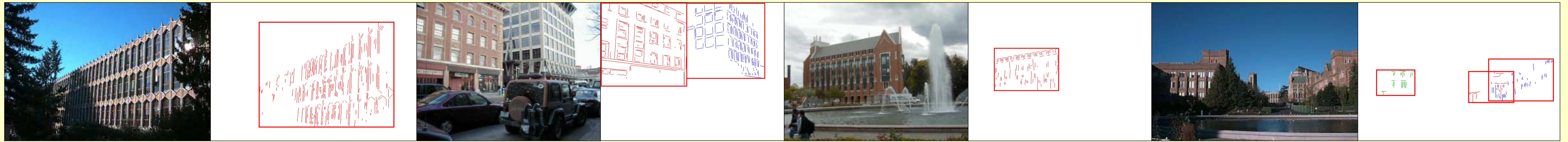


# Consistent Line Clusters for Building Recognition in CBIR\*

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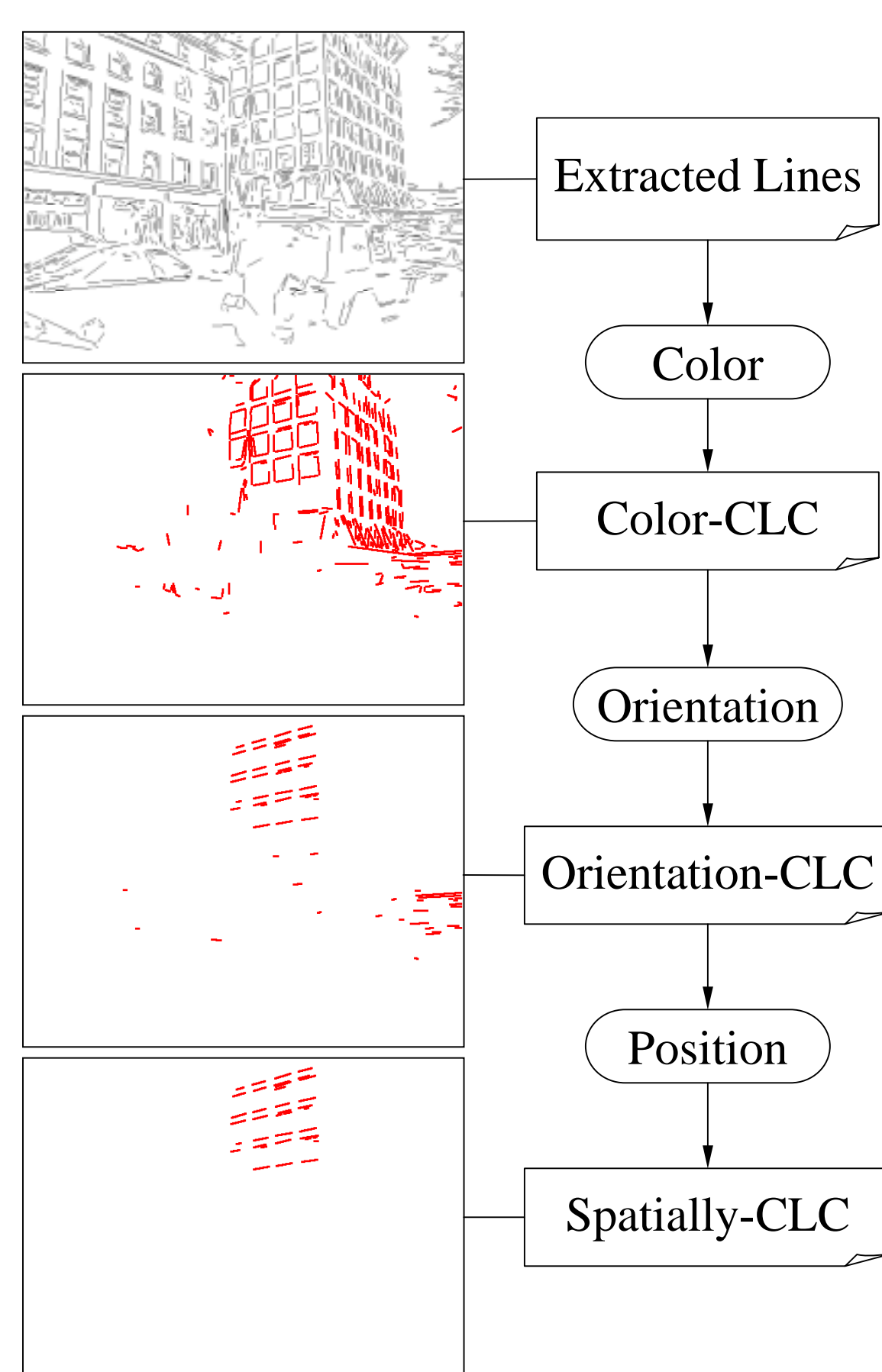


## Consistent Line Clusters

A **Consistent Line Cluster (CLC)** is a set of lines that are homogeneous in terms of some line features.

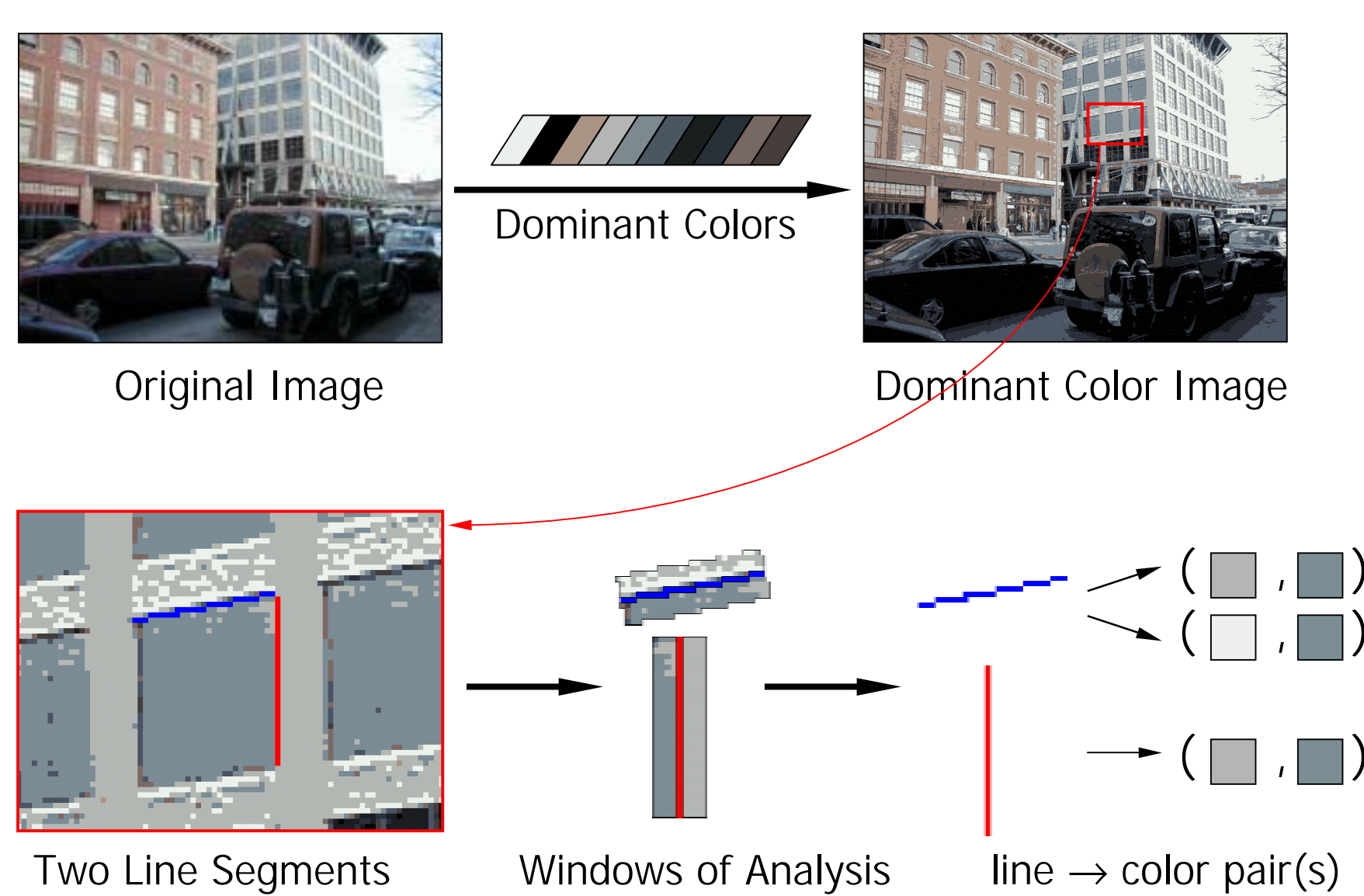
- **Color-CLC:** The lines have the same color feature.
- **Orientation-CLC:** The lines are parallel to each other.
- **Spatially-CLC:** The lines are in close proximity to each other.

### The procedure for constructing consistent line clusters

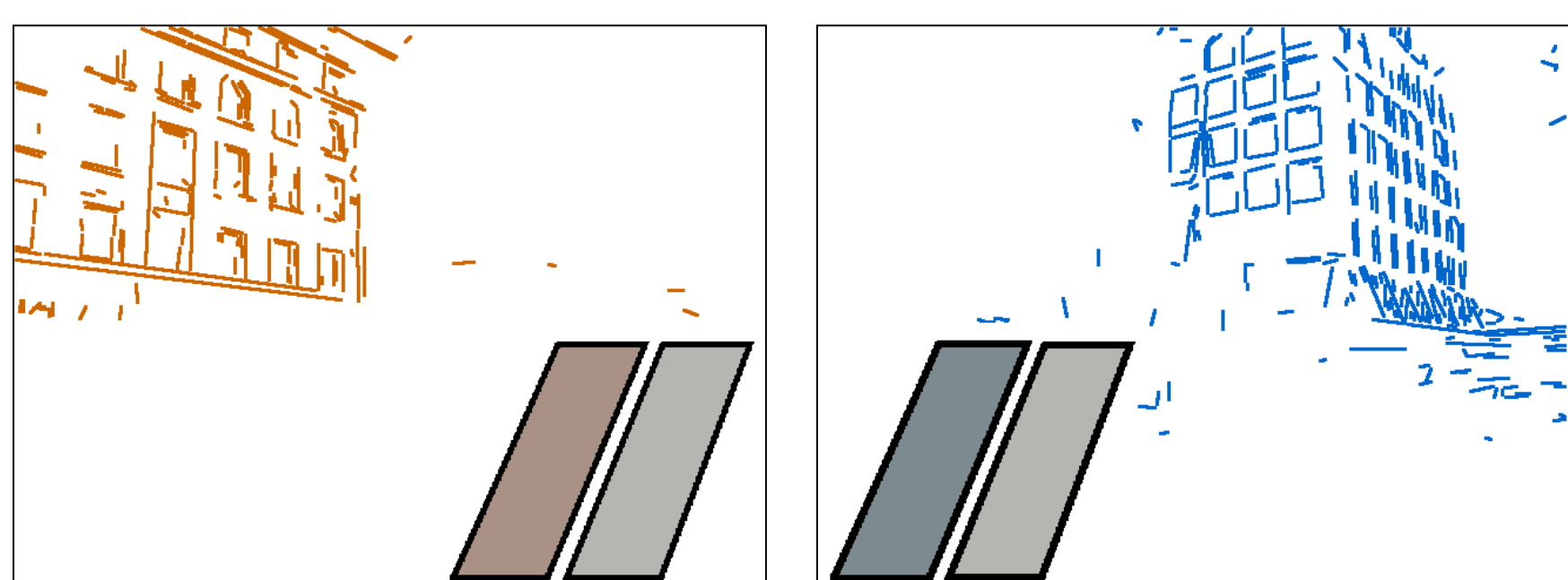


### Color-CLC

- To reduce the complexity, classify each pixel of the image as one of several dominant colors.
- Color feature of lines: **Color Pair**  $(c_1, c_2)$ .

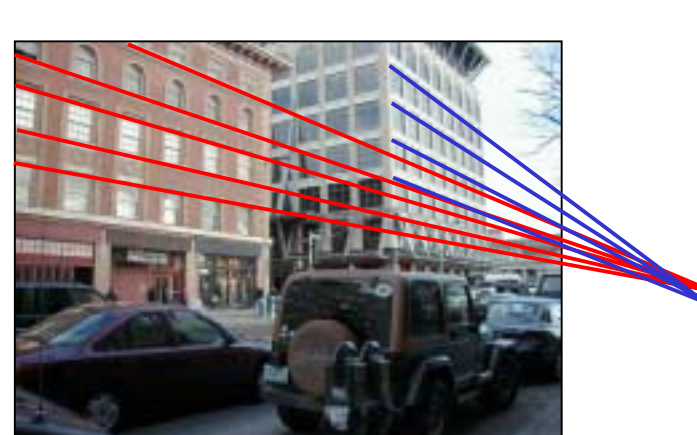


- Lines are clustered according to their color pair(s).

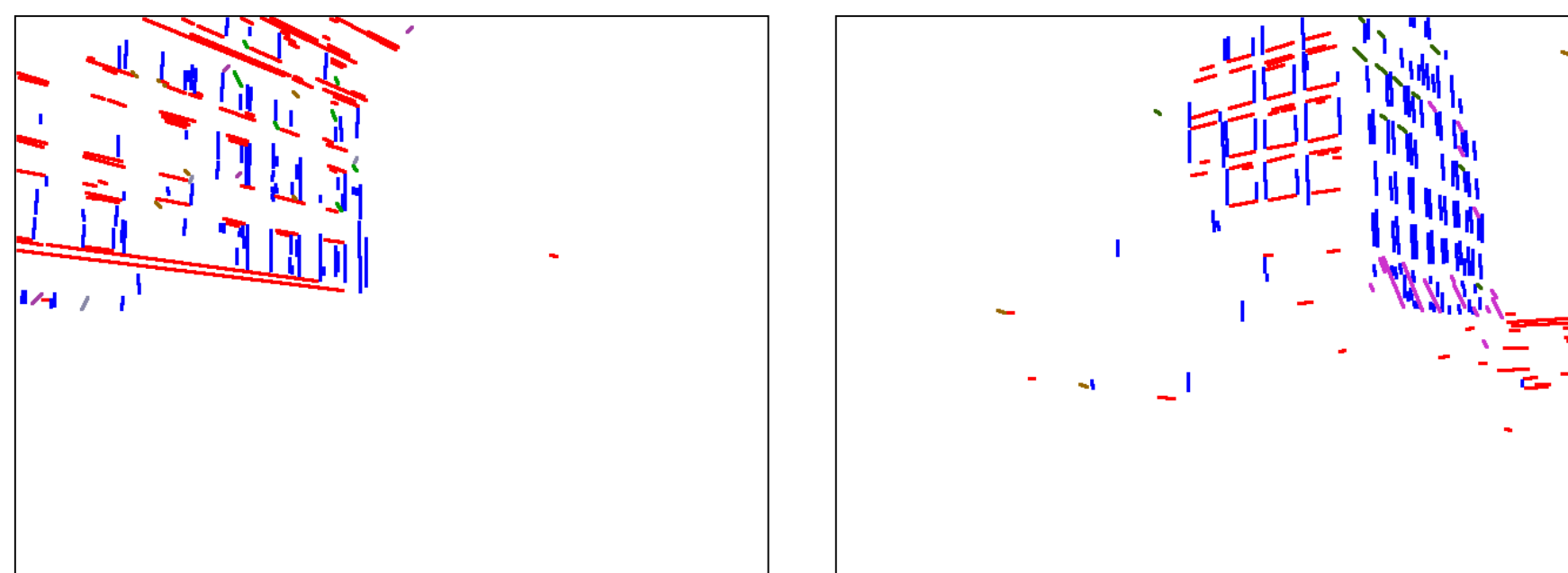


### Orientation-CLC

- The lines in an Orientation-CLC are parallel to each other in the 3D world; the parallel lines of an object in a 2D image can be:
  - Still parallel;
  - Converging to a vanishing point.

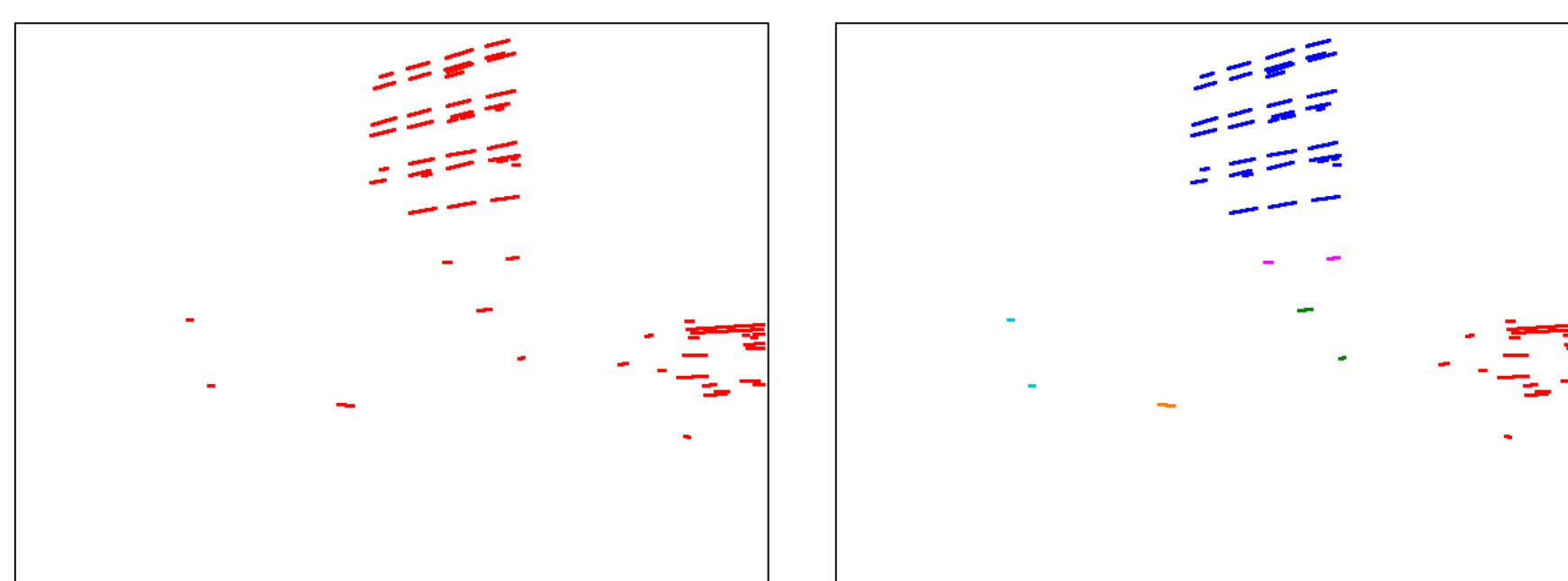


- Two steps:
  - Construct roughly-orientation-CLC;
  - Filter line clusters using perspective information.



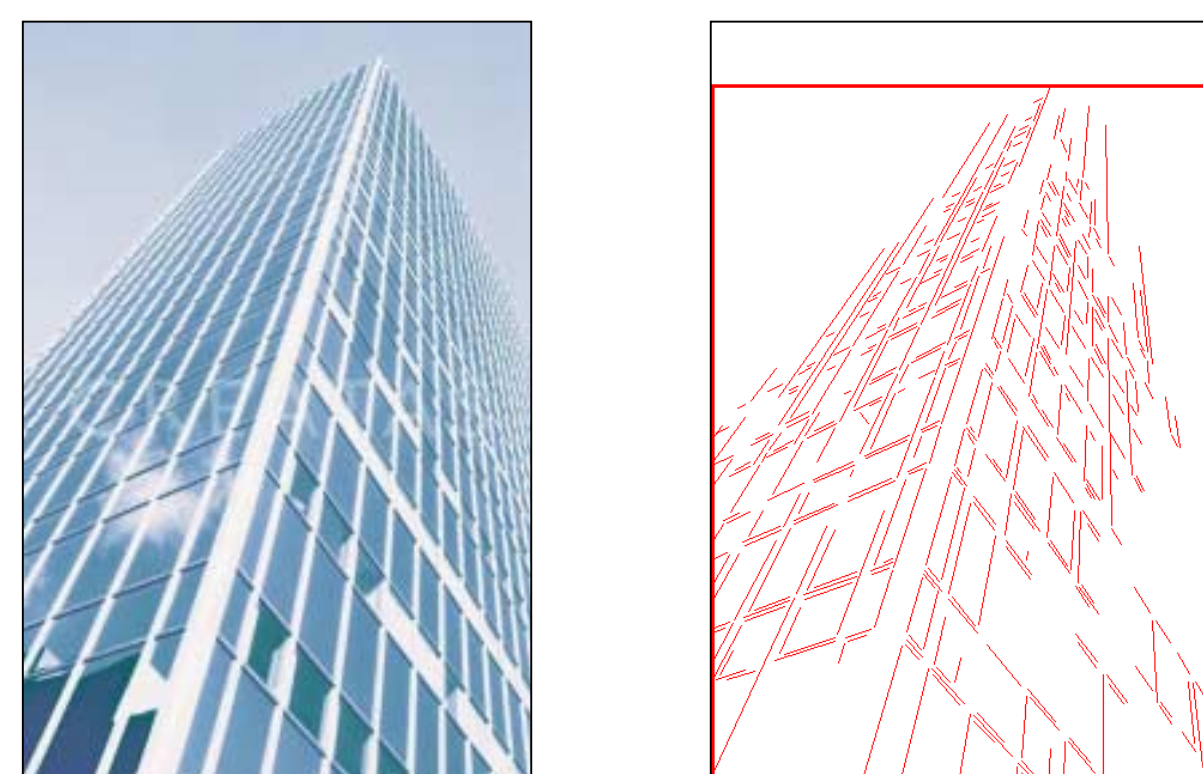
### Spatially-CLC

- Vertical position clustering
- Horizontal position clustering

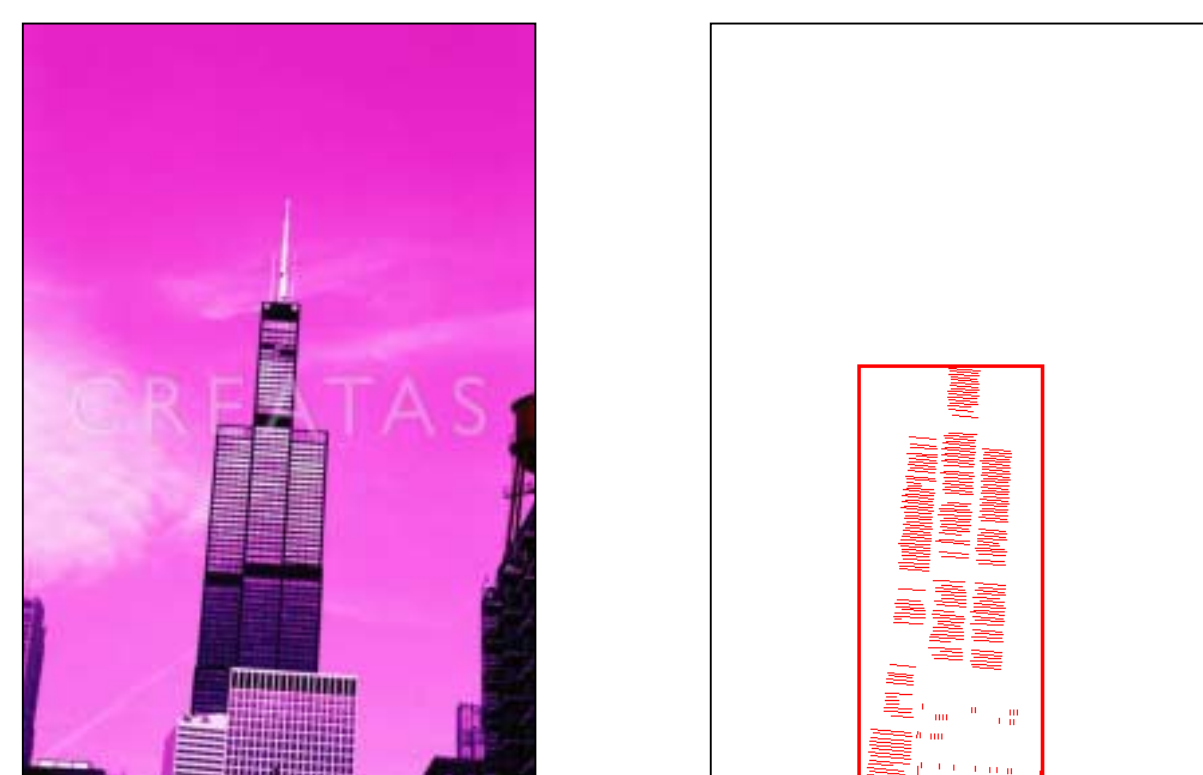


## Building Recognition

- Two types of buildings → Two criteria:
  - Inter-relationship criterion



- Intra-relationship criterion



### Inter-relationship criterion

This criterion represents the maximum number of intersecting lines of a cluster over all other clusters, normalized by the size of the cluster.

$$Ninter_{ij} = \left| \left\{ l_1 \in cl_i \mid \exists l_2 \in cl_j, l_1 \text{ intersects } l_2 \right\} \right|$$

$$Ninter_i = \max_j \{ Ninter_{ij} \mid i \neq j \}$$

$$Normalized\_inter_i = \frac{Ninter_i}{|cl_i|}$$

### Intra-relationship criterion

This criterion represents the number of overlapped line segments in a cluster normalized by the size of the cluster.

$$Nintra_i = \left| \left\{ l \in cl_i \text{ and } NumOverlap(l) \geq Threshold_{no} \right\} \right|$$

$$Normalized\_intra_i = \frac{Nintra_i}{|cl_i|}$$

## Experimental Evaluation

### CBIR

- Feature vector:  $(Ninter(1), \dots, Ninter(max_c), Nintra(1), \dots, Nintra(max_c))$  in which
  - $Ninter(k) = \max \{ Normalized\_inter_i \mid Ninter_i \geq k \}$ ,
  - $Nintra(k) = \max \{ Normalized\_intra_i \mid Nintra_i \geq k \}$ ,
  - $Max_c = 64$
- The C4.5 package was used to generate decision-tree classifiers.
- 977 test images (336 building images) from creatas.com and freefoto.com.
- A set of cross-validation experiments in each of which 90% of the images were used as the training set and the other 10% as the test set.
- The average error was 5.8%.

### Object Recognition

- 97 well-patterned buildings (bp): 97/97
- 44 not-well-patterned buildings (bnp): 42/44
- 16 non-patterned non-buildings (nbnp): 15/16
- 25 patterned non-buildings (nbp): 0/25

- Some correct results are shown just below the title.

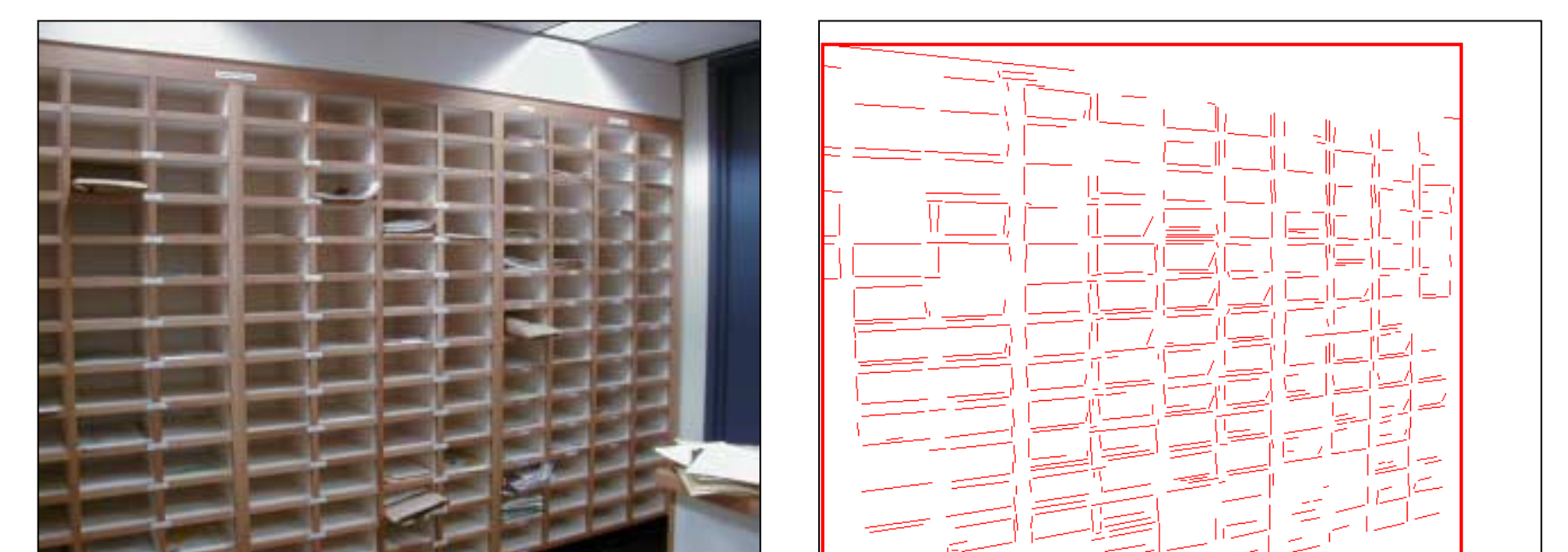
- False negative of not-well-patterned buildings:



- False positive of non-patterned non-buildings:



- False positive of patterned non-buildings:



## Future Work

- Constructing hierarchically structured clusters
- Using CLC on other objects
- Combining CLC with other features
- Developing more object recognizers for common objects
- Use these recognizers to design a new set of low- and mid-level features
- Designing a learning system that can use these features to recognize classes of objects