Line segments matching algorithm for BIM Applications

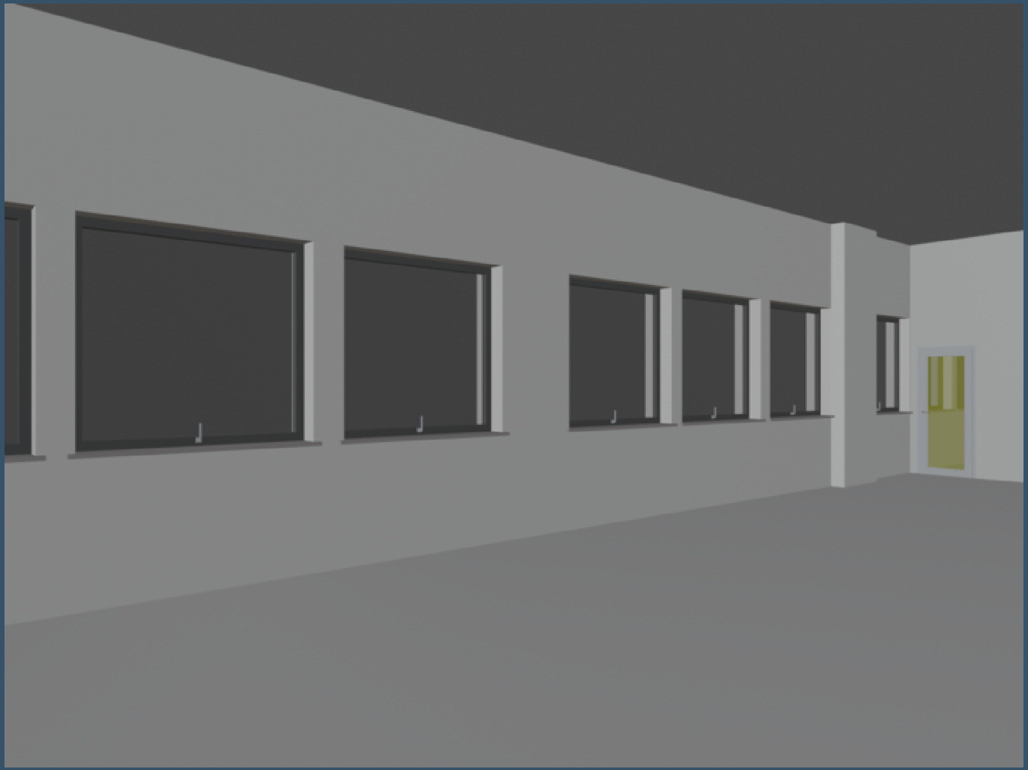
G. Scavello[1], G. Fedele[1], A. Aiello[2]

[1]Università della Calabria, DIMES
[2]Alma s.r.l.

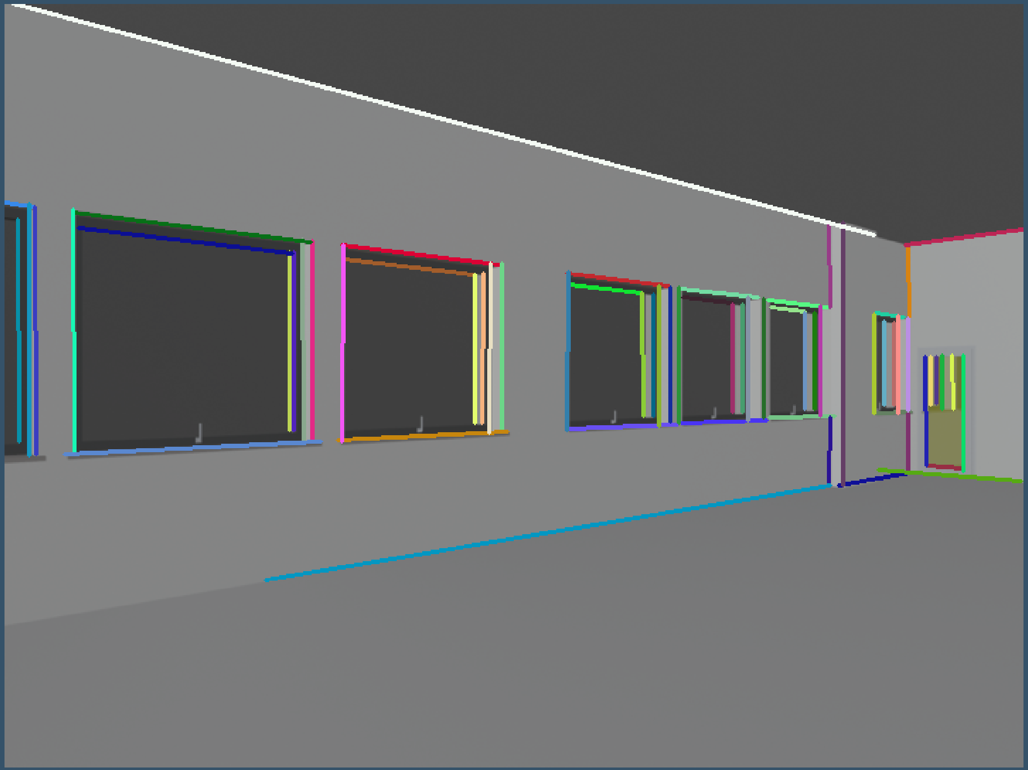
Outline

- Motivations
  - Low textured environments
  - Rendered vs Real images
- State of the art
  - Issues
- Contributions
  - Line segments extraction
  - Line segments clustering
  - Line segments descriptors
  - Matching strategy
- Results and future works

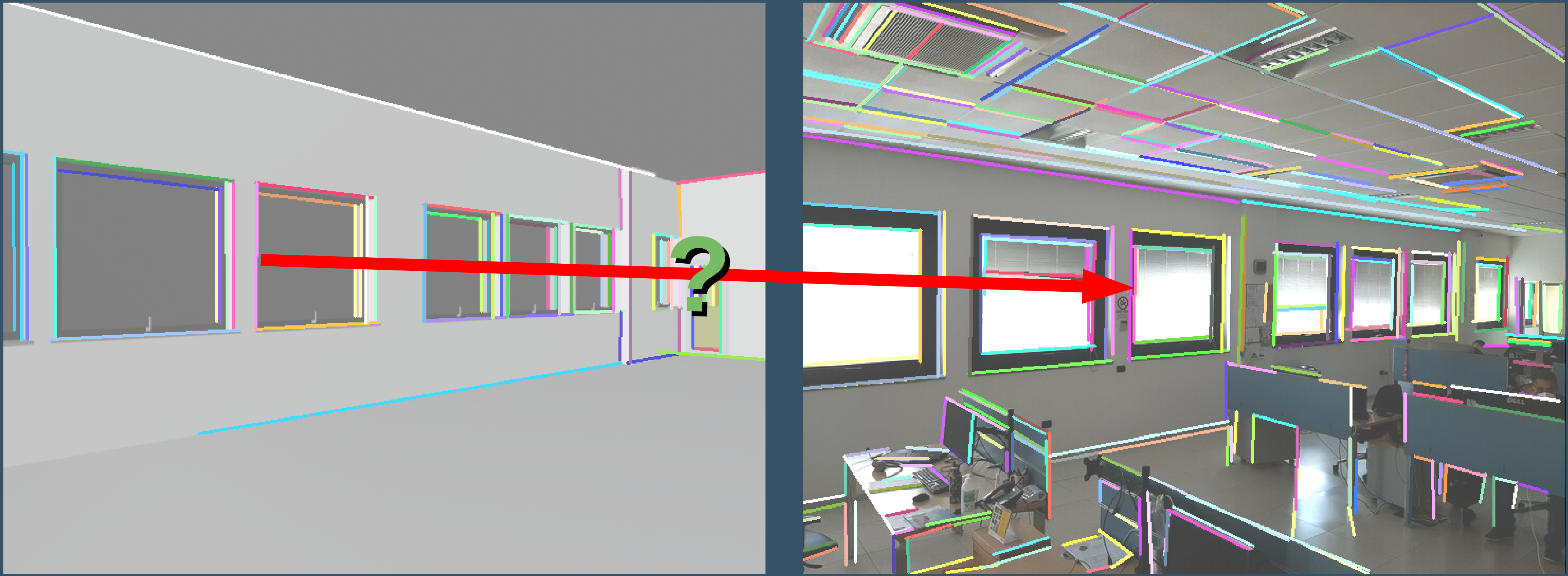
Motivations



Motivations



Motivations



State of the Art

State of the Art

- Underlying assumption
  - Images are from the same source (camera)

State of the Art

- Underlying assumption
  - Images are from the same source (camera)
- Descriptors mainly based on gray/color value
  - High informative content

State of the Art

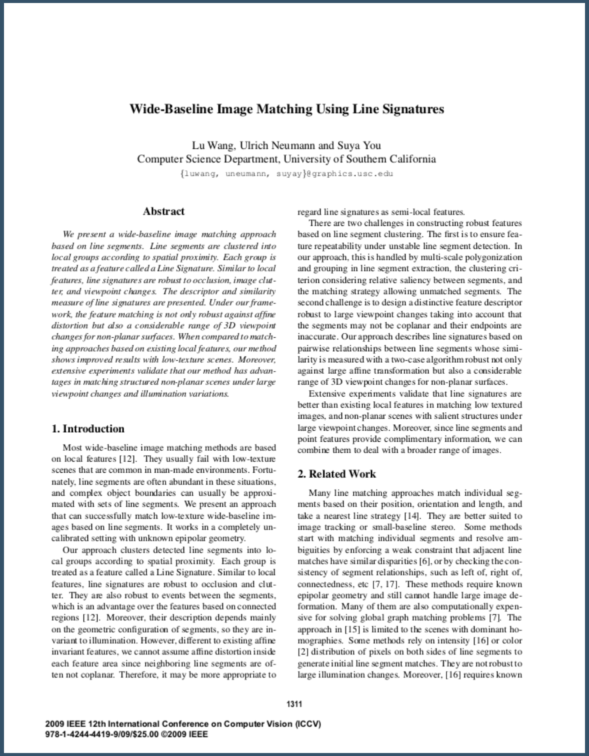
- Underlying assumption
  - Images are from the same source (camera)
- Descriptors mainly based on gray/color value
  - High informative content
- Geometry constraints
  - Accurate Matching

State of the Art

- Underlying assumption
  - Images are from the same source (camera)
- Descriptors mainly based on gray/color value
  - High informative content
- Geometry constraints
  - Accurate Matching

State of the Art

- Underlying assumption
  - Images are from the same source (camera)
- Descriptors mainly based on gray/color value
  - High informative content
- Geometry constraints
  - Accurate Matching



Wide-Baseline Image Matching Using Line Signatures

Lu Wang, Ulrich Neumann and Suya You
Computer Science Department, University of Southern California
{luwang, uneumann, suyay}@graphics.usc.edu

Abstract

We present a wide-baseline image matching approach based on line segments. Line segments are clustered into local groups according to spatial proximity. Each group is treated as a feature called a Line Signature. Similar to local features, line signatures are robust to occlusion, image clutter, and viewpoint changes. The descriptor and similarity measure of line signatures are presented. Under our framework, the feature matching is not only robust against affine distortion but also a considerable range of 3D viewpoint changes for non-planar surfaces. When compared to matching approaches based on existing local features, our method shows improved results with low-texture scenes. Moreover, extensive experiments validate that our method has advantages in matching structured non-planar scenes under large viewpoint changes and illumination variations.

1. Introduction

Most wide-baseline image matching methods are based on local features [12]. They usually fail with low-texture scenes that are common in man-made environments. Fortunately, line segments are often abundant in these situations, and complex object boundaries can usually be approximated with sets of line segments. We present an approach that can successfully match low-texture wide-baseline images based on line segments. It works in a completely uncalibrated setting with unknown epipolar geometry.

Our approach clusters detected line segments into local groups according to spatial proximity. Each group is treated as a feature called a Line Signature. Similar to local features, line signatures are robust to occlusion and clutter. They are also robust to events between the segments, which is an advantage over the features based on connected regions [12]. Moreover, their description depends mainly on the geometric configuration of segments, so they are invariant to illumination. However, different to existing affine invariant features, we cannot assume affine distortion inside each feature area since neighboring line segments are often not coplanar. Therefore, it may be more appropriate to regard line signatures as semi-local features.

There are two challenges in constructing robust features based on line segment clustering. The first is to ensure feature repeatability under unstable line segment detection. In our approach, this is handled by multi-scale polygonization and grouping in line segment extraction, the clustering criterion considering relative saliency between segments, and the matching strategy allowing unmatched segments. The second challenge is to design a distinctive feature descriptor robust to large viewpoint changes taking into account that the segments may not be coplanar and their endpoints are inaccurate. Our approach describes line signatures based on pairwise relationships between line segments whose similarity is measured with a two-case algorithm robust not only against large affine transformation but also a considerable range of 3D viewpoint changes for non-planar surfaces.

Extensive experiments validate that line signatures are better than existing local features in matching low textured images, and non-planar scenes with salient structures under large viewpoint changes. Moreover, since line segments and point features provide complimentary information, we can combine them to deal with a broader range of images.

2. Related Work

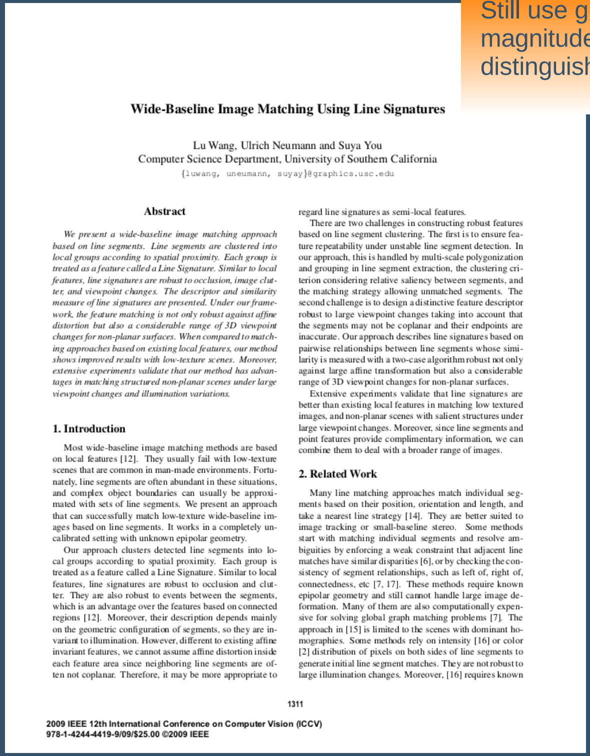
Many line matching approaches match individual segments based on their position, orientation and length, and take a nearest line strategy [14]. They are better suited to image tracking or small-baseline stereo. Some methods start with matching individual segments and resolve ambiguities by enforcing a weak constraint that adjacent line matches have similar disparities [6], or by checking the consistency of segment relationships, such as left of, right of, connectedness, etc [7, 17]. These methods require known epipolar geometry and still cannot handle large image deformation. Many of them are also computationally expensive for solving global graph matching problems [7]. The approach in [15] is limited to the scenes with dominant homographies. Some methods rely on intensity [16] or color [2] distribution of pixels on both sides of line segments to generate initial line segment matches. They are not robust to large illumination changes. Moreover, [16] requires known

2009 IEEE 12th International Conference on Computer Vision (ICCV)
978-1-4244-4419-9/09/$25.00 ©2009 IEEE

State of the Art

- Underlying assumption
  - Images are from the same source (camera)
- Descriptors mainly based on gray/color value
  - High informative content
- Geometry constraints
  - Accurate Matching

Still use gradient magnitude for better distinguishing matching



Wide-Baseline Image Matching Using Line Signatures

Lu Wang, Ulrich Neumann and Suya You
Computer Science Department, University of Southern California
{luwang, uneumann, suyay}@graphics.usc.edu

Abstract

We present a wide-baseline image matching approach based on line segments. Line segments are clustered into local groups according to spatial proximity. Each group is treated as a feature called a Line Signature. Similar to local features, line signatures are robust to occlusion, image clutter, and viewpoint changes. The descriptor and similarity measure of line signatures are presented. Under our framework, the feature matching is not only robust against affine distortion but also a considerable range of 3D viewpoint changes for non-planar surfaces. When compared to matching approaches based on existing local features, our method shows improved results with low-texture scenes. Moreover, extensive experiments validate that our method has advantages in matching structured non-planar scenes under large viewpoint changes and illumination variations.

1. Introduction

Most wide-baseline image matching methods are based on local features [12]. They usually fail with low-texture scenes that are common in man-made environments. Fortunately, line segments are often abundant in these situations, and complex object boundaries can usually be approximated with sets of line segments. We present an approach that can successfully match low-texture wide-baseline images based on line segments. It works in a completely uncalibrated setting with unknown epipolar geometry.

Our approach clusters detected line segments into local groups according to spatial proximity. Each group is treated as a feature called a Line Signature. Similar to local features, line signatures are robust to occlusion and clutter. They are also robust to events between the segments, which is an advantage over the features based on connected regions [12]. Moreover, their description depends mainly on the geometric configuration of segments, so they are invariant to illumination. However, different to existing affine invariant features, we cannot assume affine distortion inside each feature area since neighboring line segments are often not coplanar. Therefore, it may be more appropriate to regard line signatures as semi-local features.

There are two challenges in constructing robust features based on line segment clustering. The first is to ensure feature repeatability under unstable line segment detection. In our approach, this is handled by multi-scale polygonization and grouping in line segment extraction, the clustering criterion considering relative saliency between segments, and the matching strategy allowing unmatched segments. The second challenge is to design a distinctive feature descriptor robust to large viewpoint changes taking into account that the segments may not be coplanar and their endpoints are inaccurate. Our approach describes line signatures based on pairwise relationships between line segments whose similarity is measured with a two-case algorithm robust not only against large affine transformation but also a considerable range of 3D viewpoint changes for non-planar surfaces.

Extensive experiments validate that line signatures are better than existing local features in matching low textured images, and non-planar scenes with salient structures under large viewpoint changes. Moreover, since line segments and point features provide complimentary information, we can combine them to deal with a broader range of images.

2. Related Work

Many line matching approaches match individual segments based on their position, orientation and length, and take a nearest line strategy [14]. They are better suited to image tracking or small-baseline stereo. Some methods start with matching individual segments and resolve ambiguities by enforcing a weak constraint that adjacent line matches have similar disparities [6], or by checking the consistency of segment relationships, such as left of, right of, connectedness, etc [7, 17]. These methods require known epipolar geometry and still cannot handle large image deformation. Many of them are also computationally expensive for solving global graph matching problems [7]. The approach in [15] is limited to the scenes with dominant homographies. Some methods rely on intensity [16] or color [2] distribution of pixels on both sides of line segments to generate initial line segment matches. They are not robust to large illumination changes. Moreover, [16] requires known

2009 IEEE 12th International Conference on Computer Vision (ICCV)
978-1-4244-4419-9/09/$25.00 ©2009 IEEE

State of the Art

- Underlying assumption
  - Images are from the same source (camera)
- Descriptors mainly based on gray/color value
  - High informative content
- Geometry constraints
  - Accurate Matching

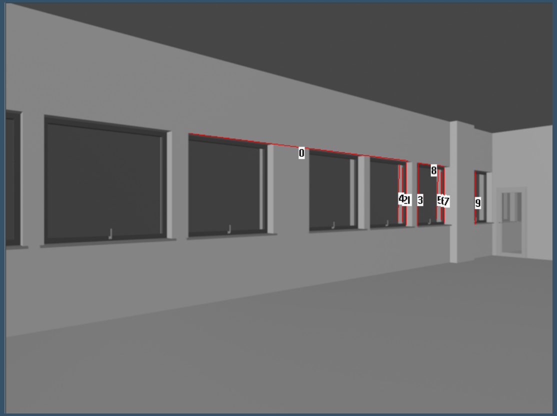
Kai Li, Jian Yao, Mengsheng Lu, Yuan Heng, Teng Wu, Yinxuan Li. Line Segment Matching: A Benchmark. IEEE Winter Conference of Applications of Computer Vision (WACV), 2016.

State of the Art

- Underlying assumption
  - Images are from the same source (camera)
- Descriptors mainly based on gray/color value
  - High informative content
- Geometry constraints
  - Accurate Matching

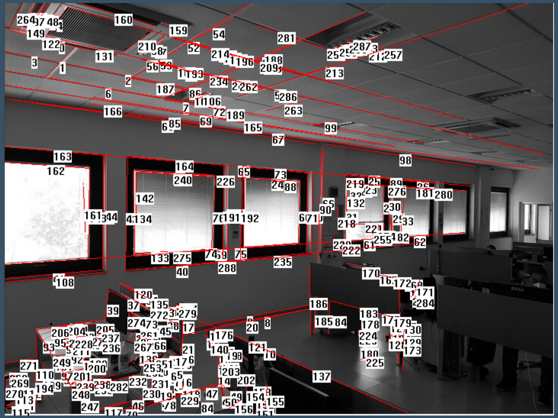
State of the Art

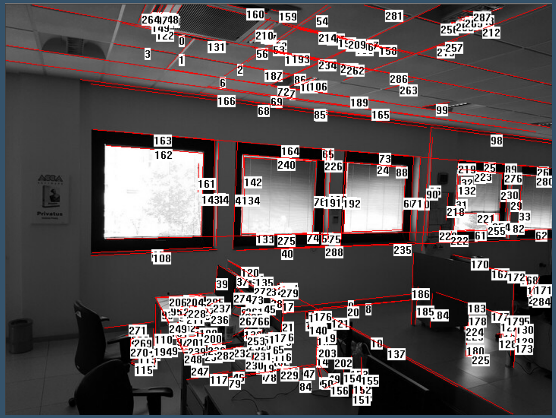
- Underlying assumption
  - Images are from the same source (camera)
- Descriptors mainly based on gray/color value
  - High informative content
- Geometry constraints
  - Accurate Matching

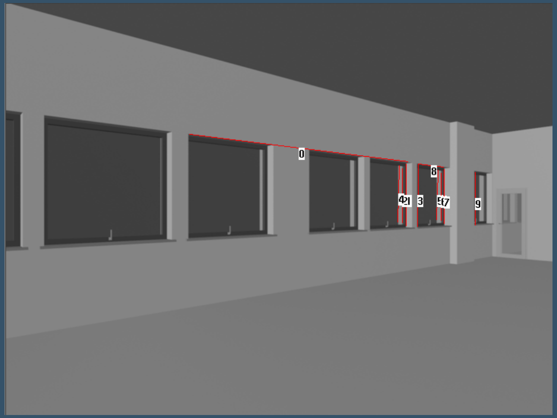


Kai Li, Jian Yao, Mengsheng Lu, Yuan Heng, Teng Wu, Yinxuan Li. Line Segment Matching: A Benchmark. IEEE Winter Conference of Applications of Computer Vision (WACV), 2016.

State of the Art

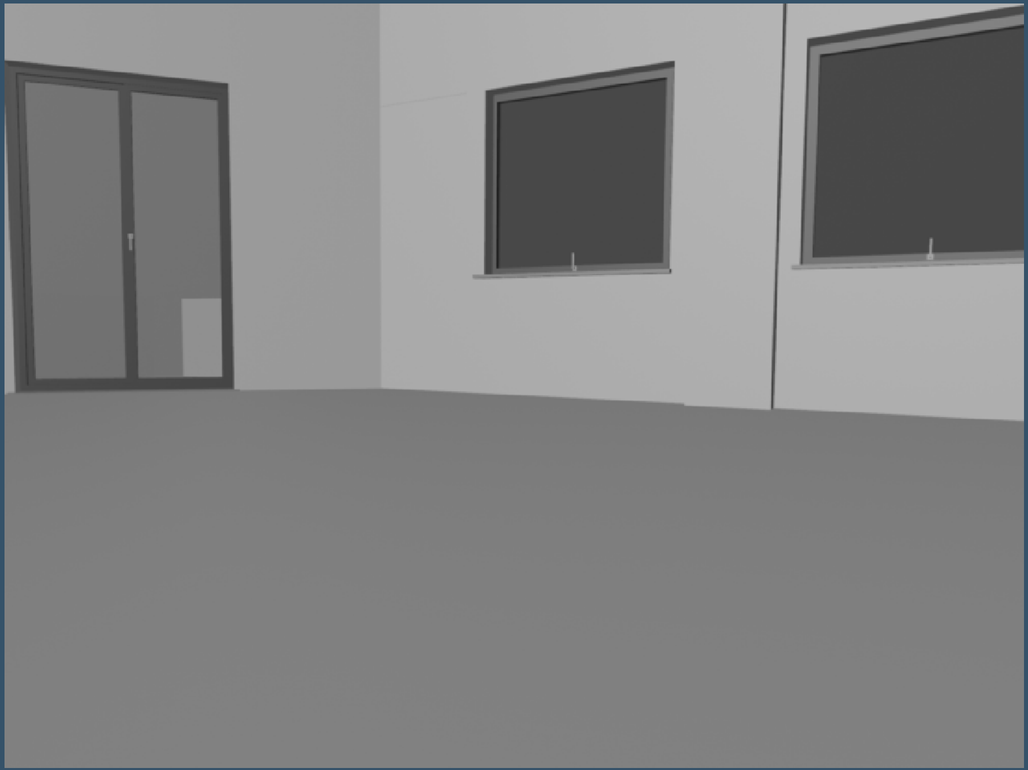




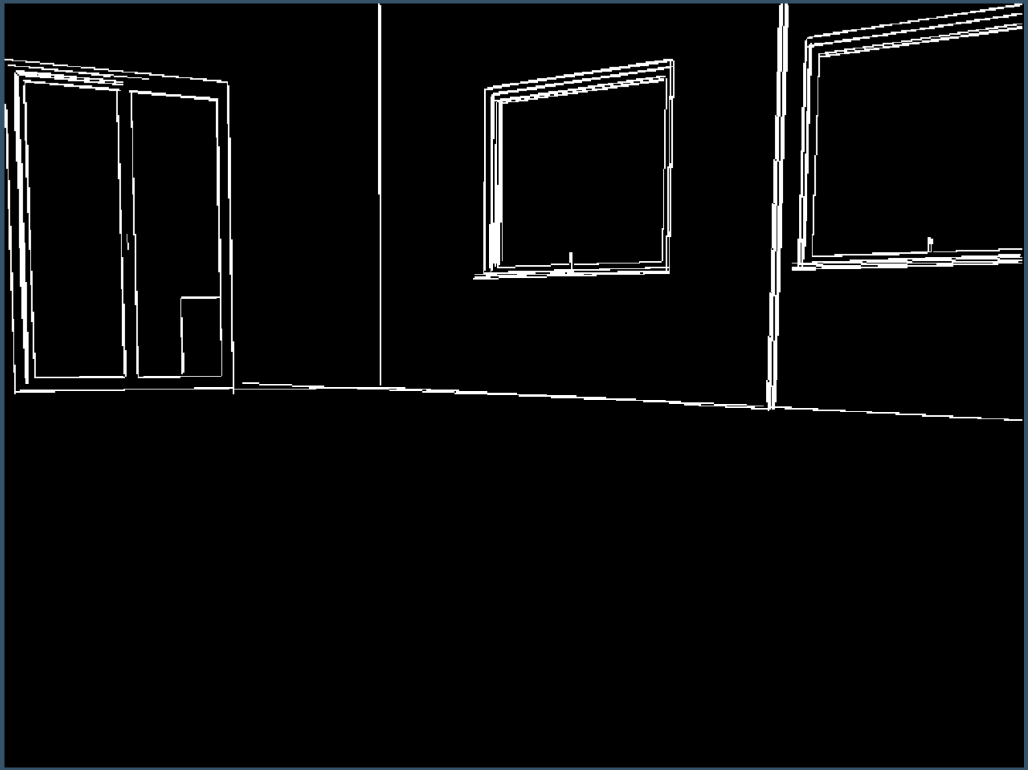


Kai Li, Jian Yao, Mengsheng Lu, Yuan Heng, Teng Wu, Yinxuan Li. Line Segment Matching: A Benchmark. IEEE Winter Conference of Applications of Computer Vision (WACV), 2016.

Contributions

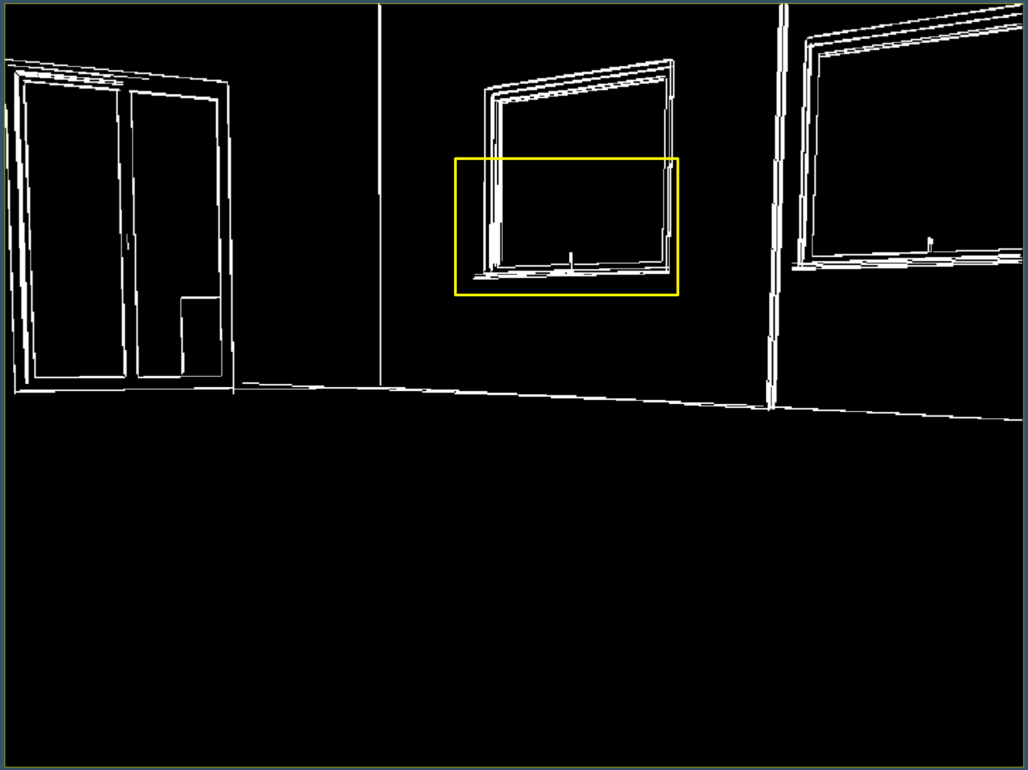


Extraction

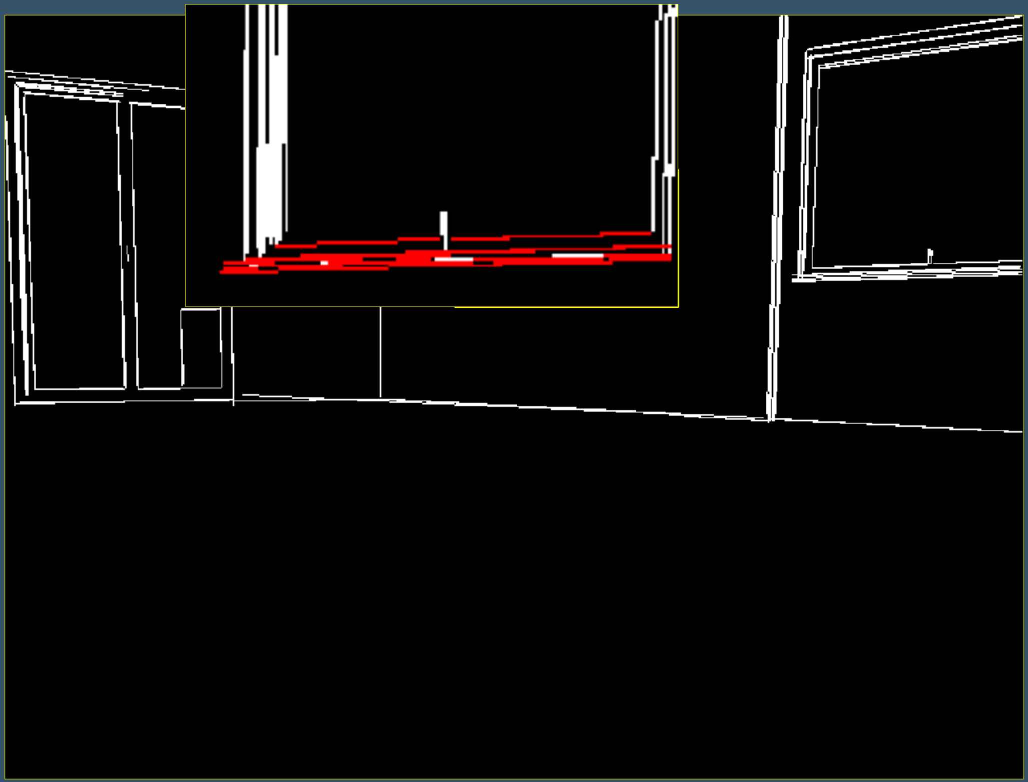


R. Grompone von Gioi, J. Jakubowicz, J. -M. Morel and G. Randall, "LSD: A Fast Line Segment Detector with a False Detection Control," in IEEE Transactions on Pattern Analysis and Machine Intelligence, vol. 32, no. 4, pp. 722-732, April 2010

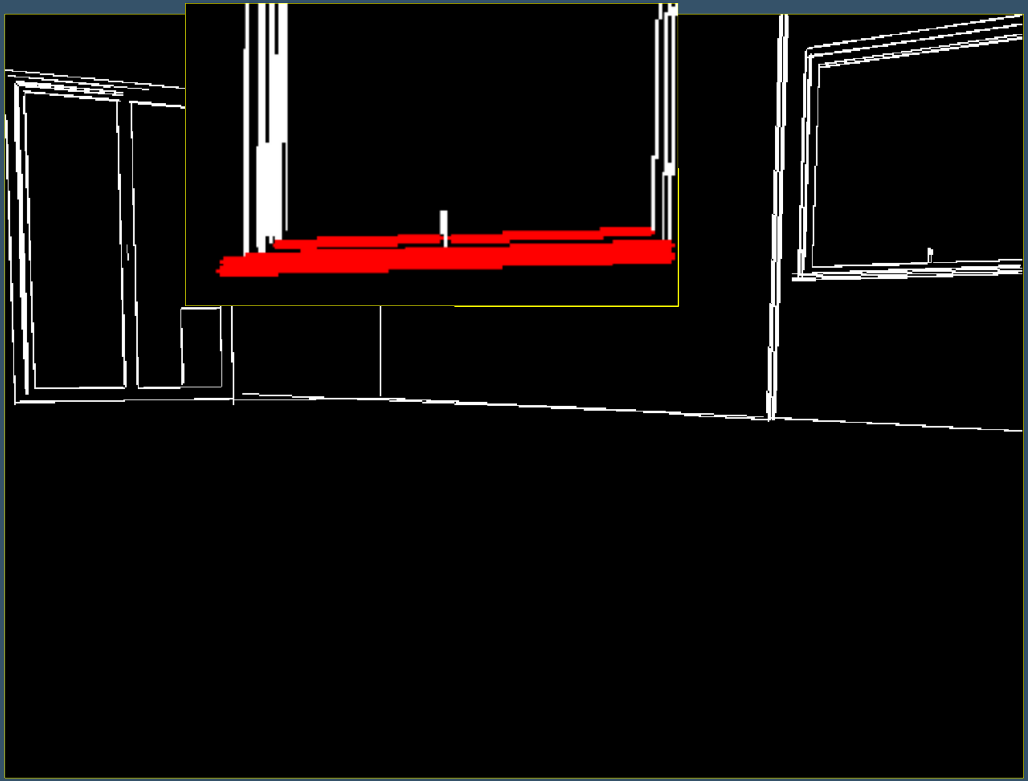
Clustering



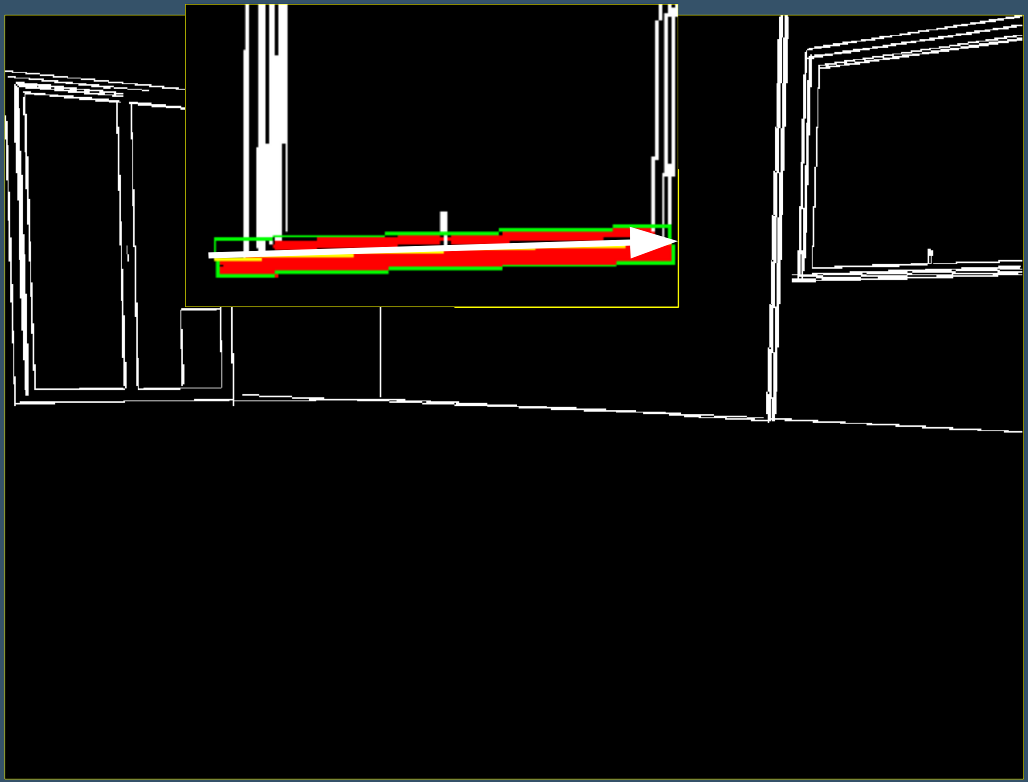
Clustering



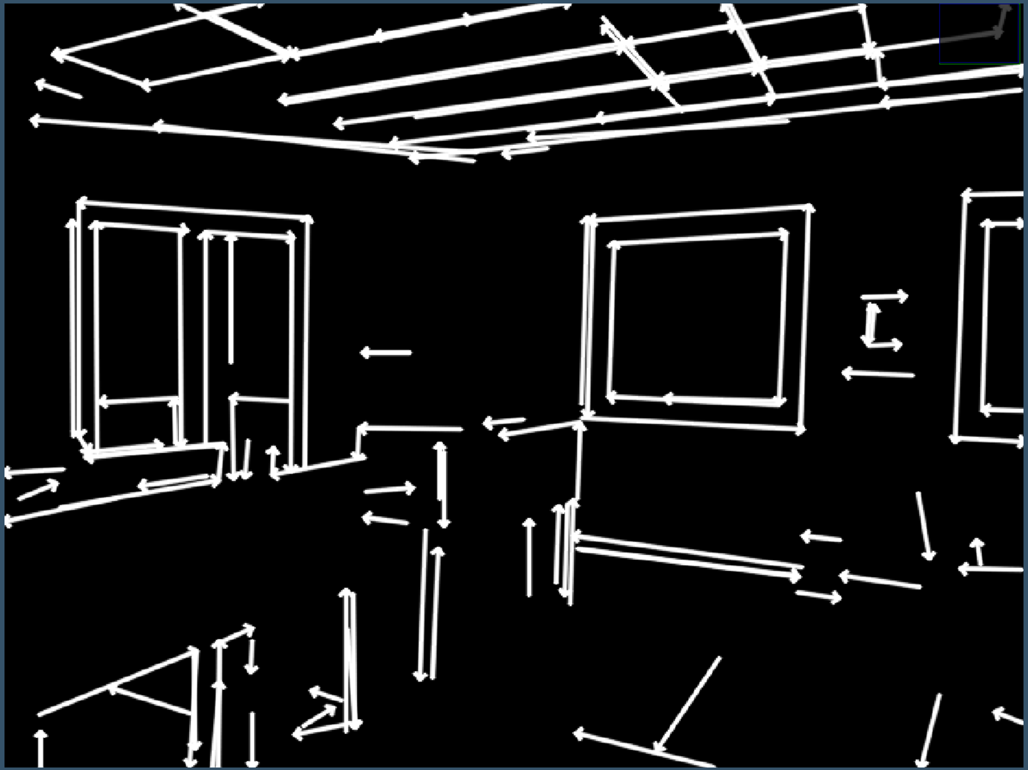
Clustering

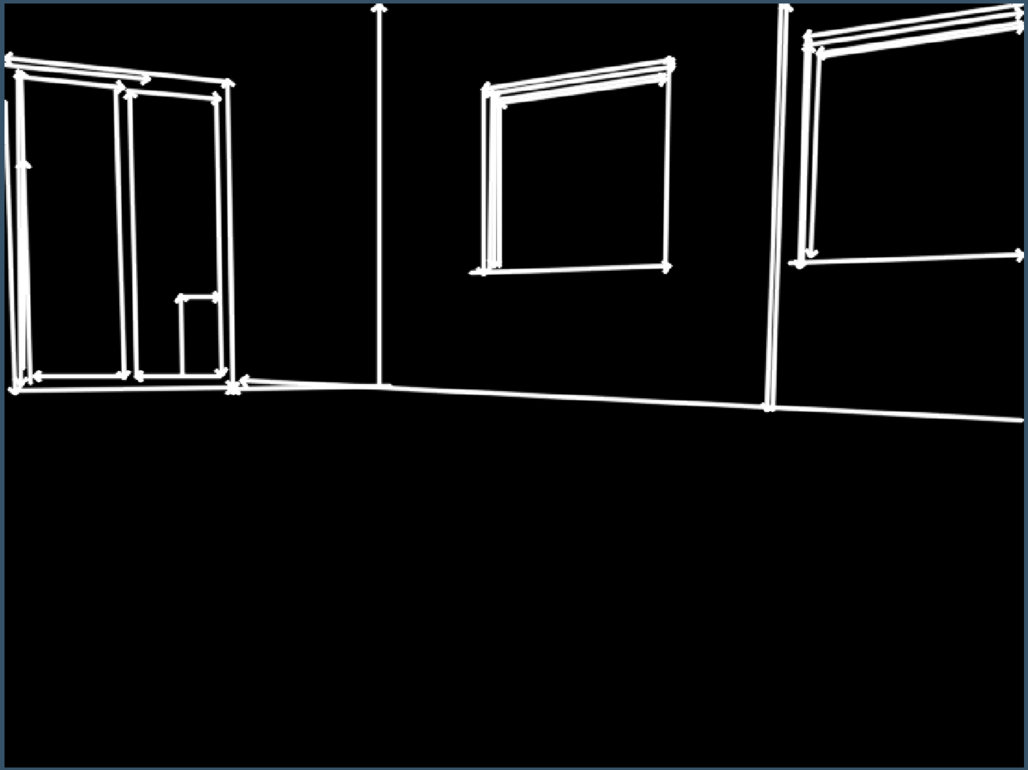


Clustering

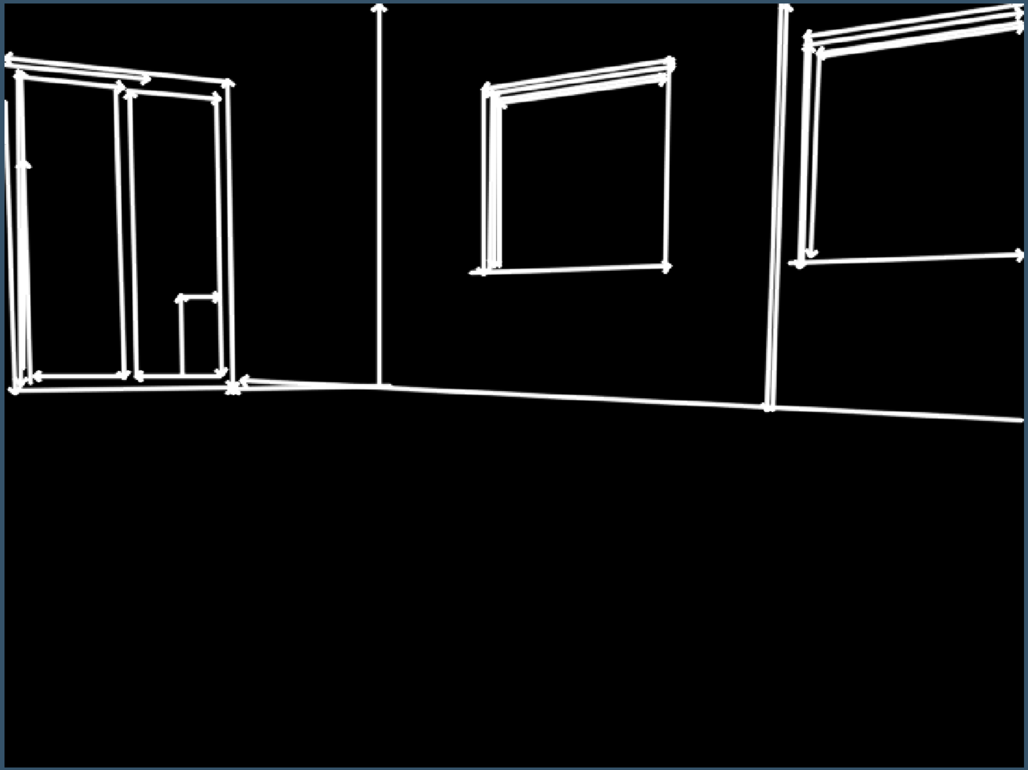


Clustering

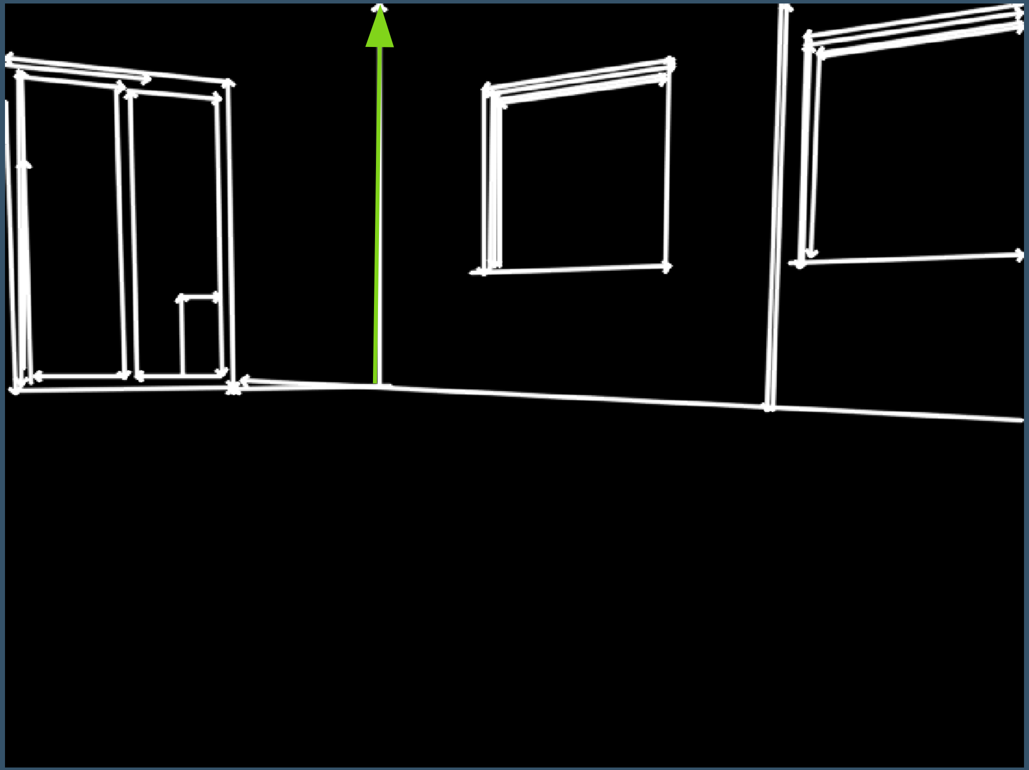




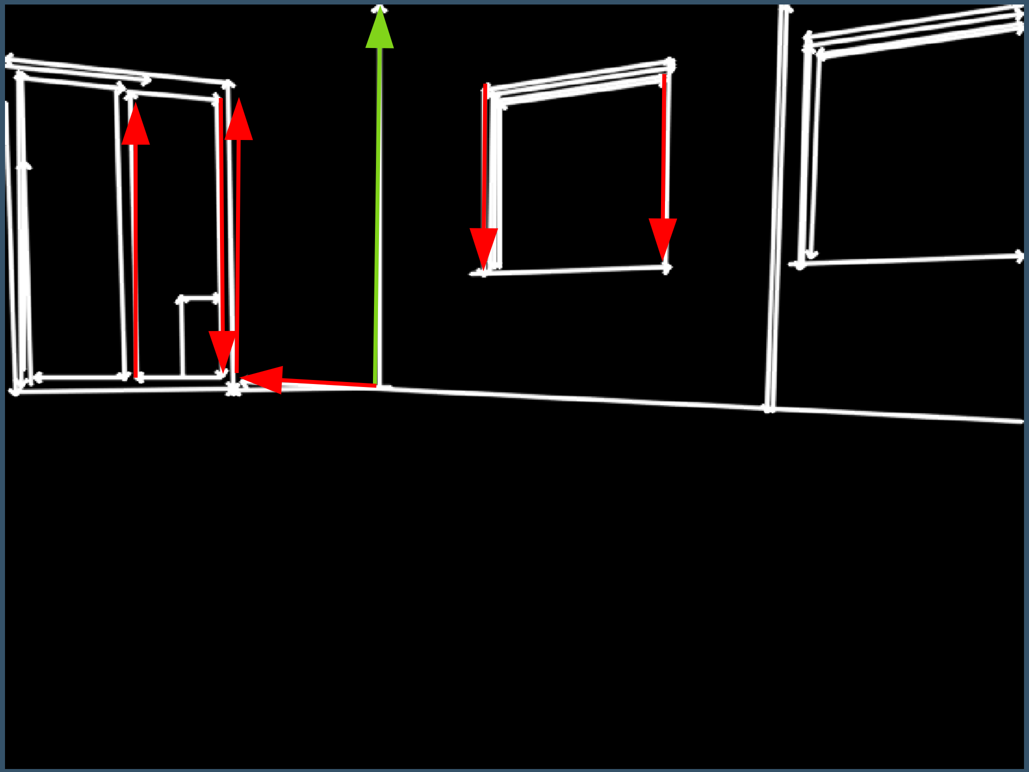
Descriptors



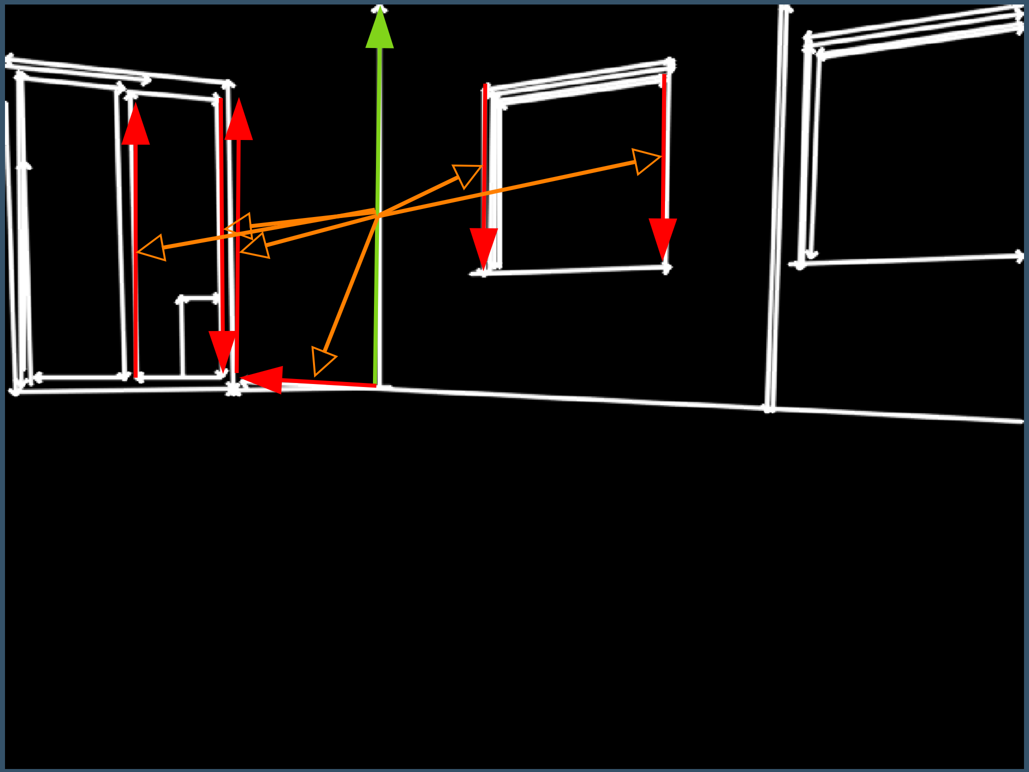
Descriptors



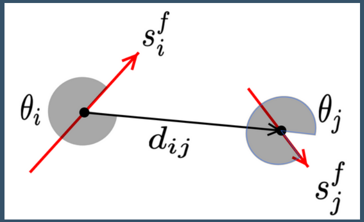
Descriptors

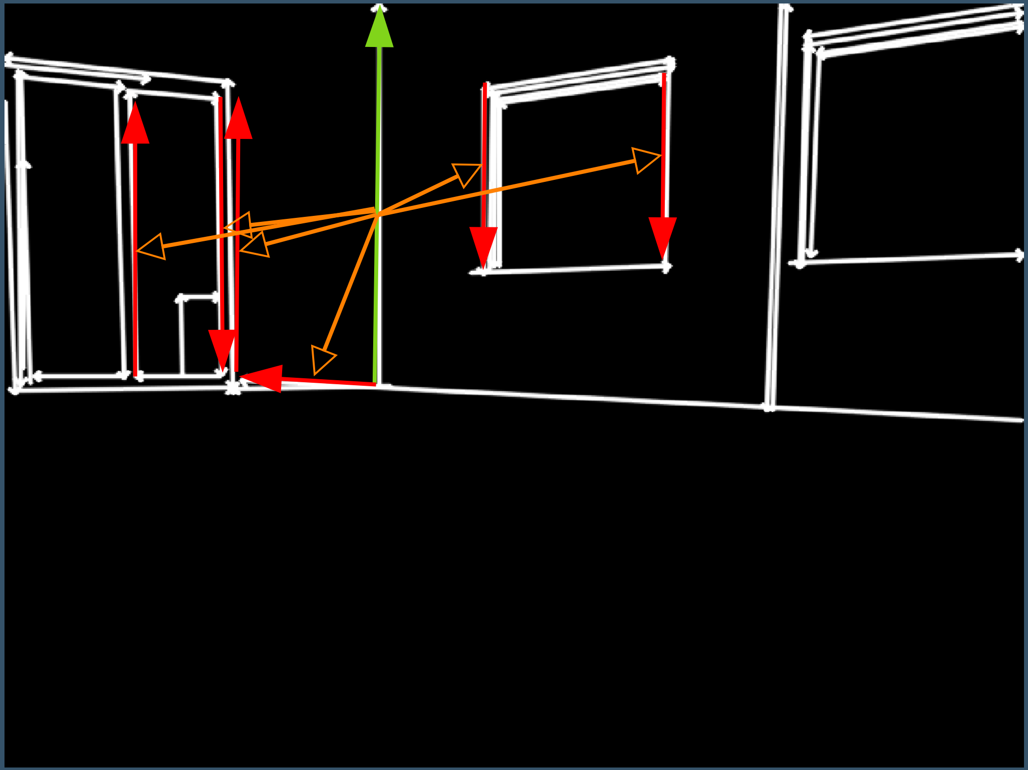


Descriptors

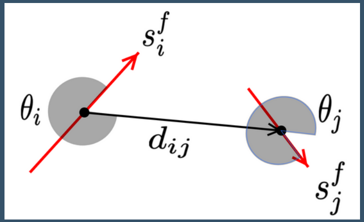


Descriptors

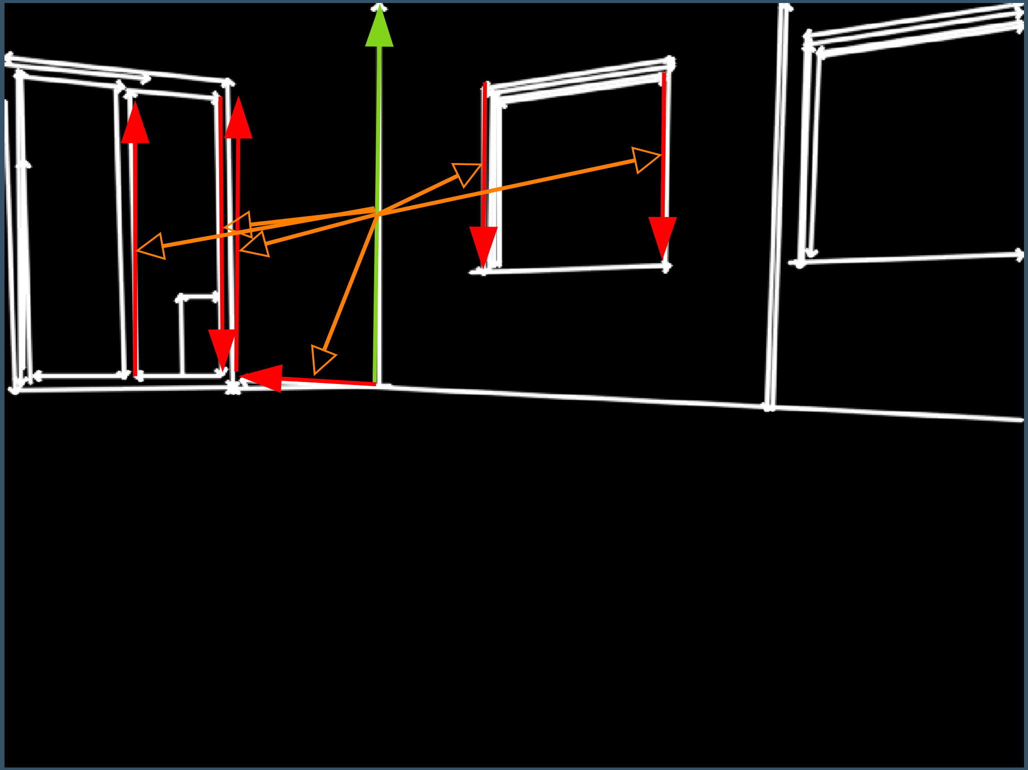




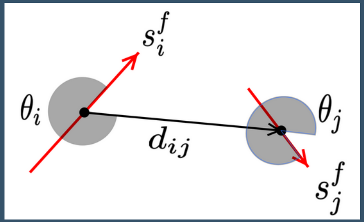
Descriptors



$$\left(\frac{|s_i^f|}{|d_{ij}|}, \theta_i, \frac{|s_j^f|}{|d_{ij}|}, \theta_j\right)$$

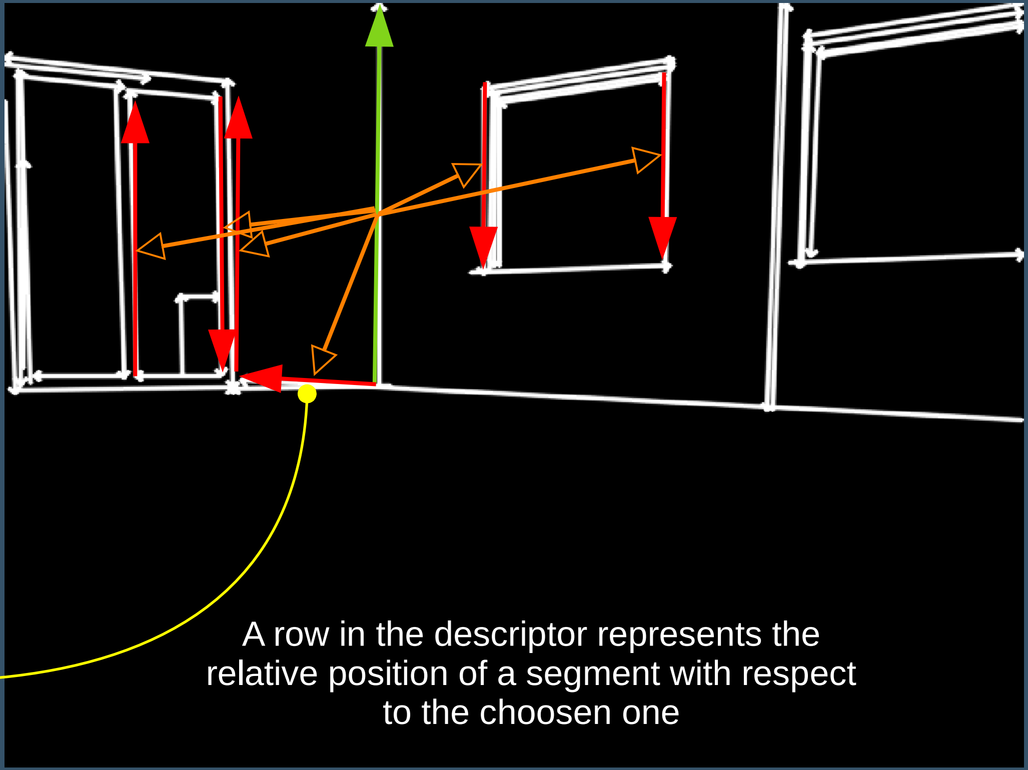


Descriptors



$$\left(\frac{|s_i^f|}{|d_{ij}|}, \theta_i, \frac{|s_j^f|}{|d_{ij}|}, \theta_j\right)$$

Descriptor of s_i^f			
$\frac{\lvert s_i^f \rvert}{\lvert d_{ij} \rvert}$	θ_i	$\frac{\lvert s_j^f \rvert}{\lvert d_{ij} \rvert}$	θ_j
...	...	...	...
...	...	...	...
...	...	...	...



Matching Strategy

Matching Strategy

Suppose we know a reference segment in both images

Matching Strategy

Suppose we know a reference segment

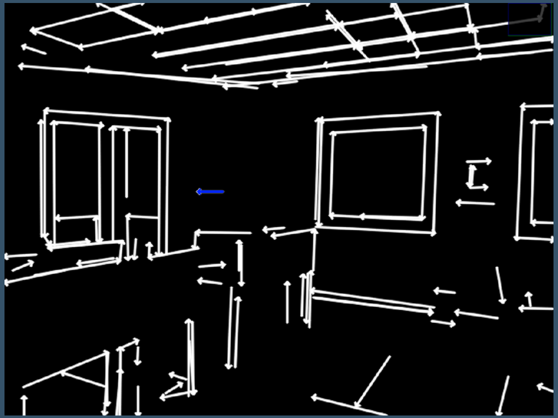
in both images

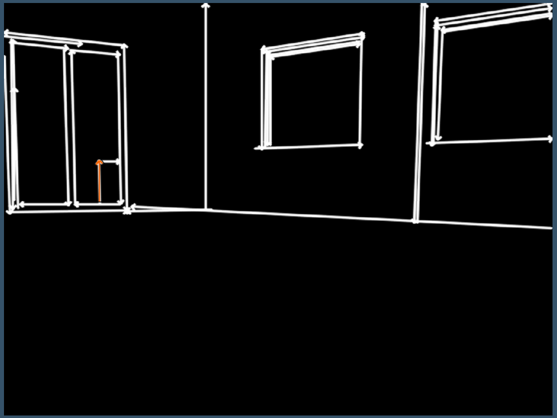
↓

We can directly compare

the relative positions of the surrounding segments

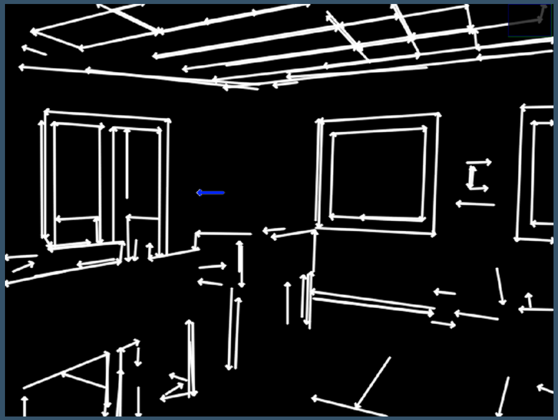
Find a reference segment

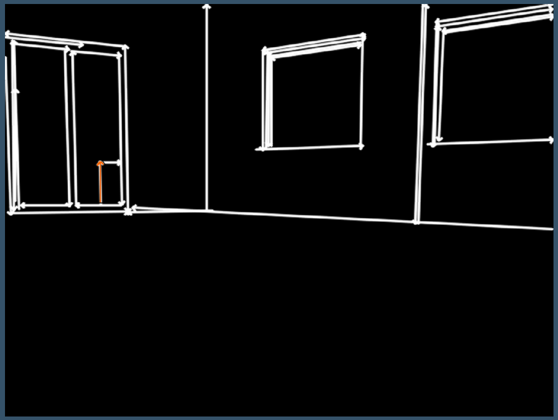


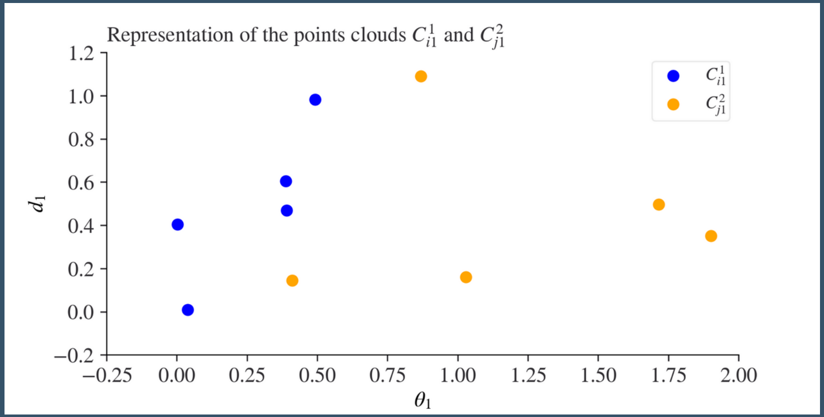


$\frac{\lvert s_i^f \rvert}{\lvert d_{ij} \rvert}$	θ_i	$\frac{\lvert s_j^f \rvert}{\lvert d_{ij} \rvert}$	θ_j
...	...	...	...
...	...	...	...
...	...	...	...

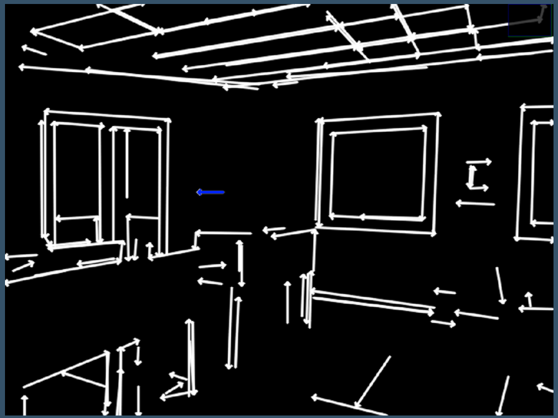
Find a reference segment

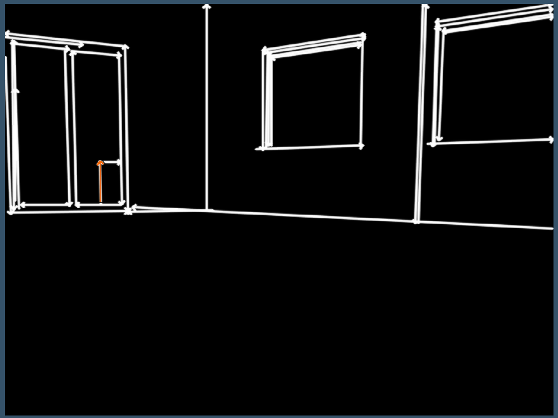


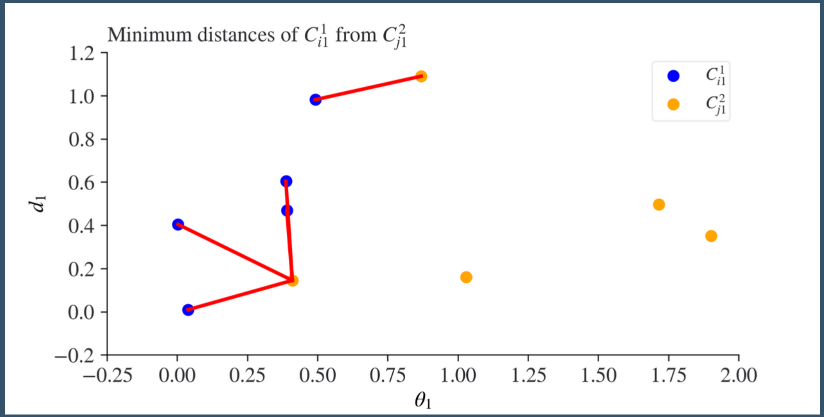


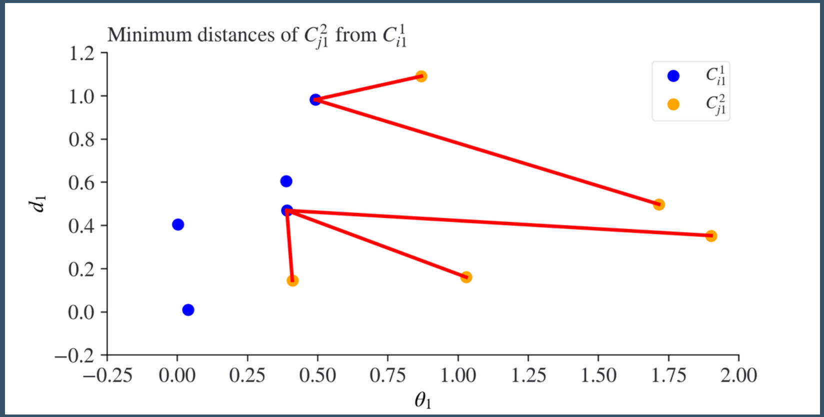


Find a reference segment

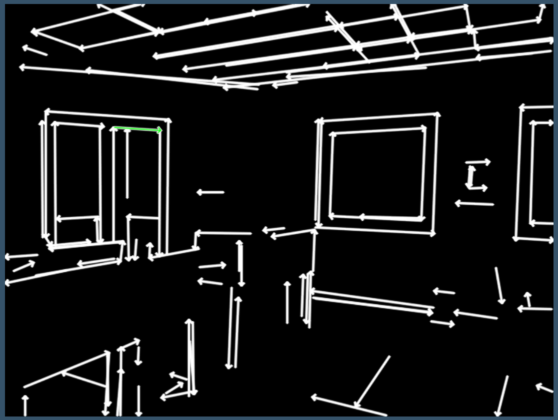


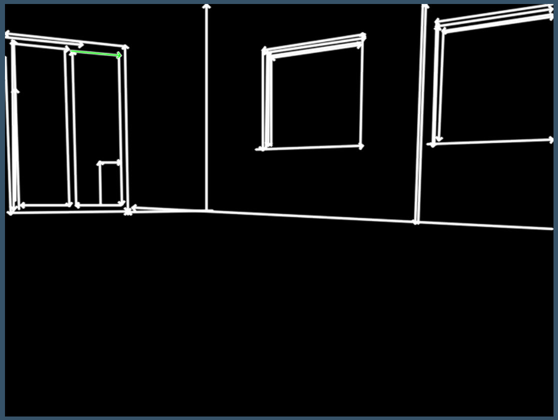






Find a reference segment





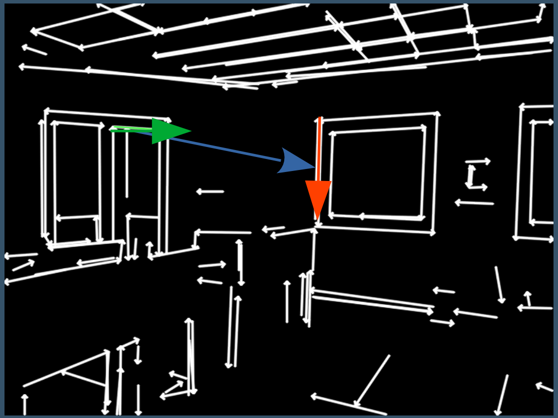
Once minimum distance is computed,

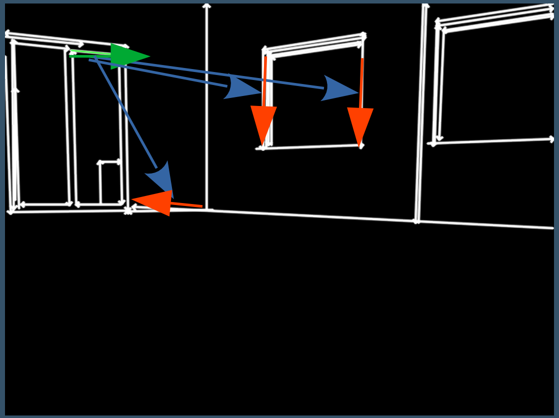
the selected segment is taken as reference

Compare descriptors

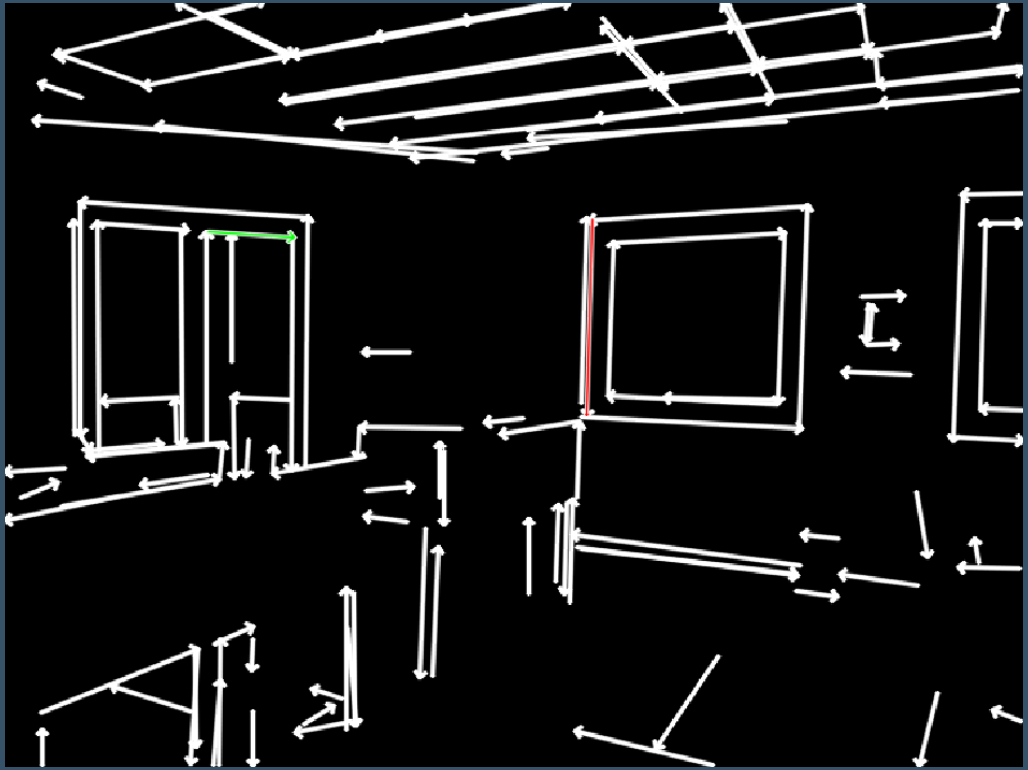
Given a reference

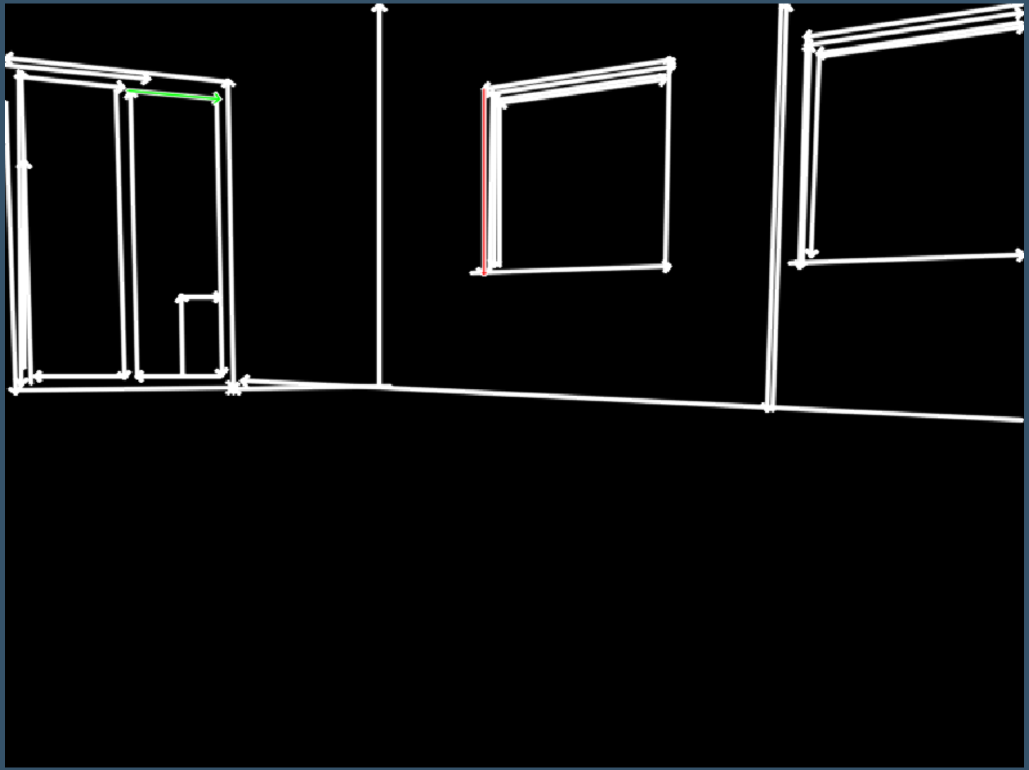
- Any other segment is uniquely located by its position
- Match the most similar position (SSD)



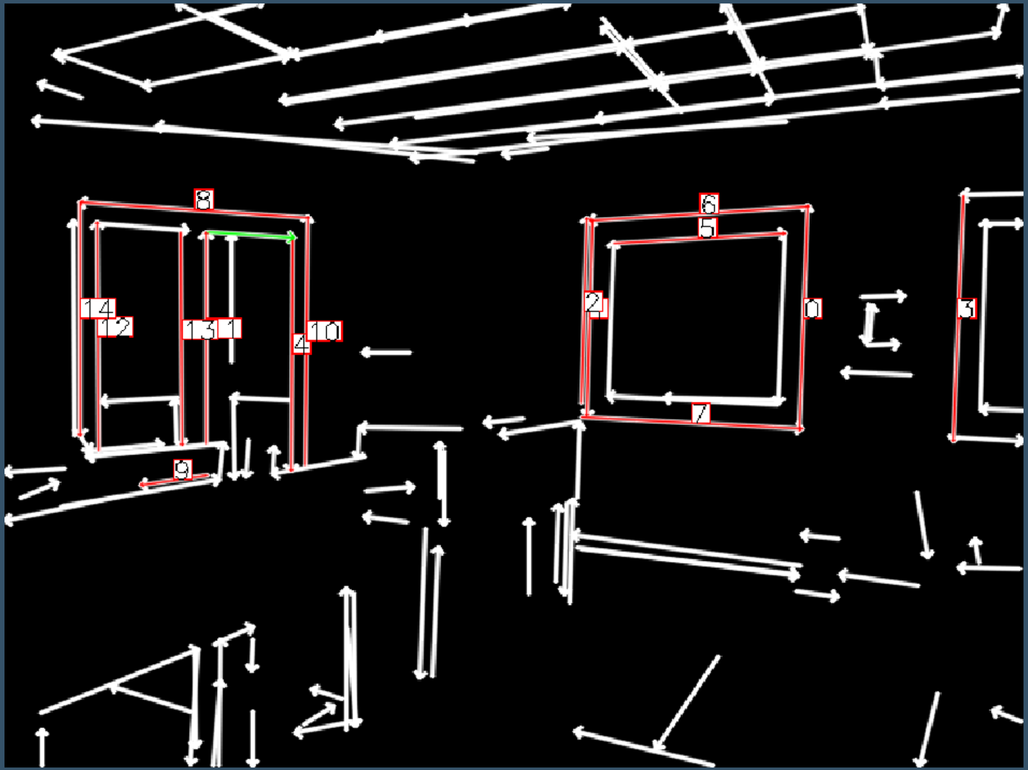


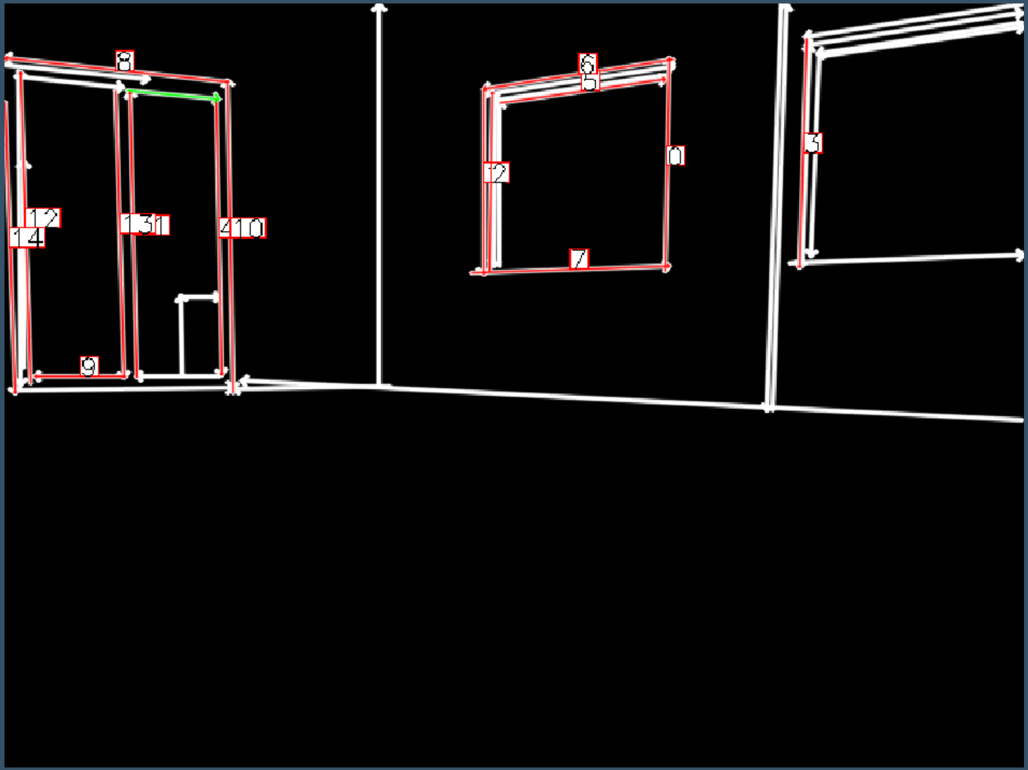
Compare descriptors



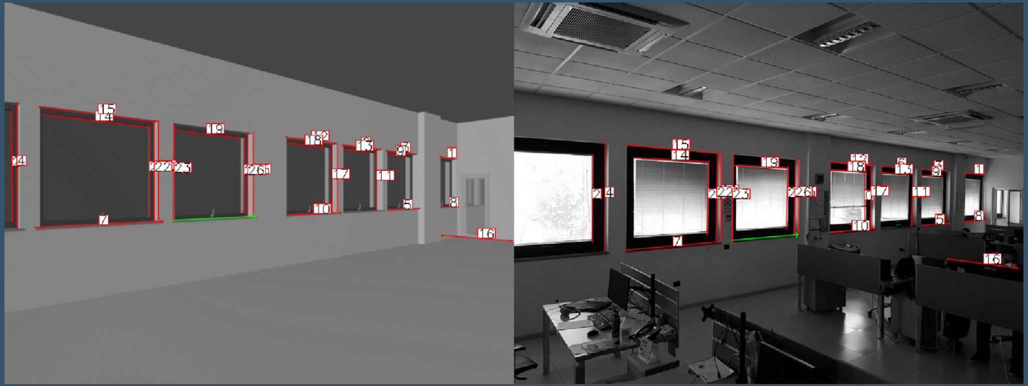


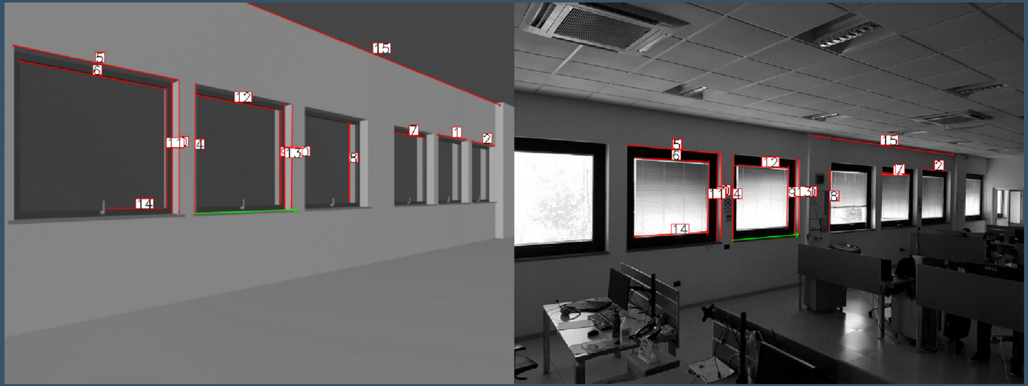
Compare descriptors

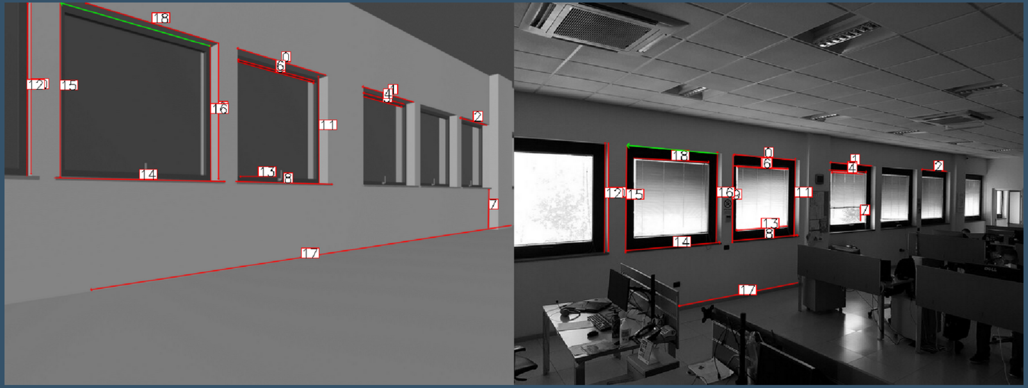


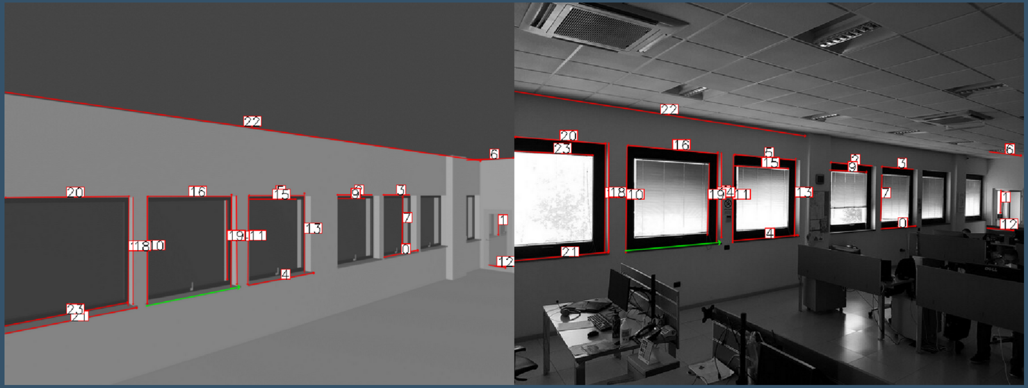


Results

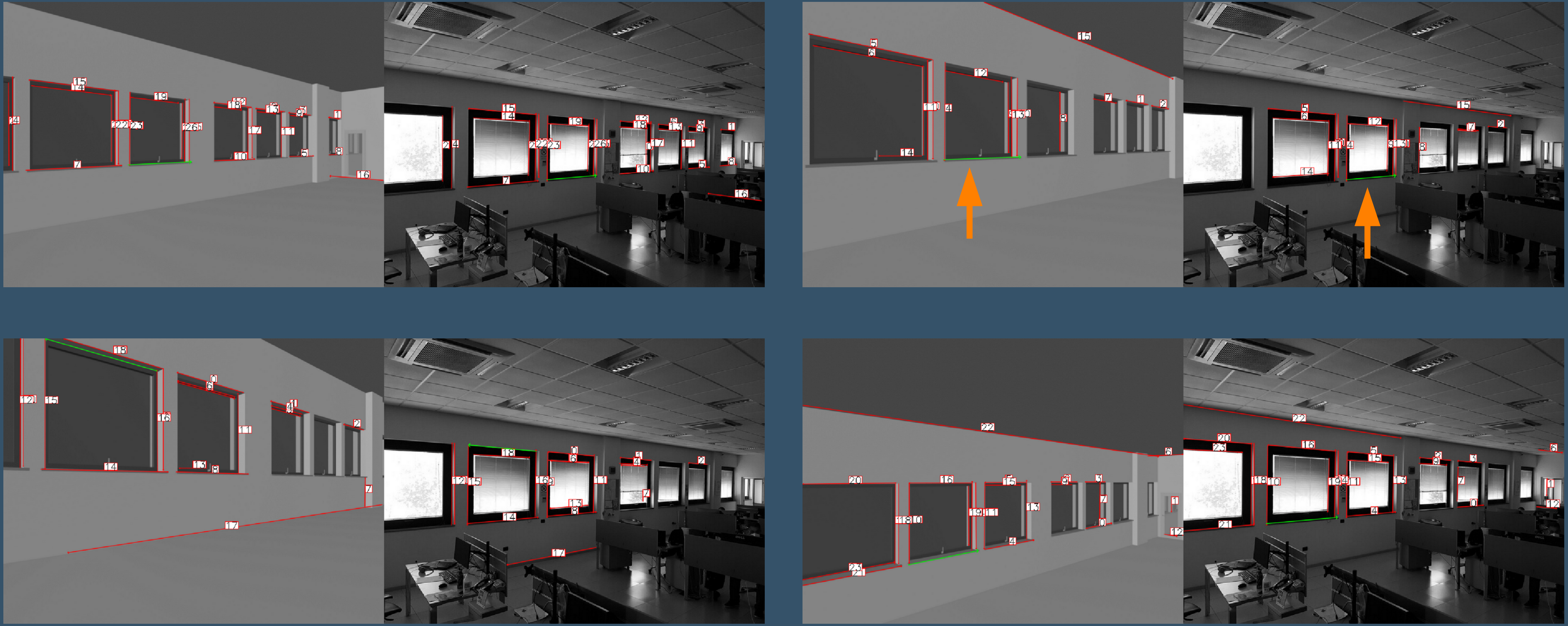




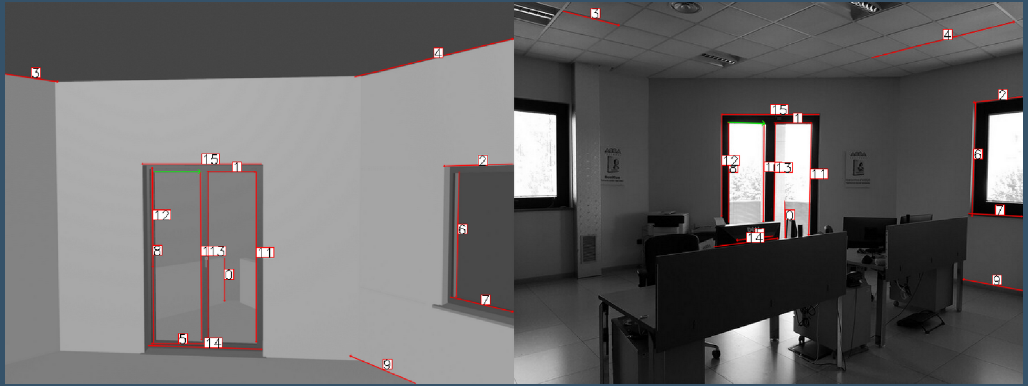


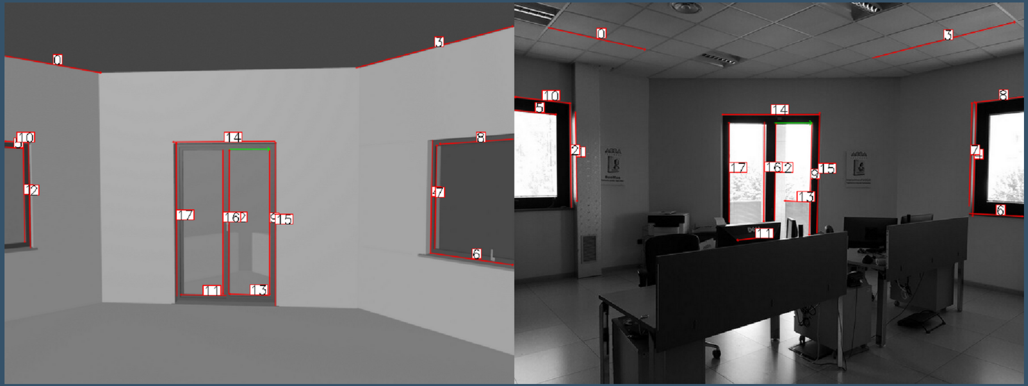


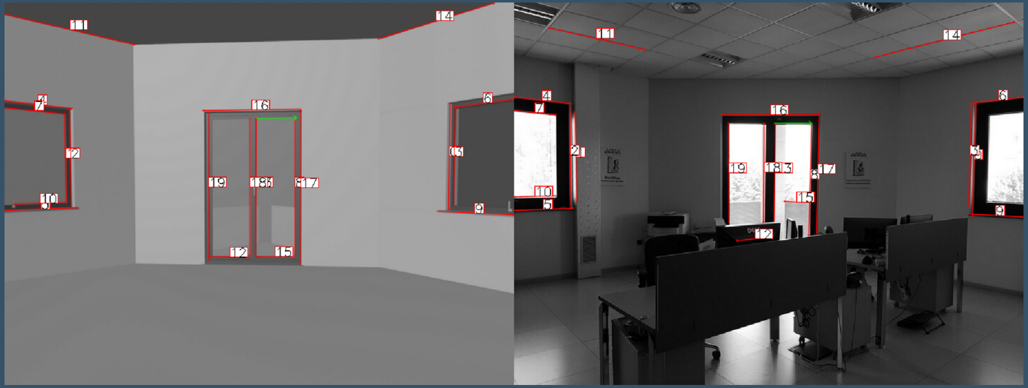
Results

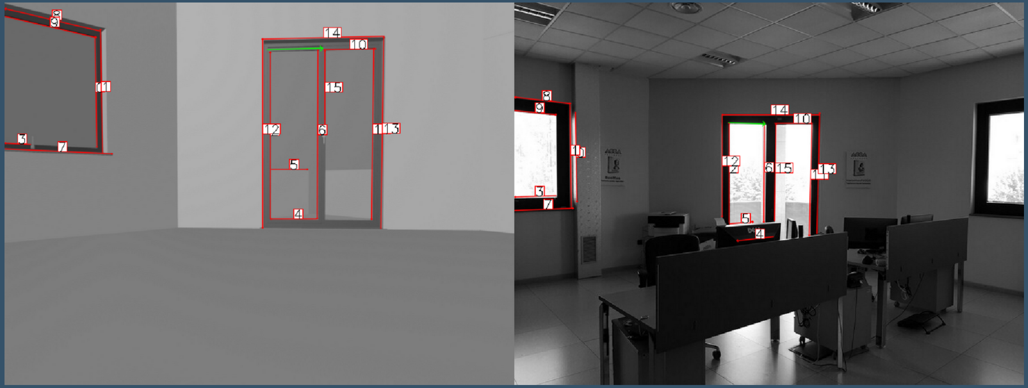


Results

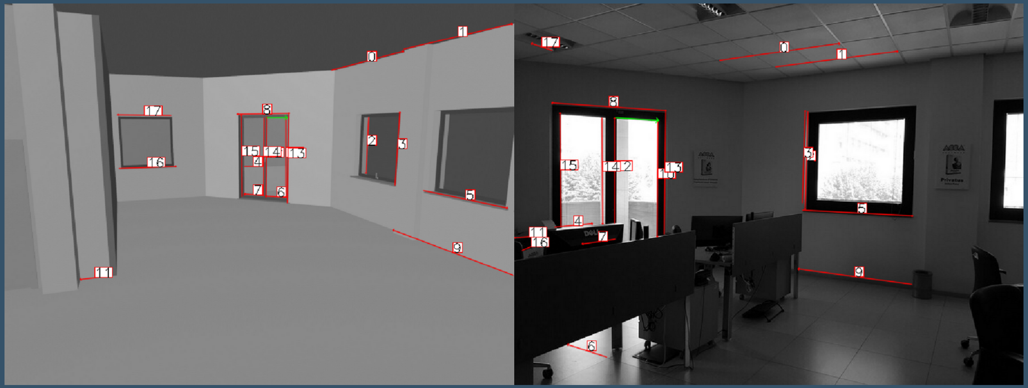


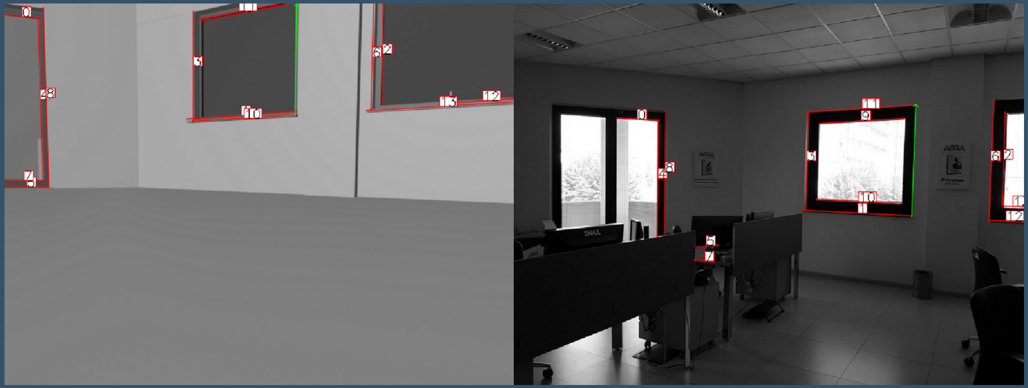


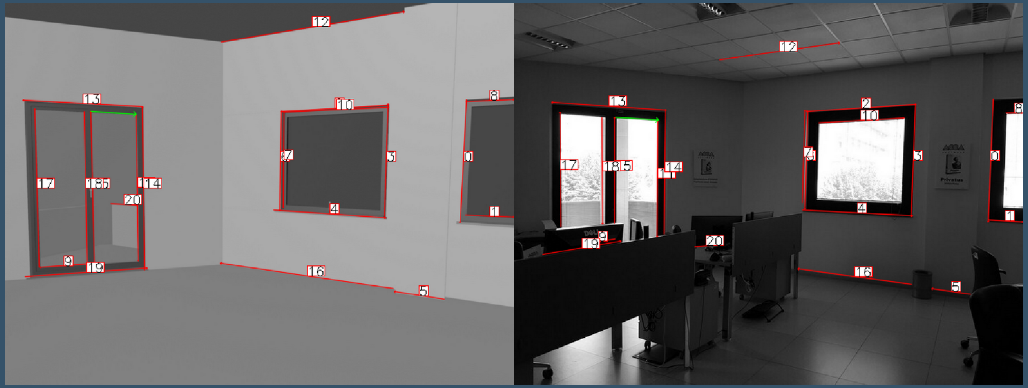


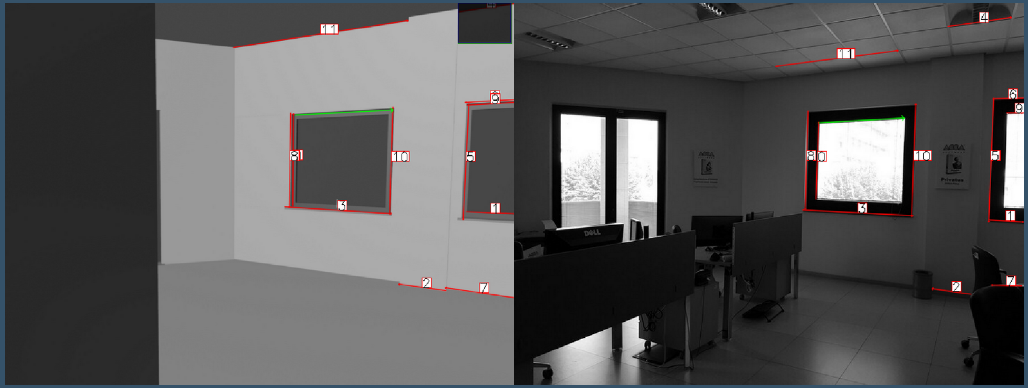


Results

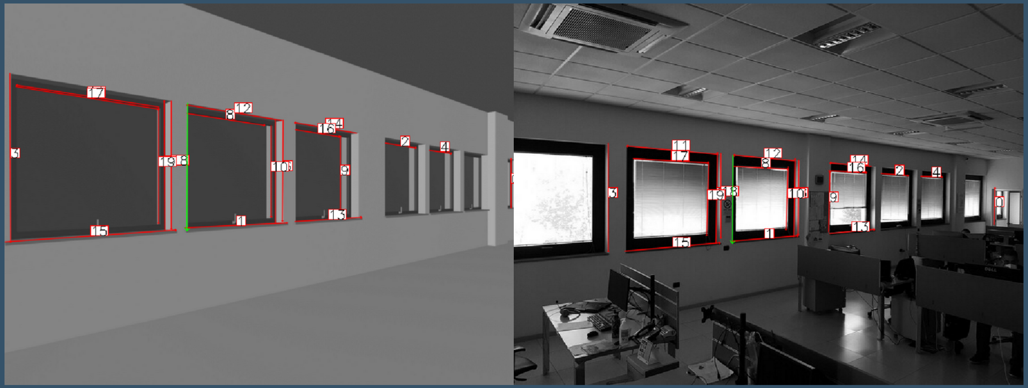


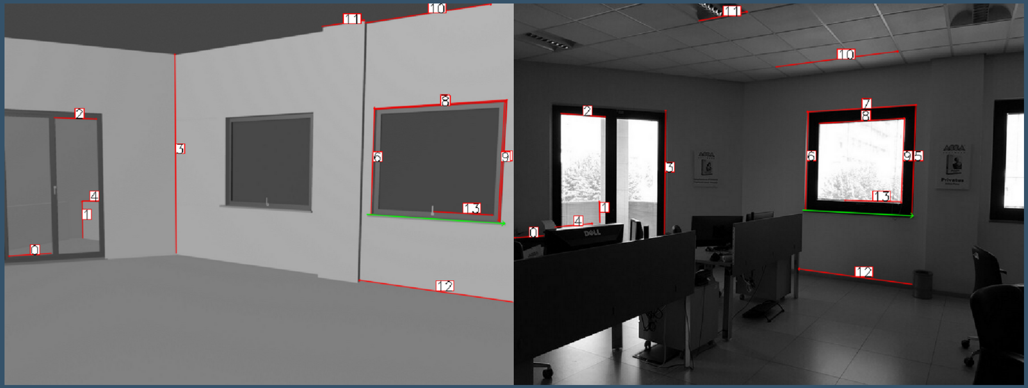


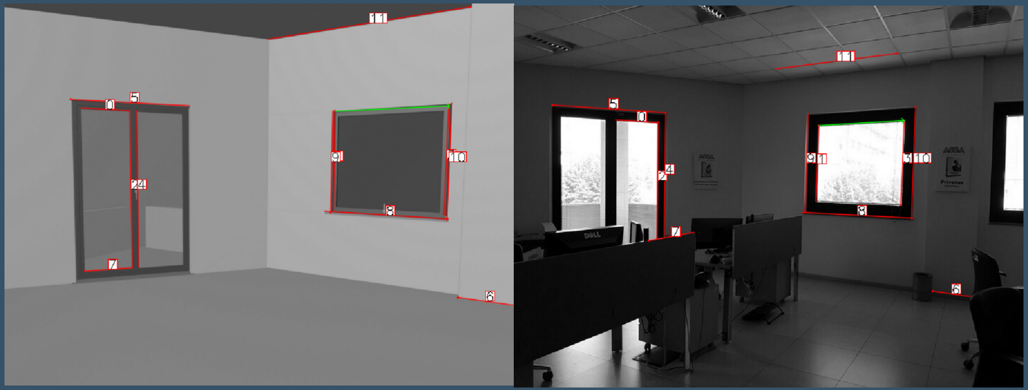


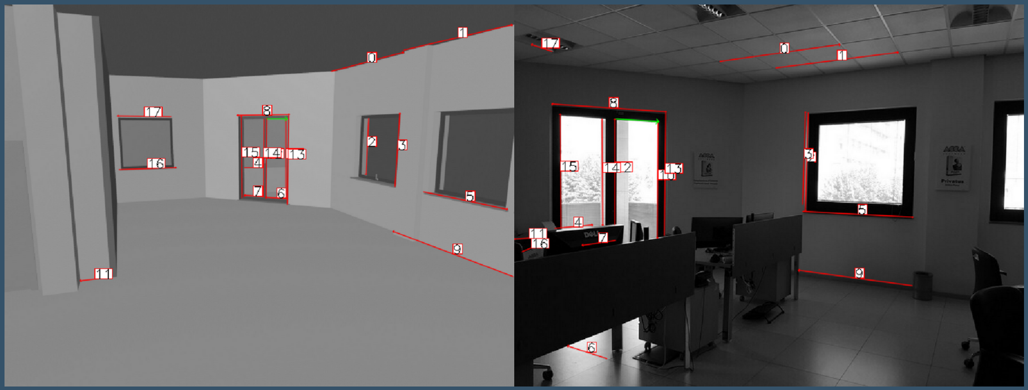


Errors









Conclusions

- A new approach for line segment matching has been explored
- The method does not rely on any gray/color values
- Geometric relationships between images are exploited
- Comparison of simulated and real image is more stable

Future works

Image matching for BIM-aided dead-reckoning navigation

More experiments from different BIM models

Improve the robustness of the reference segment location

Question time

Thank you