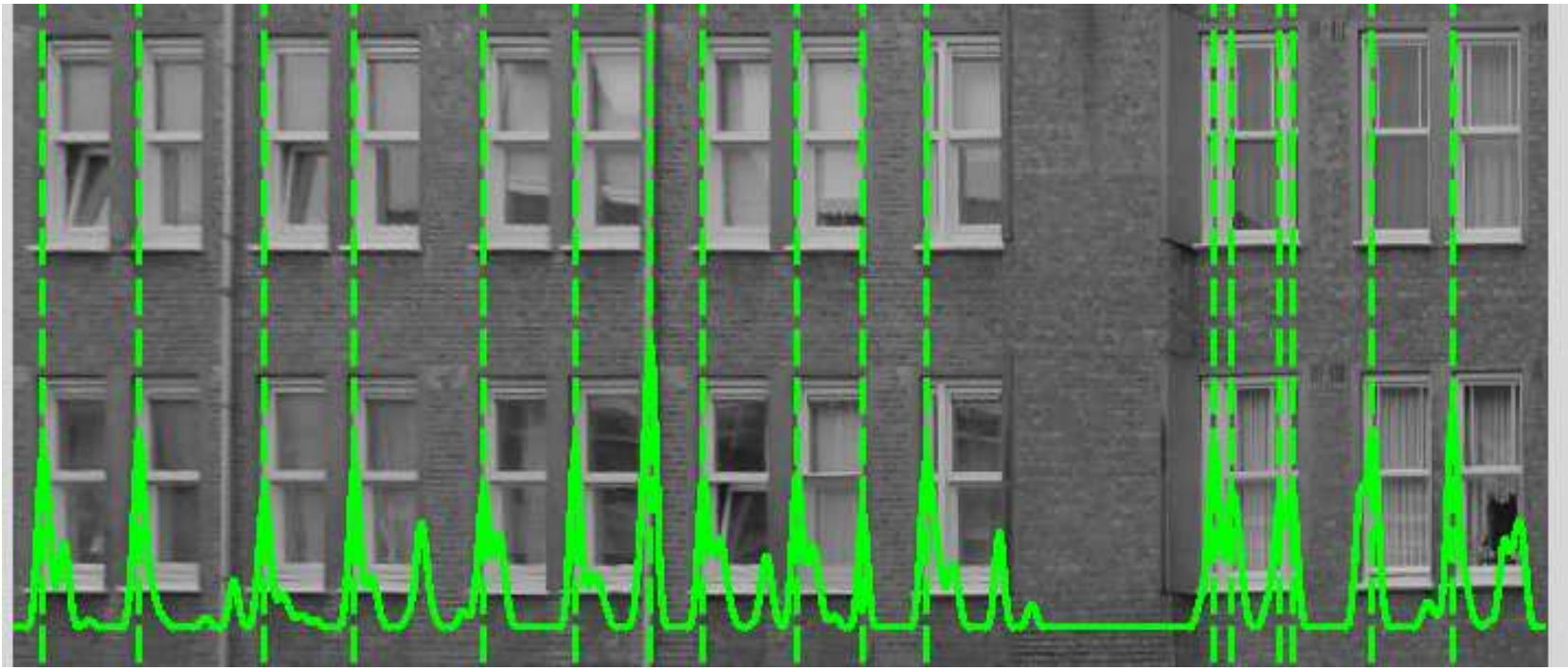


Reasons for improvement

- Window alignment at wrong locations
- Right side of window frame of first 4 columns not found
- Main reason: perspective distortion creates occlusion effect



Alternative window alignment

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  - Line segment endpoints

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  - Histogram shape analysis

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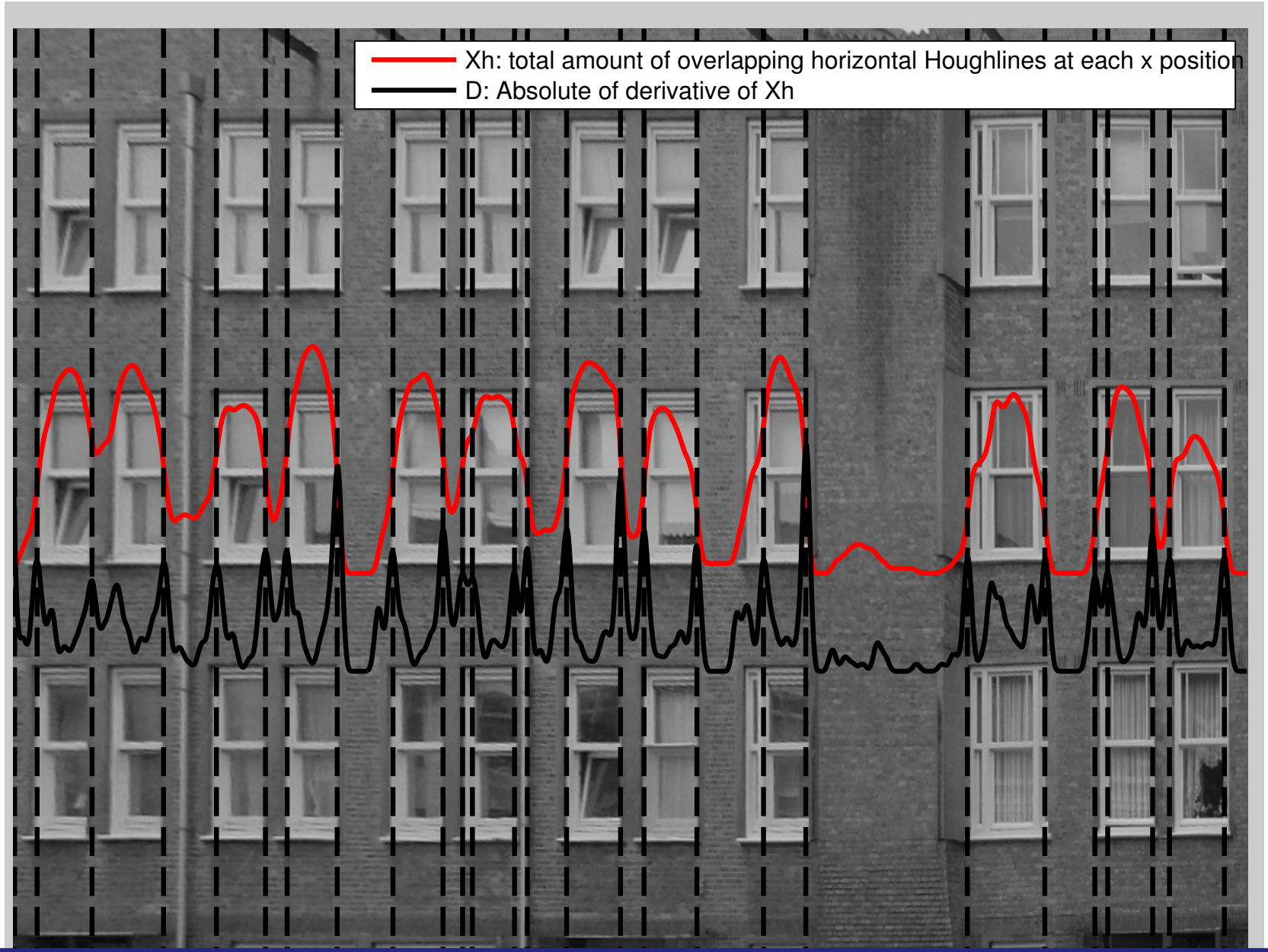
- peak function

$$D = abs(X_h')$$


Xh: total amount of overlapping horizontal Houghlines at each x position
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Fusing the window alignment methods

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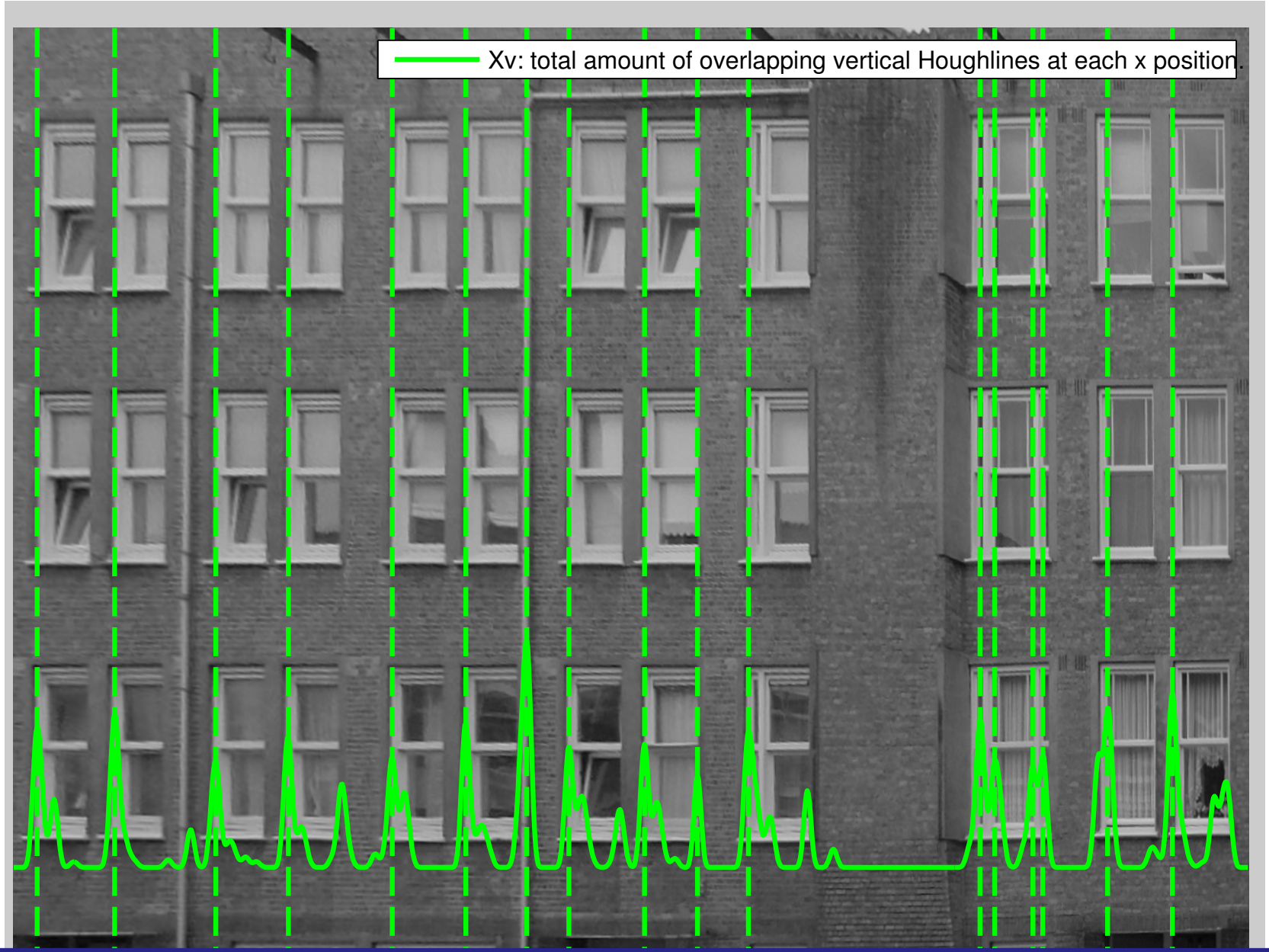
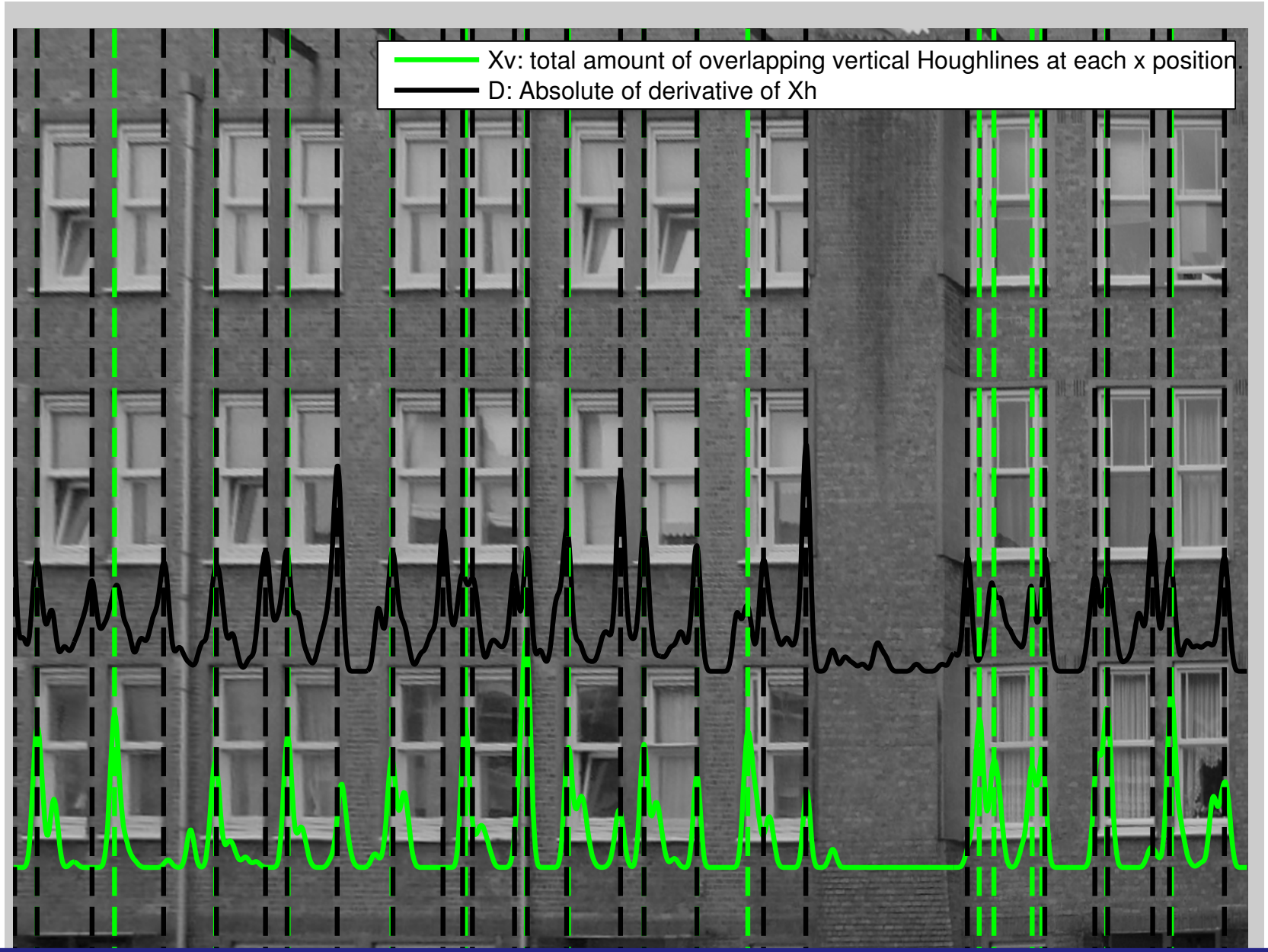
  - Merge peaks that are close


Xv: total amount of overlapping vertical Houghlines at each x position.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Other dataset


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Window classification

- Alignment lines give grid of blocks

Window classification

- Alignment lines give grid of blocks
- Classify blocks

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  - window or non-window block

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    - based on shape of histogram function

Basic window classification assumptions

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Basic window classification assumptions

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  - a block contains a high amount of Houghlines: window
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- The windows are aligned
  - a row or column contains either zero windows or multiple windows

Basic window classification algorithm

- Exploit window alignment:
  - classify full block rows and block columns

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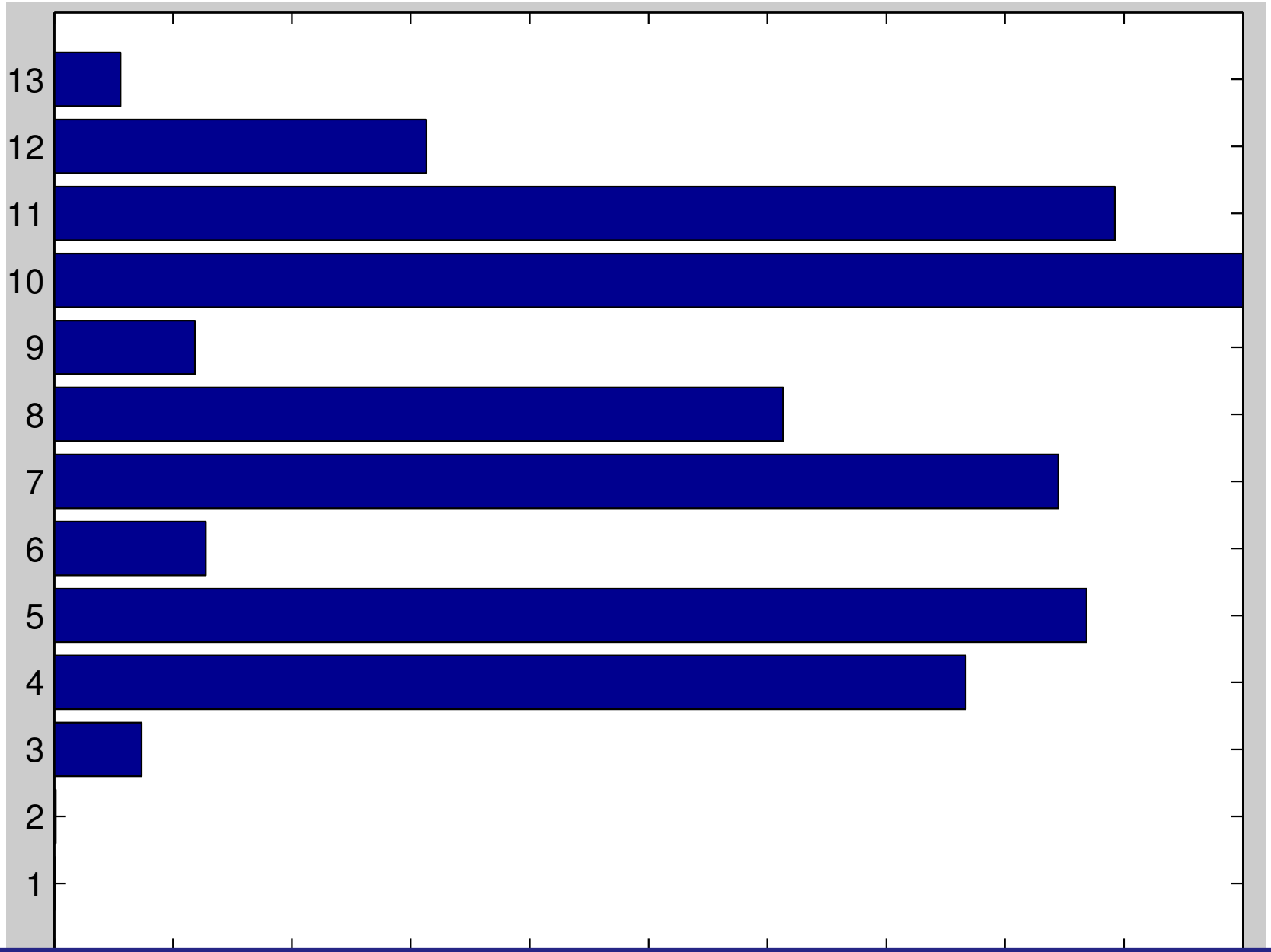
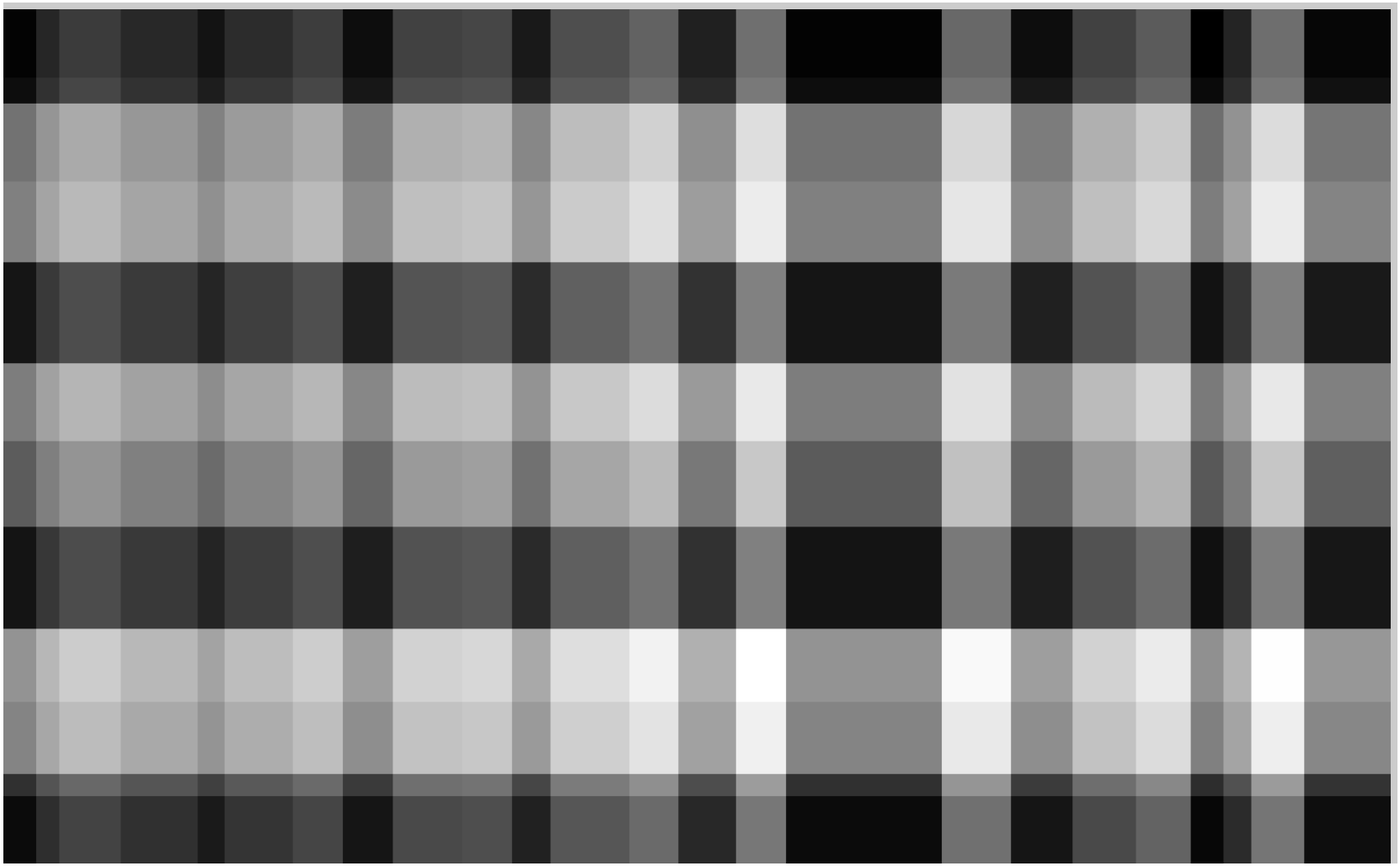
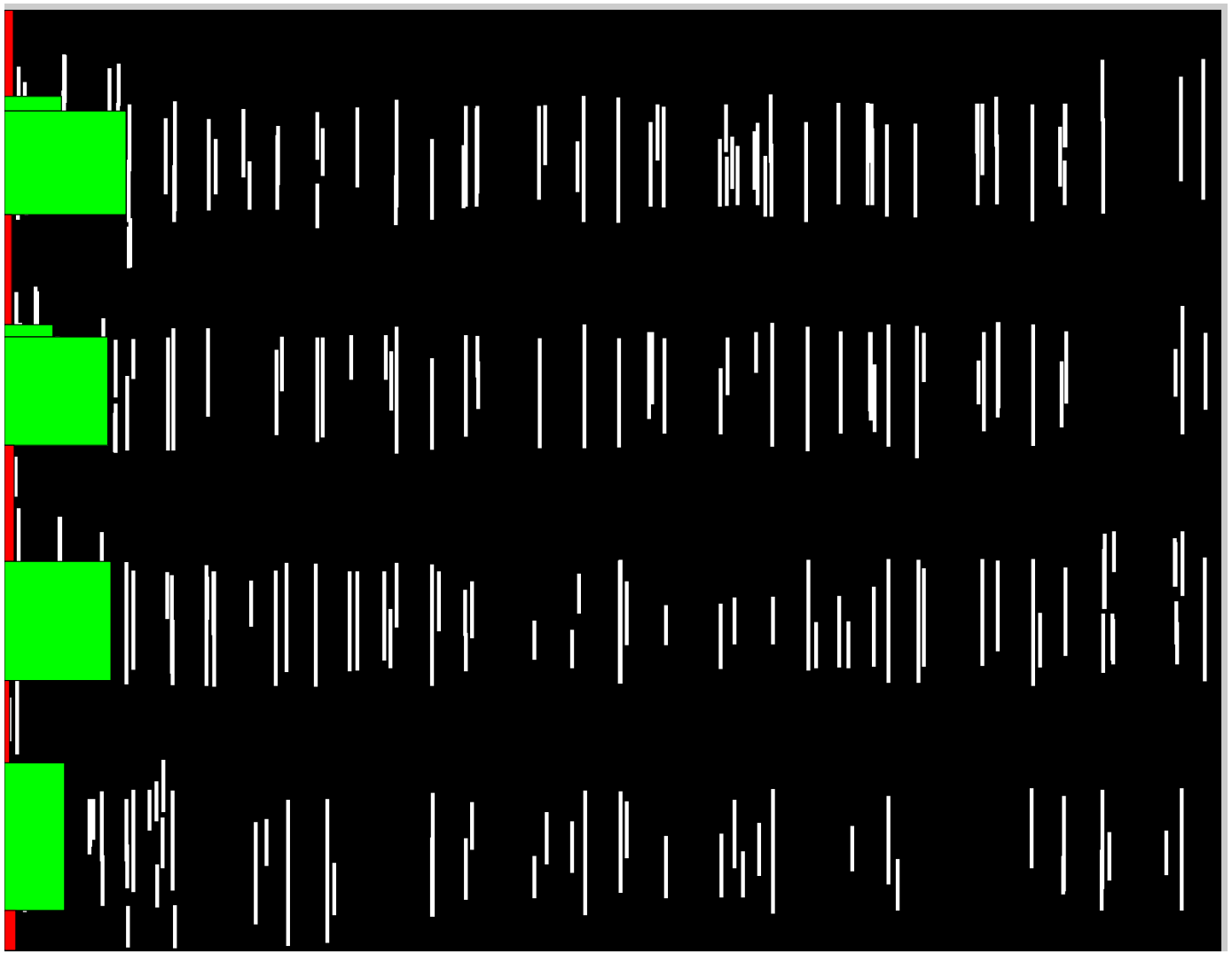
- Output: $||R||$ scalar values that ranks a row being window area or not

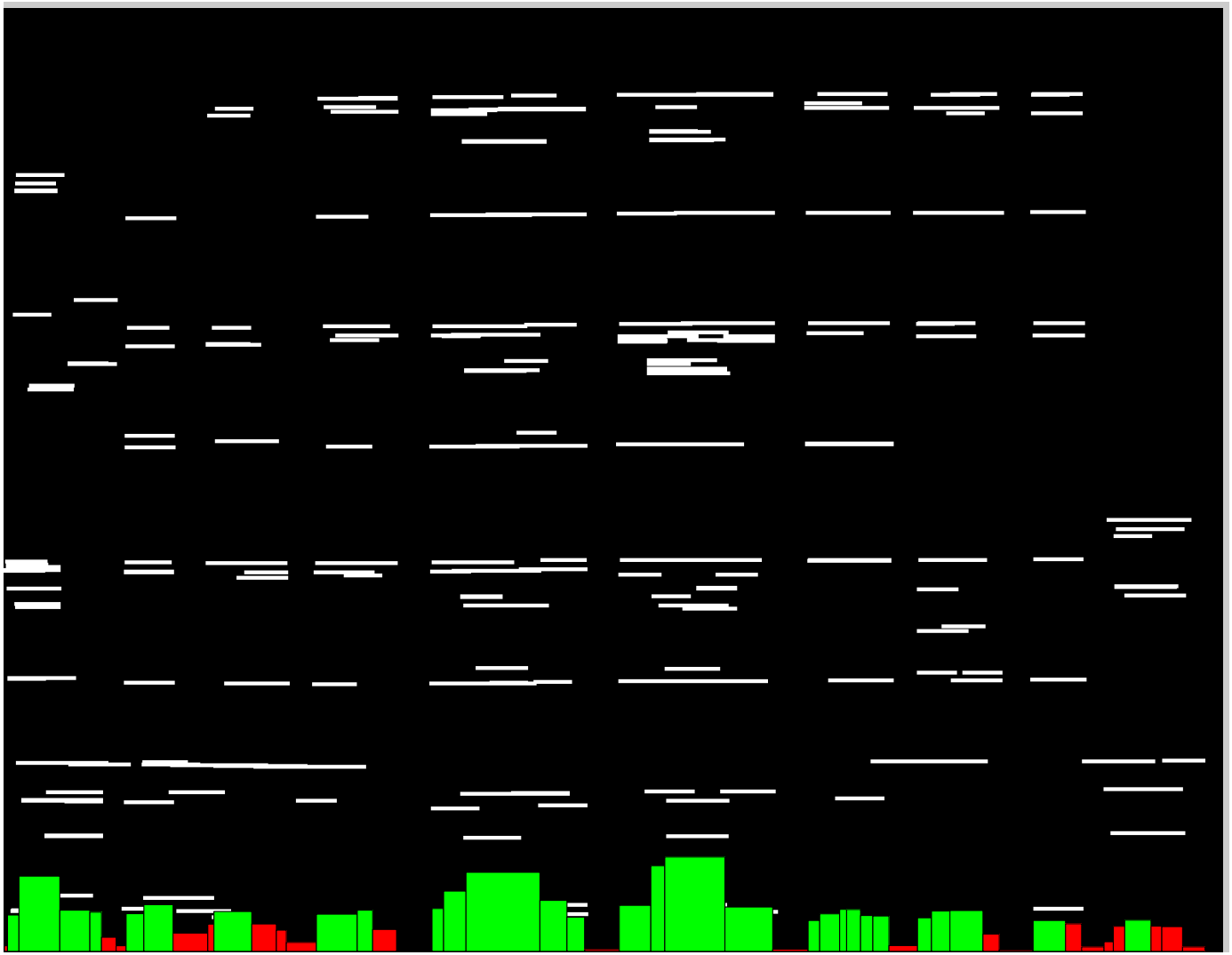

13
12
11
10
9
8
7
6
5
4
3
2
1

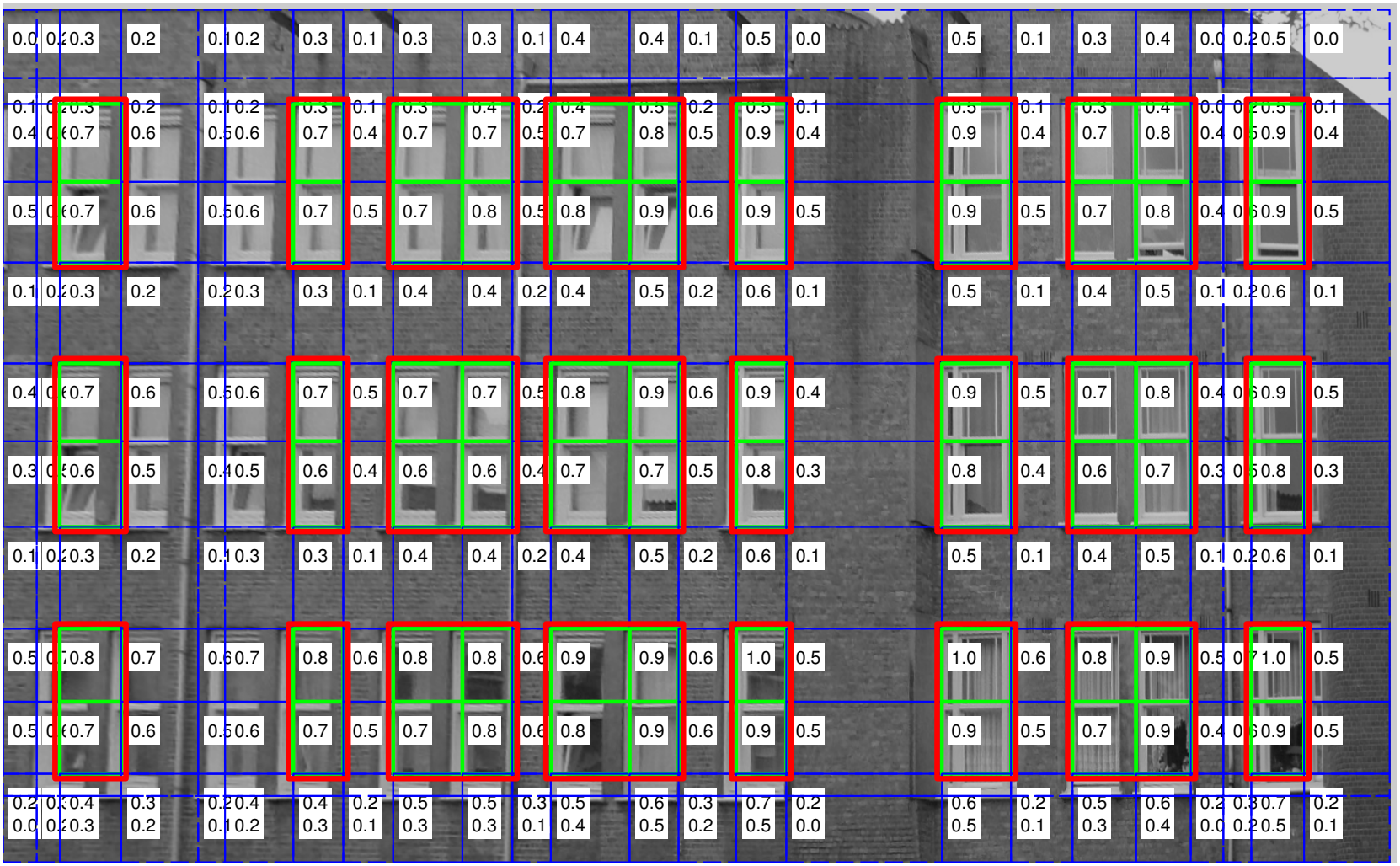


From certainty to classification

- k-means classification on R and C values







Improved window classification

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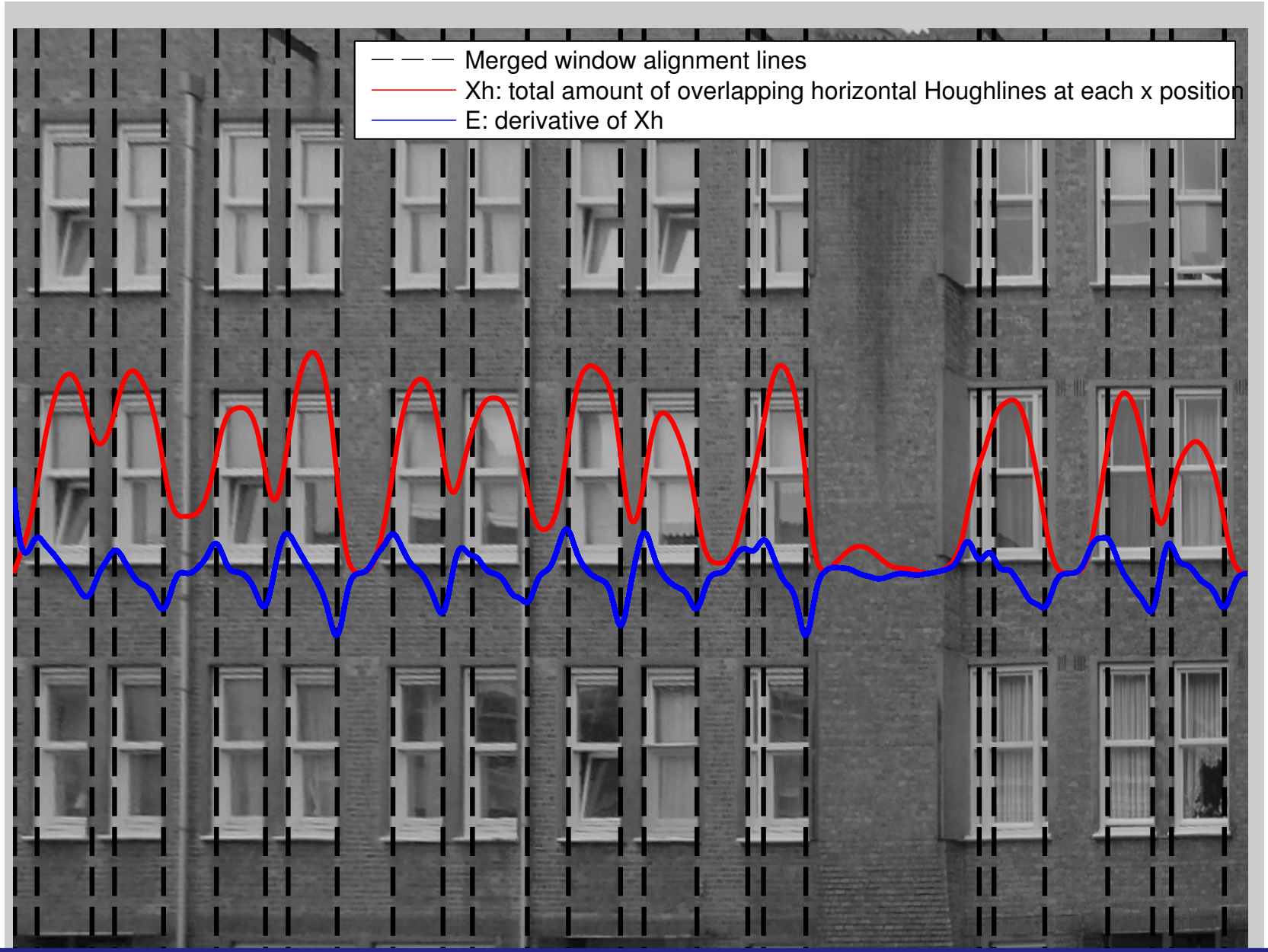
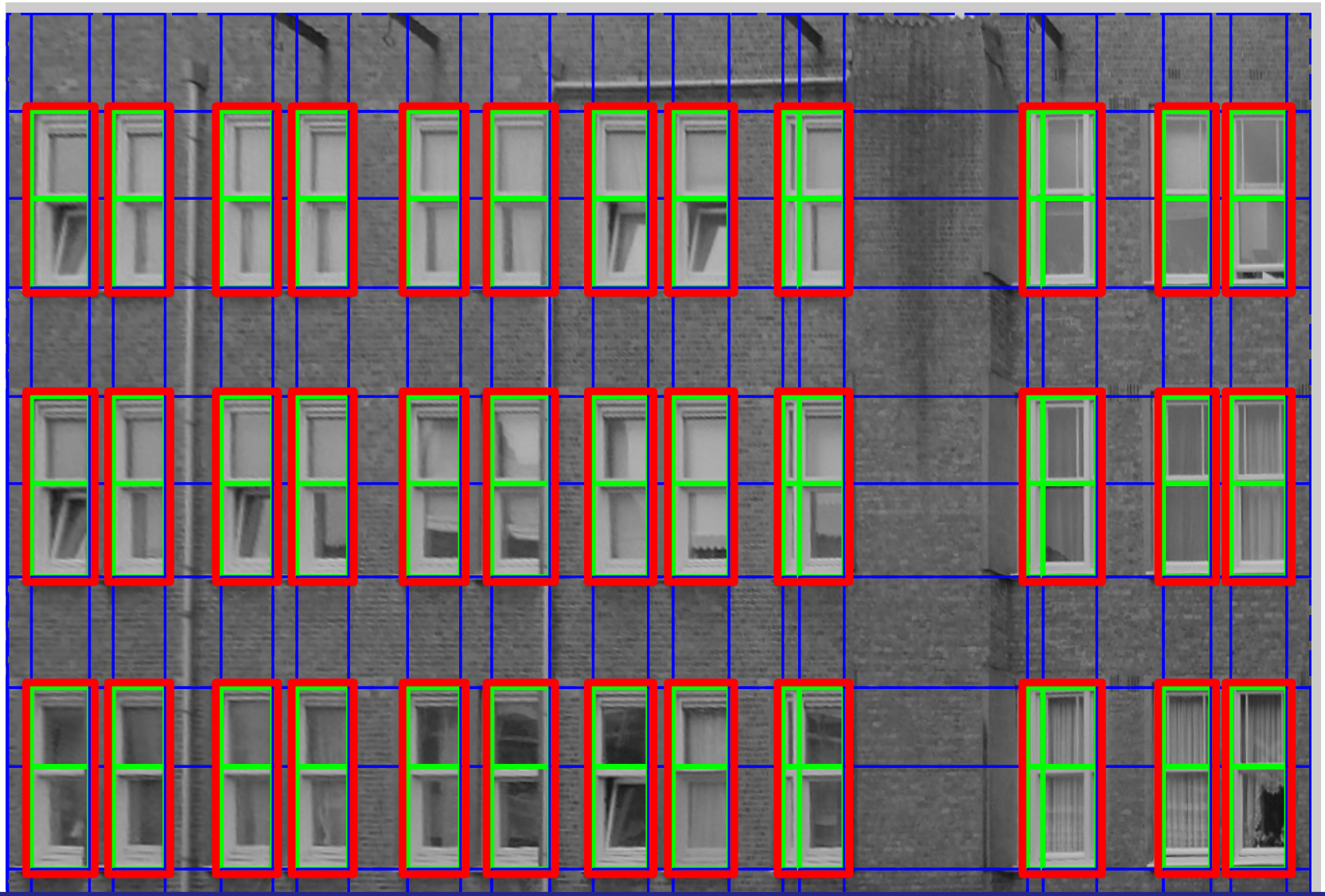

Merged window alignment lines
Xh: total amount of overlapping horizontal Houghlines at each x position
E: derivative of Xh

Result



Conclusion:Connected corner

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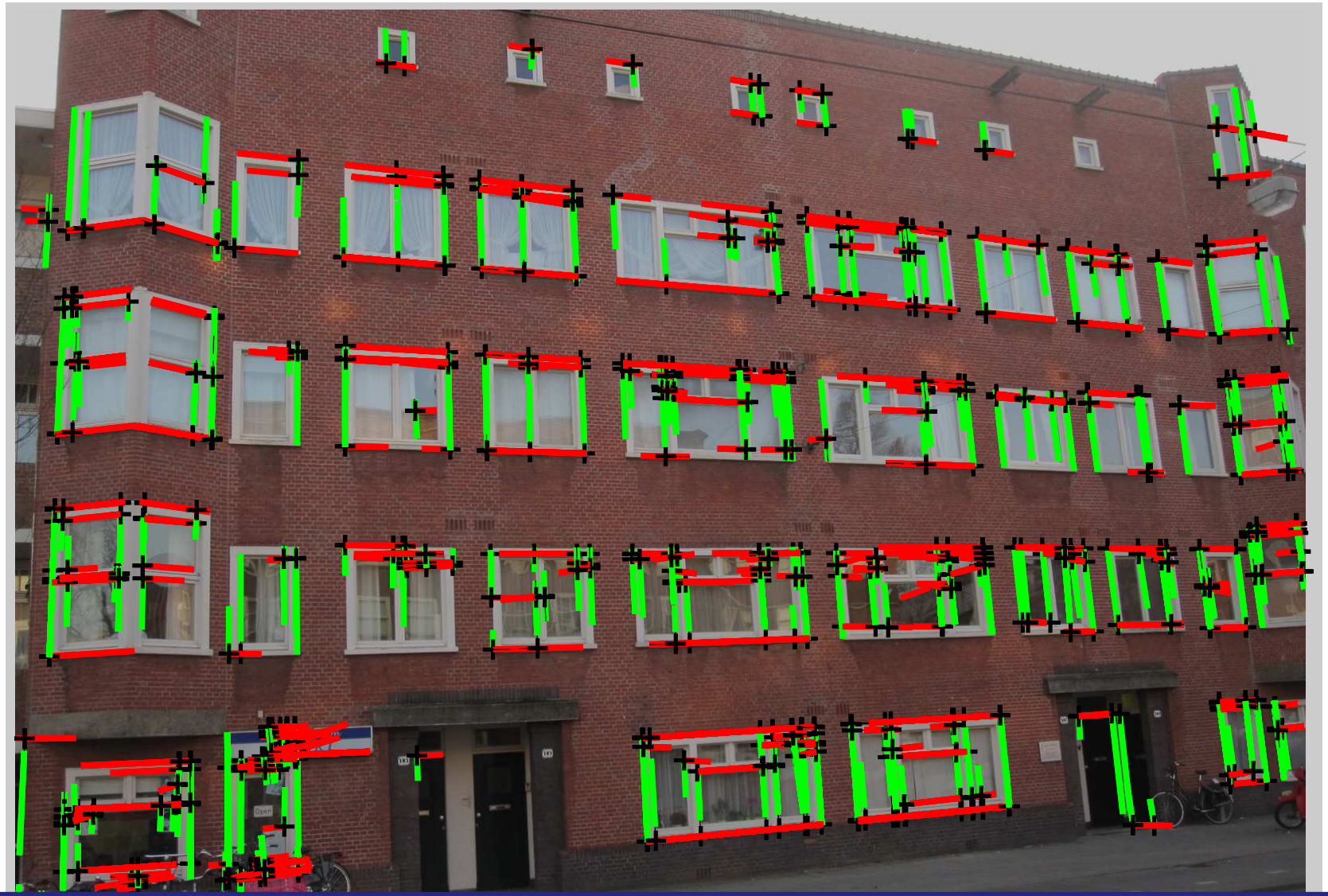

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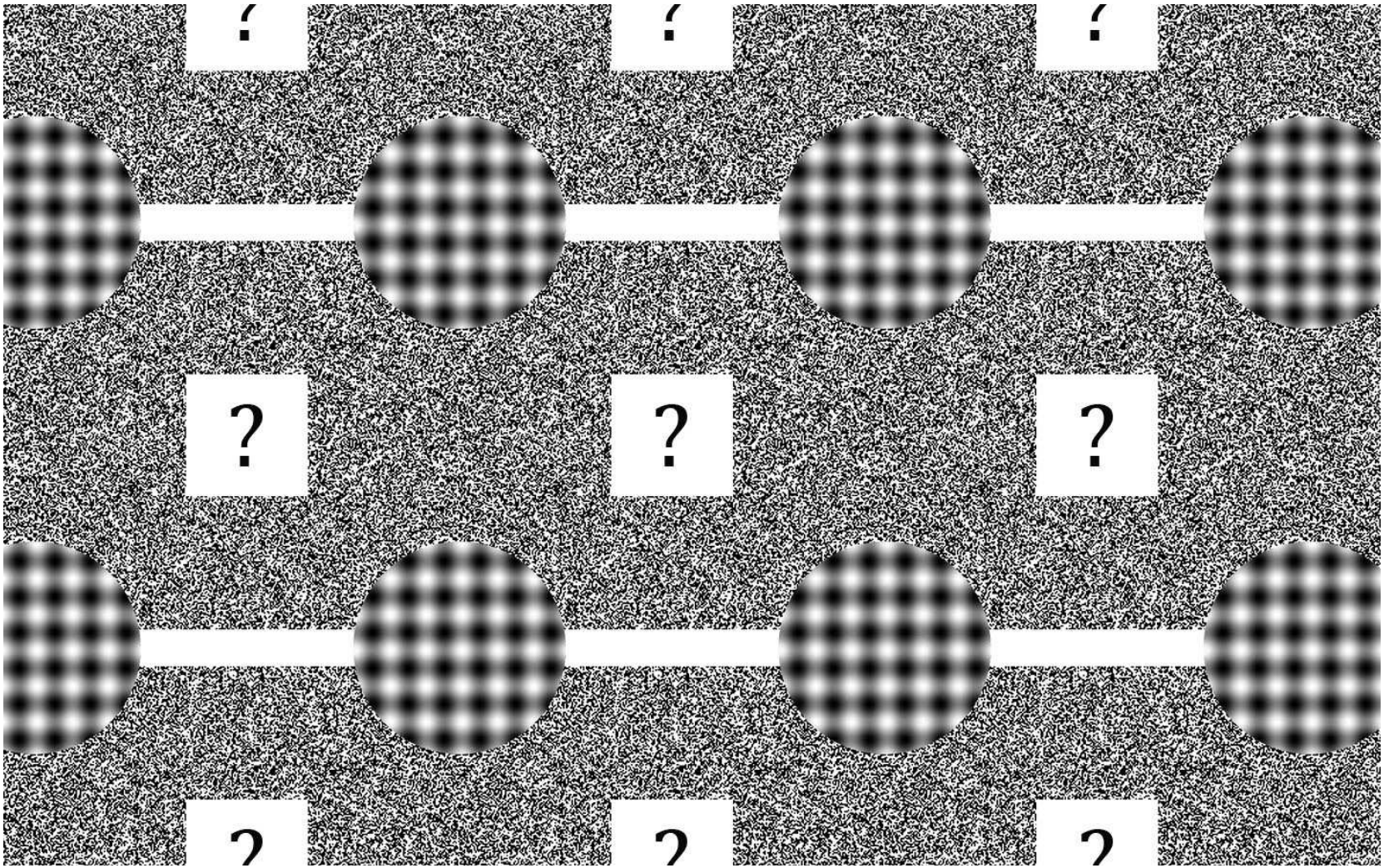
  - The extraction of windows
  - For a set of urban scenes with different properties

Questions



Questions

Questions?