Graduation project 2014

Exploring Regularities for Improving Façade Reconstruction from Point Cloud

Kaixuan Zhou

Supervisors
Dr. Ben Gorte
Dr. Sisi Zlatanova
Pirouz Nourian

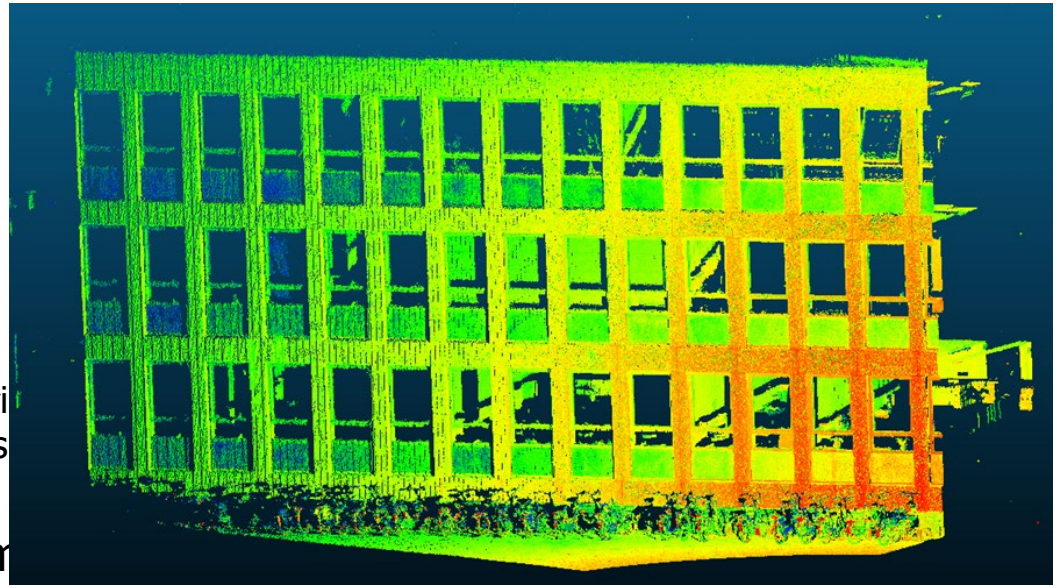
Client
Cyclomedia

Content

- Introduction
- Wall and hole extraction (relevant objects)
- Regularity identification and application
- Quality analysis
- Conclusion

Introduction

- LoD3
  - Façade details
  - Applications
    - Serious games: Fire bri
    - Luminance calculations
- Point Clouds- (Semi)-Autom
  - Terrestrial LiDAR
  - Panoramic images

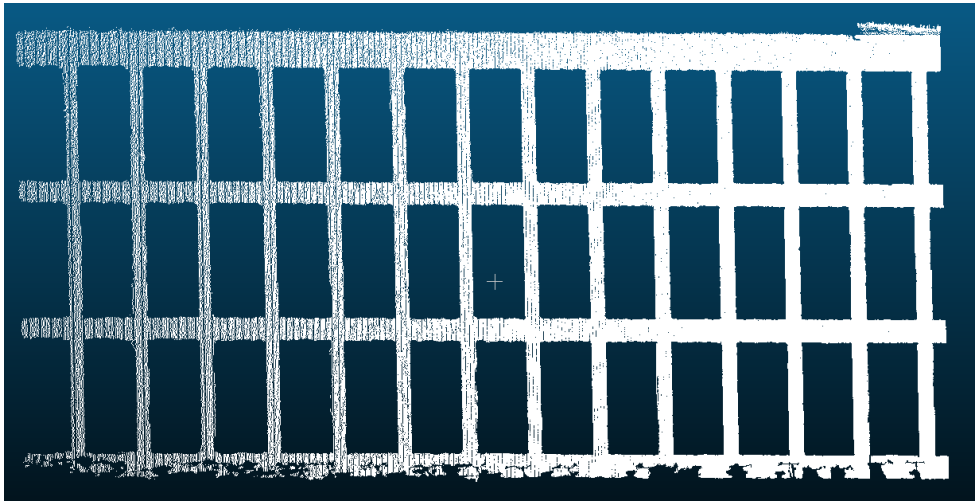


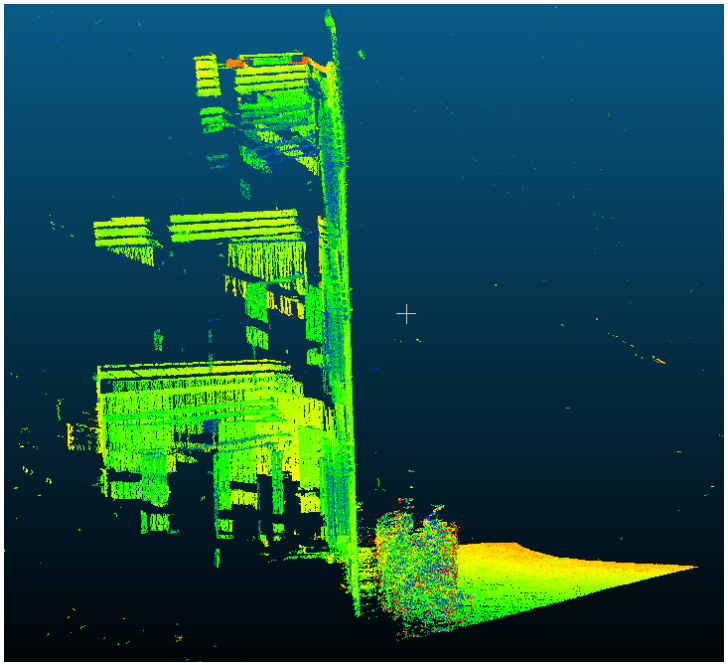
Courtesy of Karlsruhe Institute of Technology

Cyclomedia point cloud

Introduction

- **Problems of Data**
- Relevant objects
  - Wall and holes
- Occlusions
  - Out of Scope
  - Not bad for terrestrial point cloud
- Noise and varying Densities
- **Imperfectness of recognition algorithms**
- **Regularities**
  - Features shared within one object and among objects





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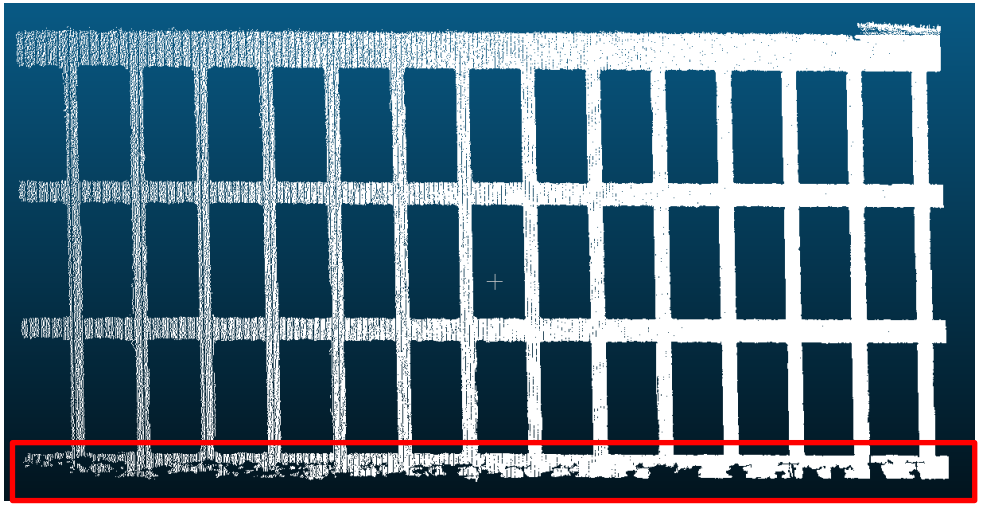

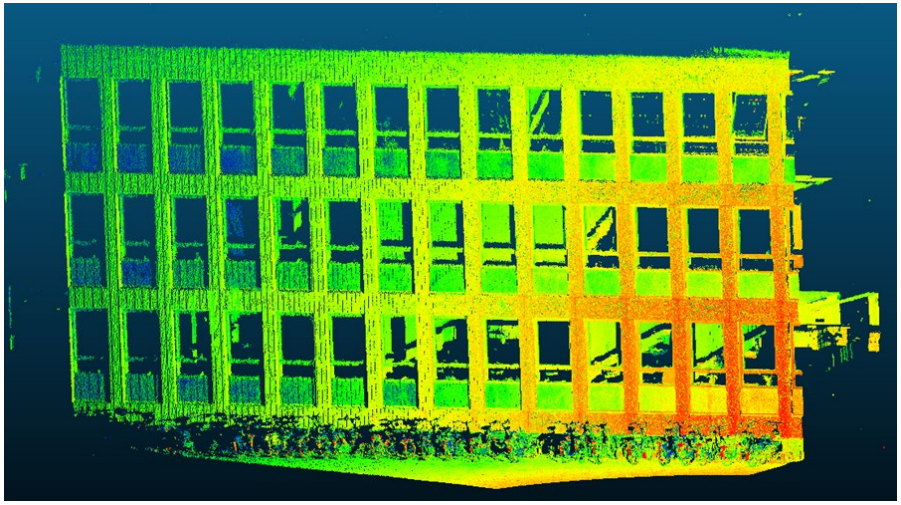

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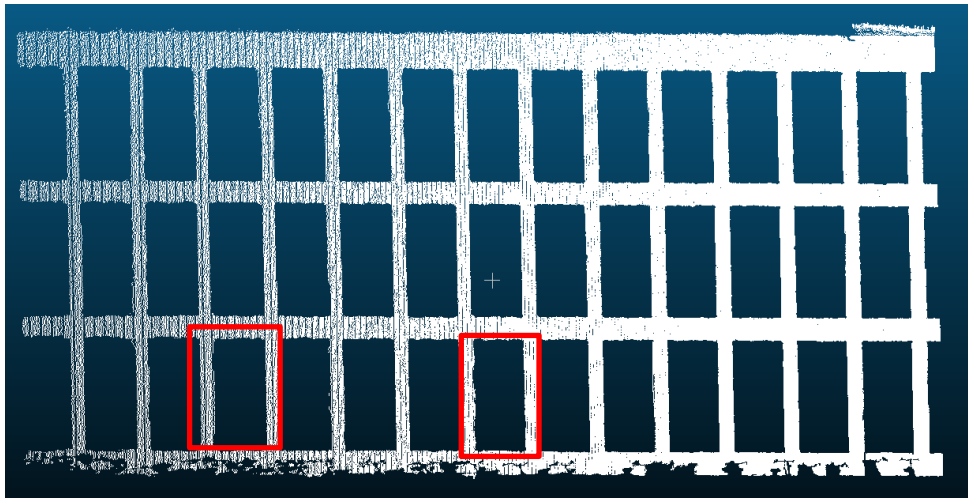

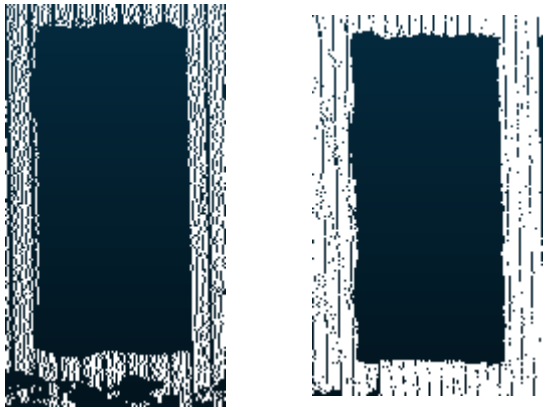

Density

low ← high

big Size of hole small

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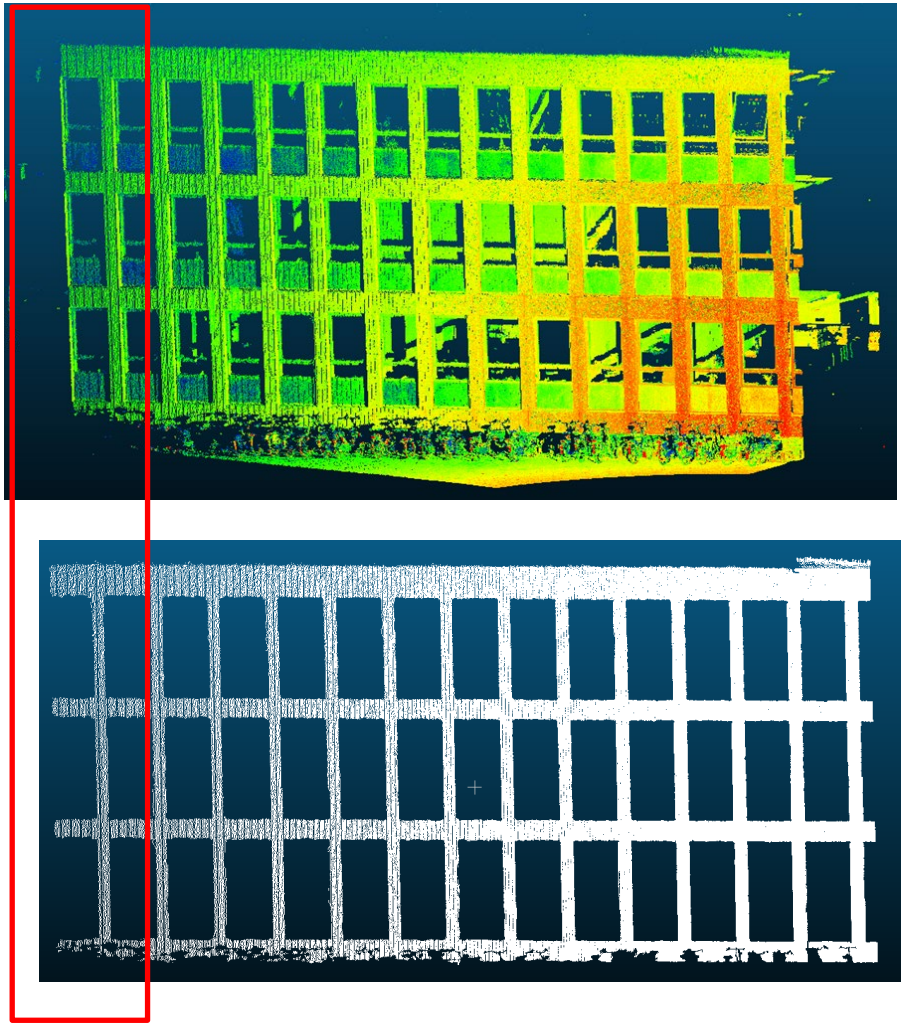
•Imperpectness of recogintion algorithms

•Regularities

•Features shared within one object and among objects



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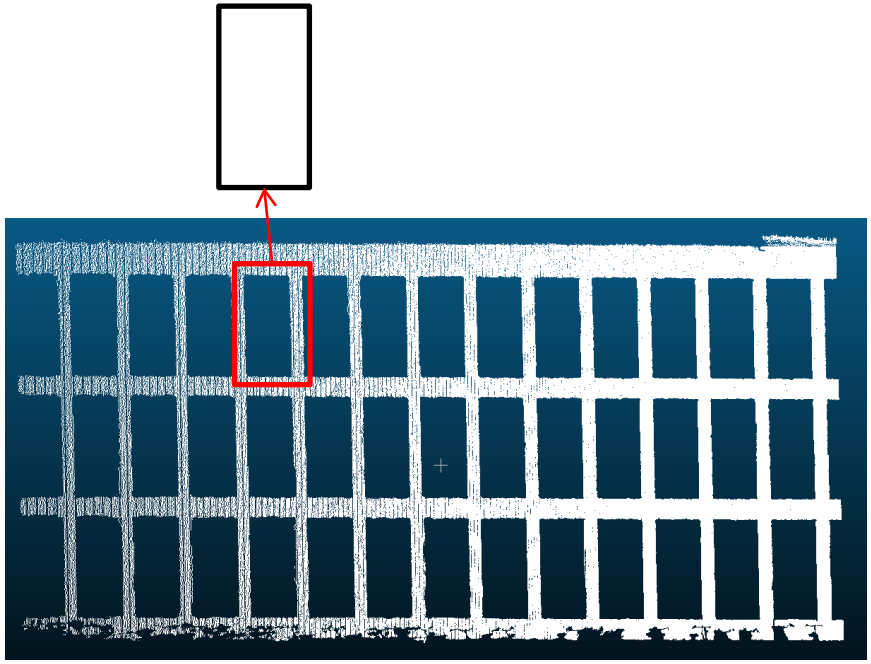
- **Imperpectness of recogintion algorithms**

- **Regularities**
  - Features shared within one object and among objects



Introduction

- Noise, varying density and imperfectness of algorithm can affect quality of extracted separate objects.

- **Research Question:**
  - In which way regularities can be identified from point cloud and applied in order to improve quality of 3D facade reconstruction?

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- Wall and hole extraction (relevant objects)
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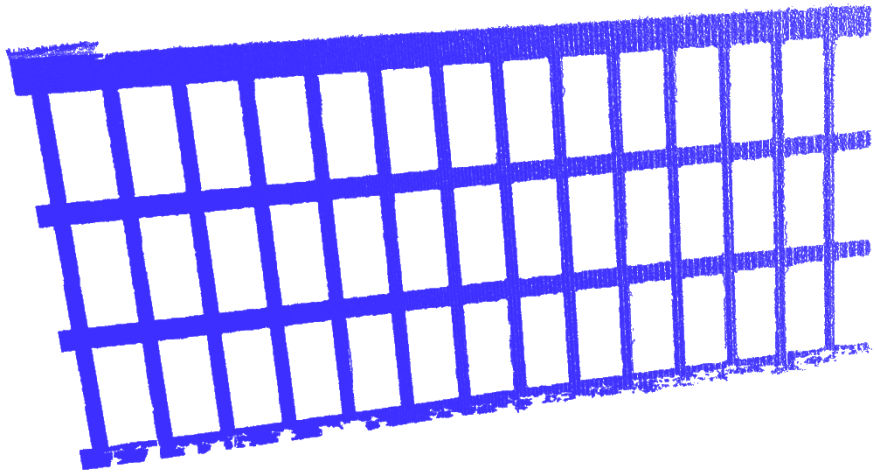
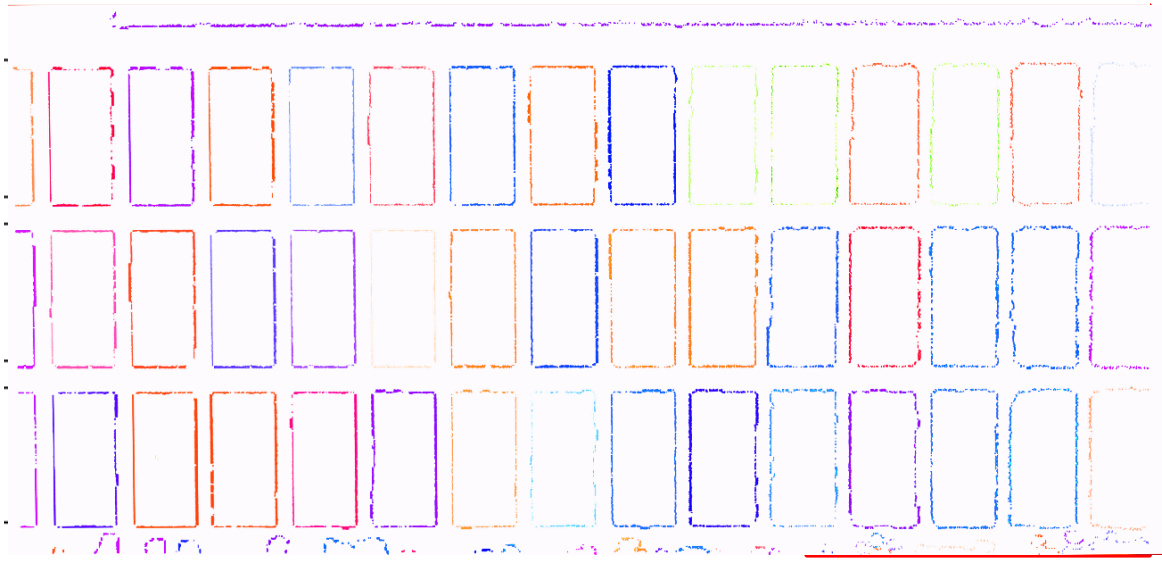
Wall and Hole extraction

- Facade of Faculty of Applied Sciences (TN)
- RANSAC Plane fitting and Wall extraction(knowledge rule: vertical and largest plane)



Holes extraction

- **Rasterization**
  - Rasterization
  - Dilation and erosion closing(varying density)
  - Connected component labeling
  - Hole points tracing



Holes extraction

- Advantage
- Robust to noise and varying densities.
- Tracing point back from original point cloud avoid loss of information

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Regularity identification and application

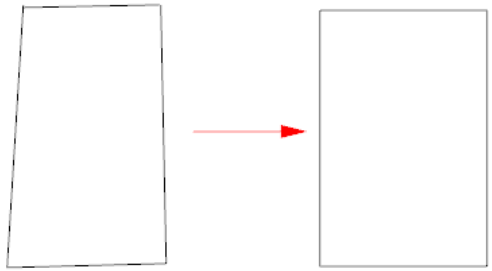
- Different regularities in the Facade

- Principle of regularities identification and application from feature and clustering method

- The procedures of regularity identification and application

Different regularities(9 Cases)

- Local Regularity: regularities within one hole
  - Orthogonal and parallel orientation
- Global regularities: regularities among holes
  - Global regularities among similar holes
    - Similar holes share
      - Same boundary
      - Same orientation
      - Position alignment
        - Same Line alignment
        - Same distance
  - Global regularities among different holes
    - The boundaries of different holes share
      - Parallel and orthogonal orientation
      - Same length
      - Position
        - Same Line alignment
        - Same distance



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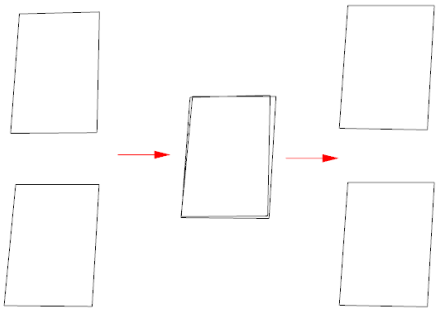

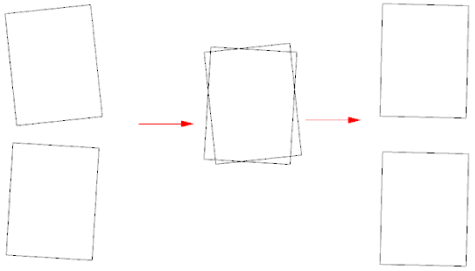

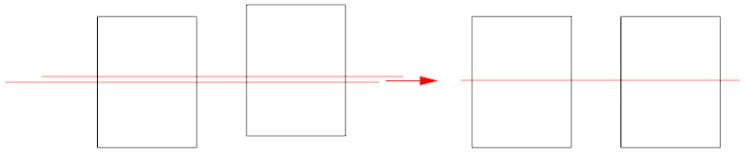

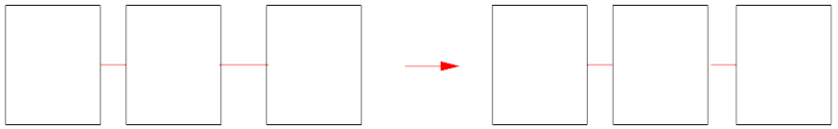

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        - Same Line alignment
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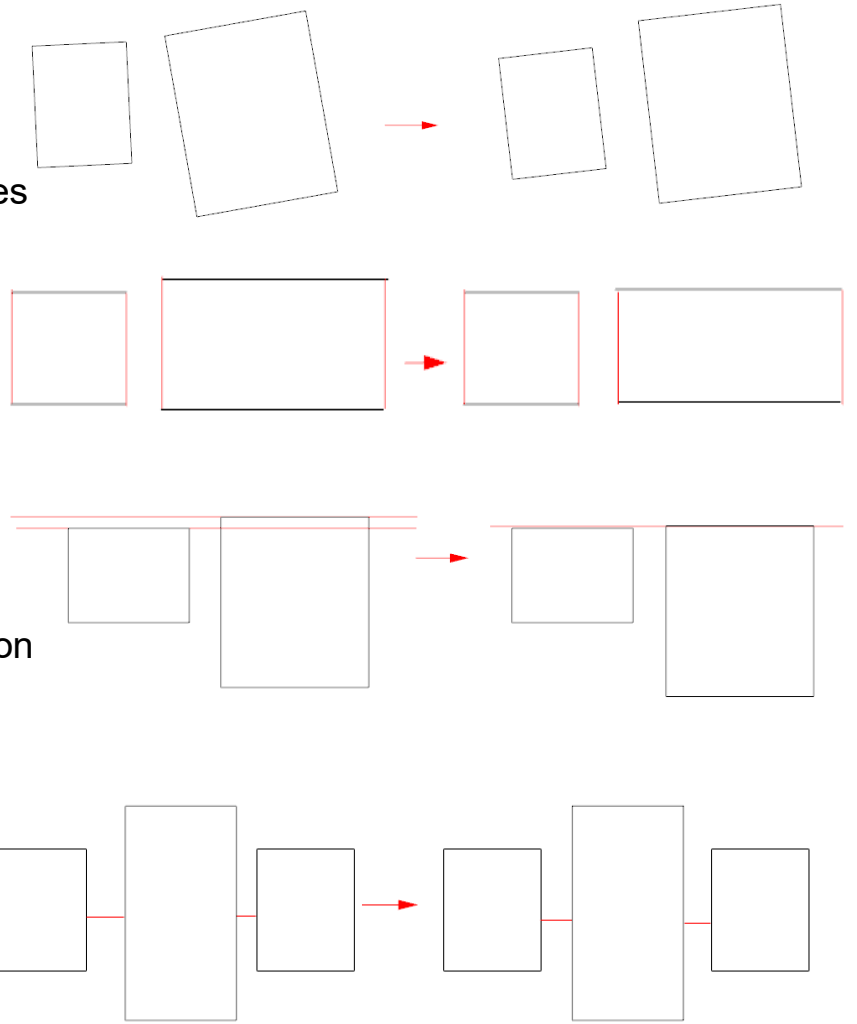
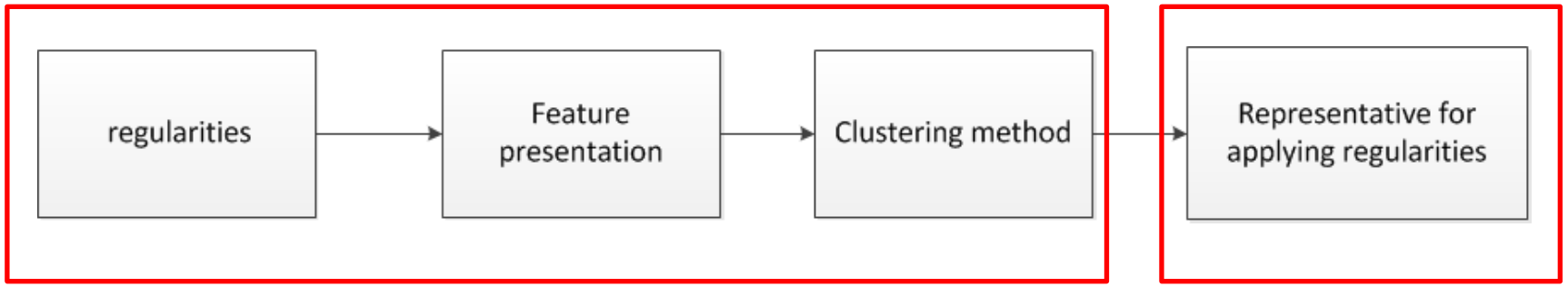
  - Global regularities among different holes
    - Different holes (Boundaries) share
      - Parallel and orthogonal orientation
      - Same length
      - Position
        - Same Line alignment
        - Same distance



Principle of regularity identification and application



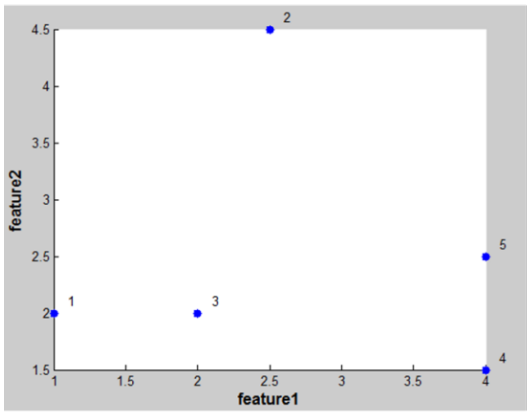
Objects sharing regularities have similar certain features

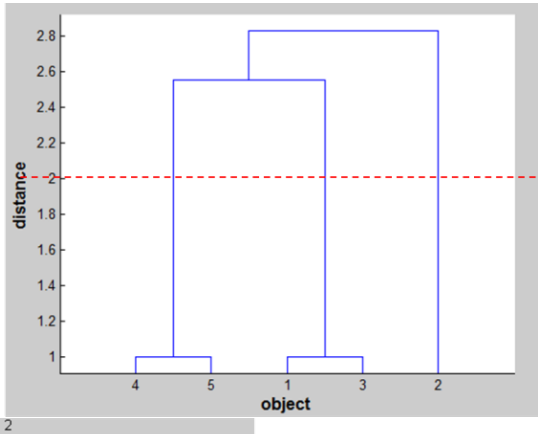
Clustering method can find the similar objects in the feature space

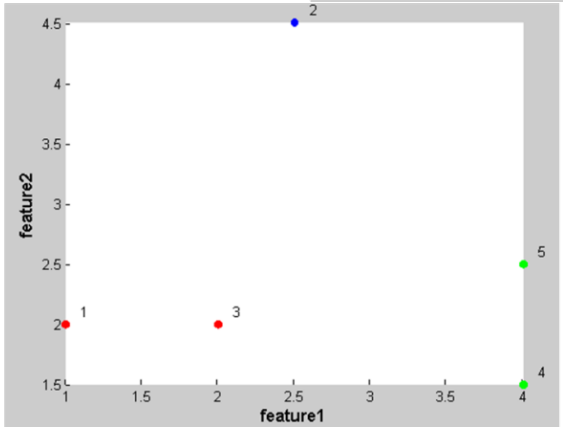
The weighted center is chosen as representative of cluster used for representing all member in cluster

Principle of regularity identification and application

Hierarchical Clustering (Group similar objects in feature space)







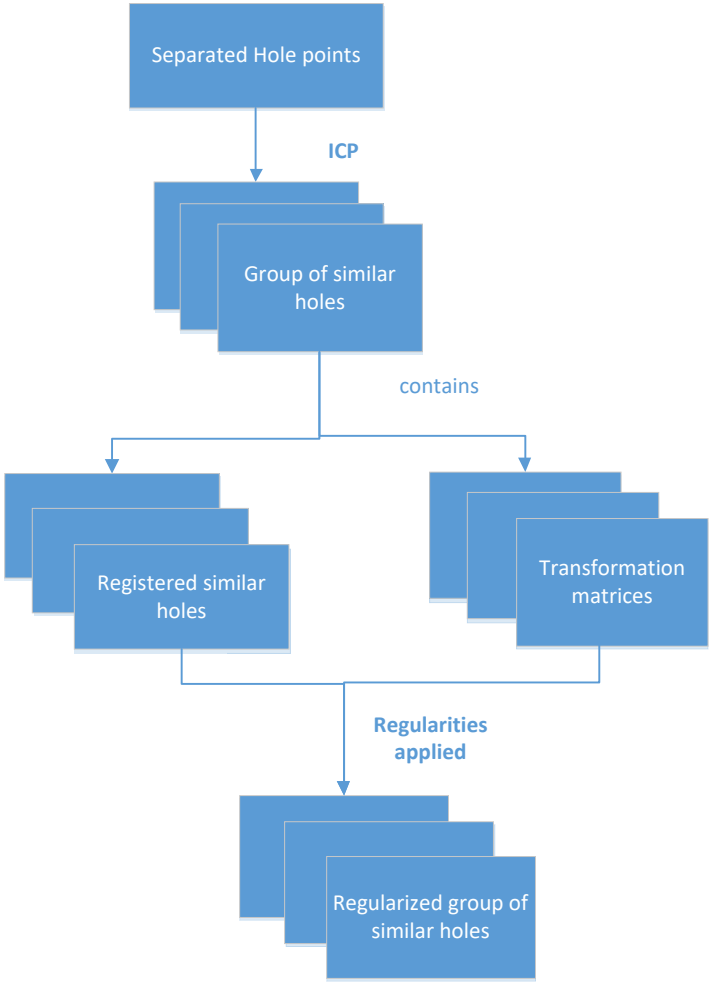
The procedures of regularity identification and application

Find features to present each regularity for clustering

Procedure (1): local regularity and global regularities among similar holes identification and application

Procedure (2): global regularities between different holes identification and application

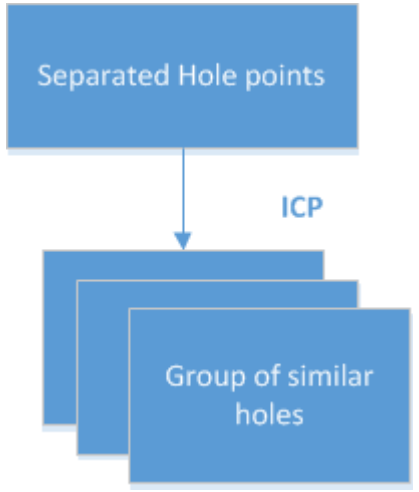
The procedures of regularity identification and application: Procedures(1)-- Overview

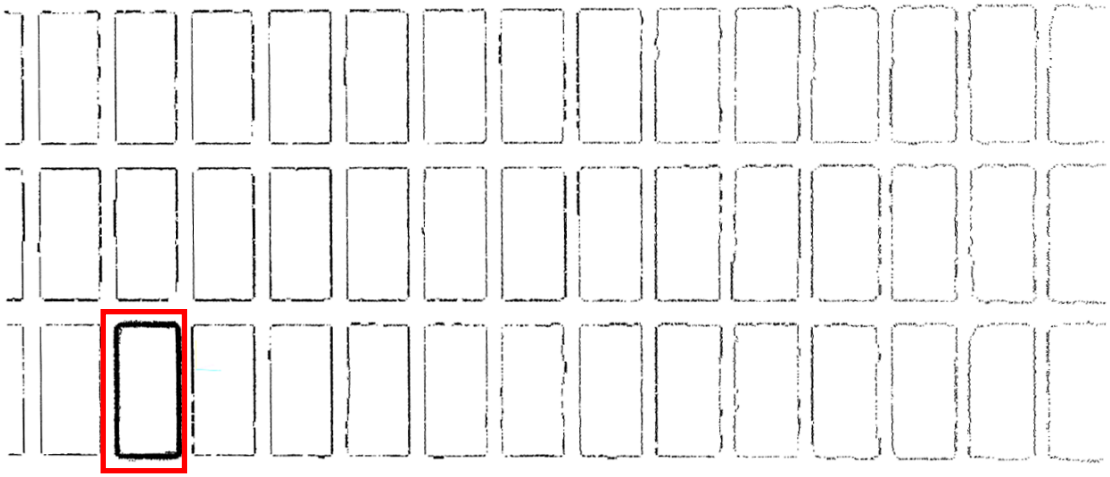


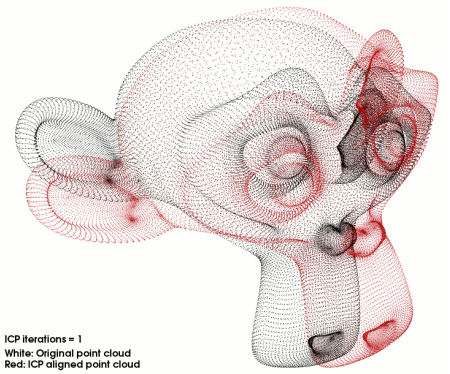
The procedures of regularity identification and application: Procedures(1)-- Overview

ICP(iterative closest points)-
similar objects identification and registration

- Score: distance of closest pairs



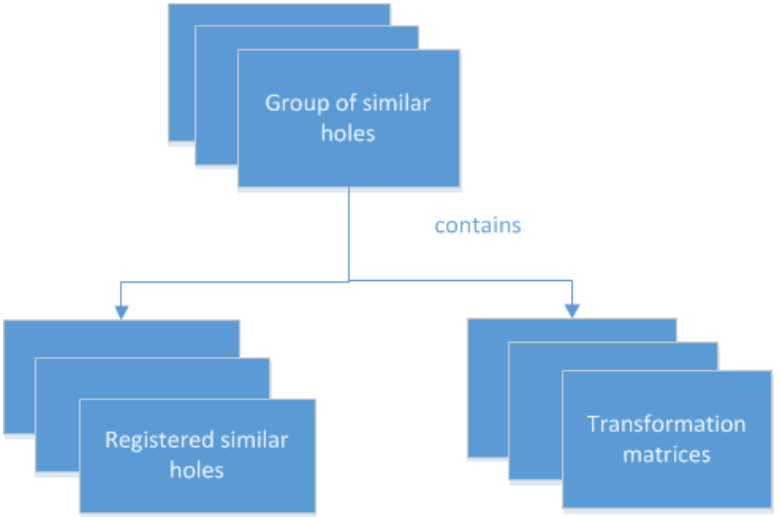




The procedures of regularity identification and application: Procedures(1)-- Overview

Register holes points

contains all boundary information

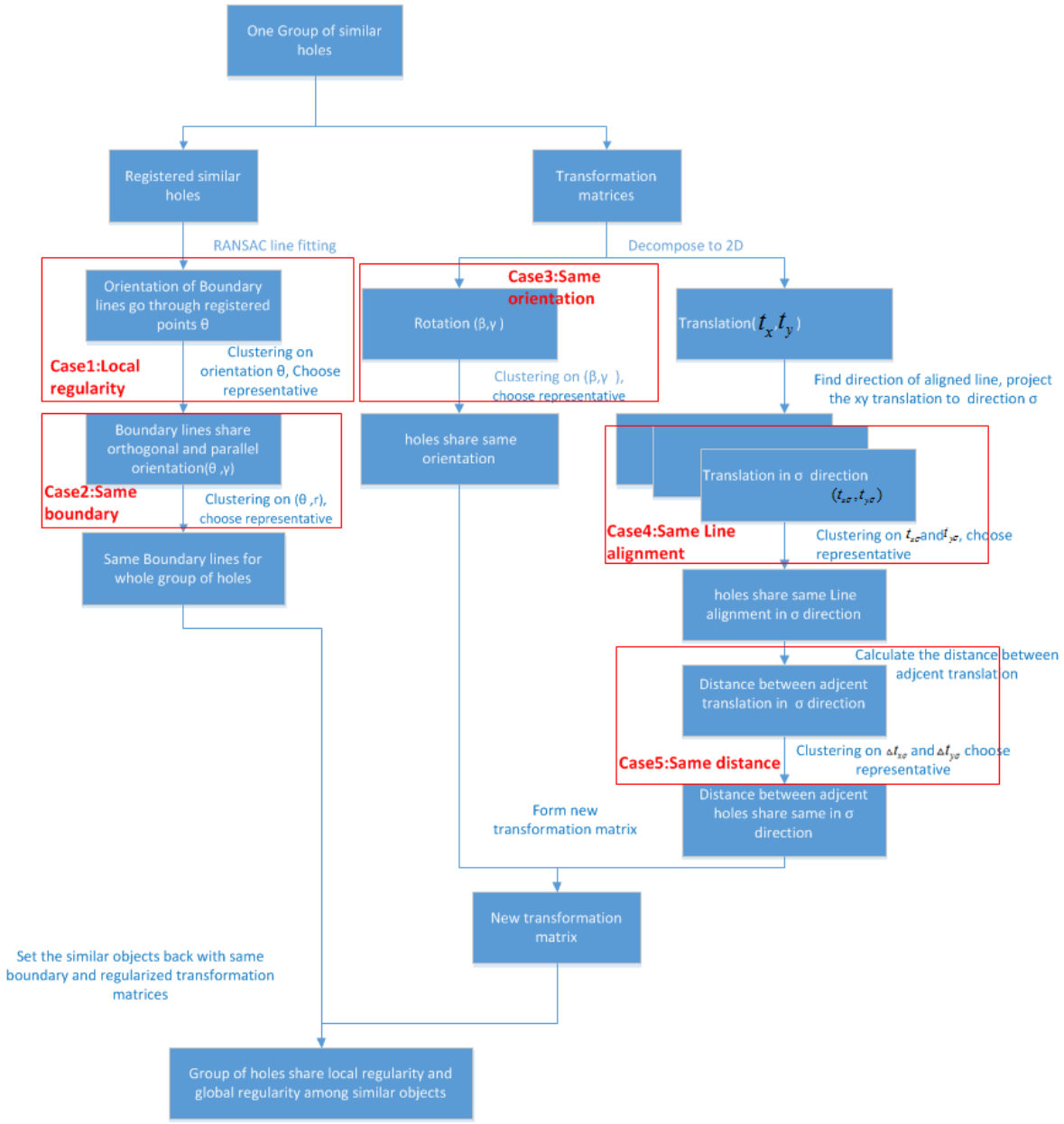


Transformation matrices

$$M = \begin{pmatrix} R & T \\ 0 & 1 \end{pmatrix}$$ contain orientation and position information

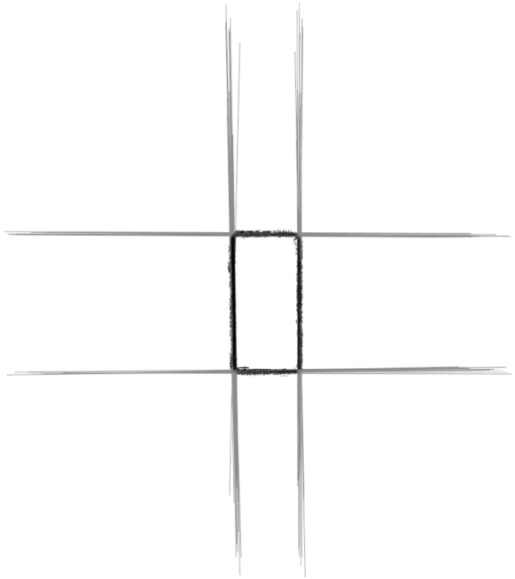
The procedures of regularity identification and application:

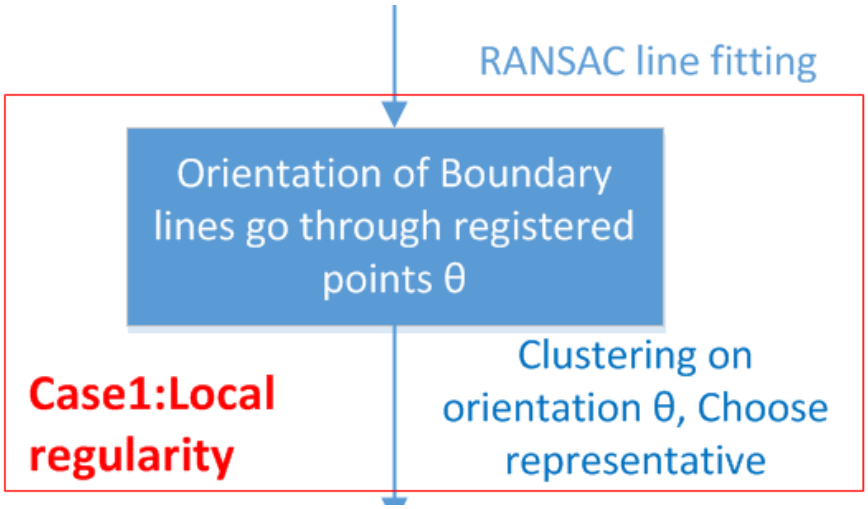
Procedures(1)– Detail



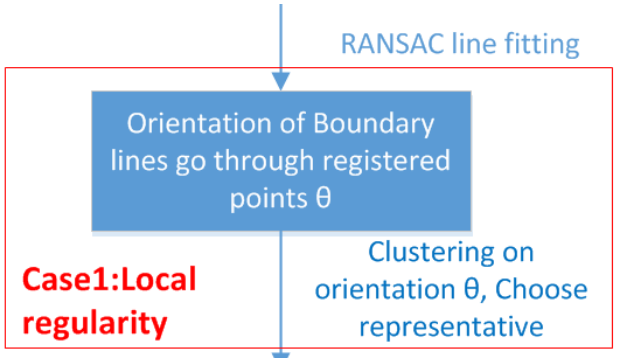
The procedures of regularity identification and application: Procedures(1)– Detail

RANSAC line fitting: boundary line candidates





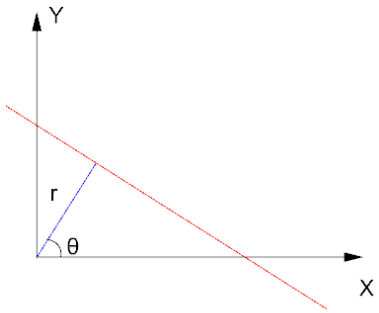
The procedures of regularity identification and application: Procedures(1)– Detail

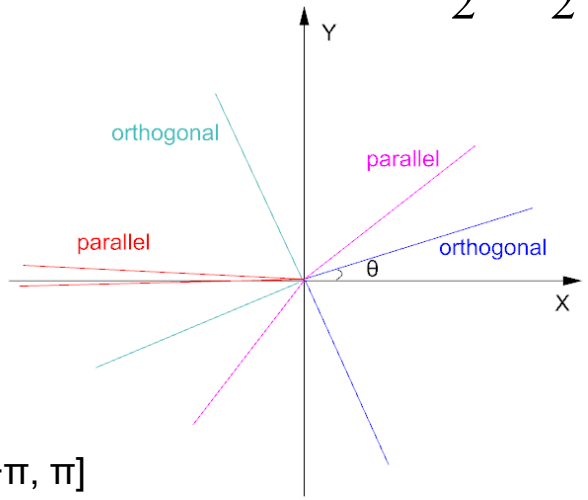


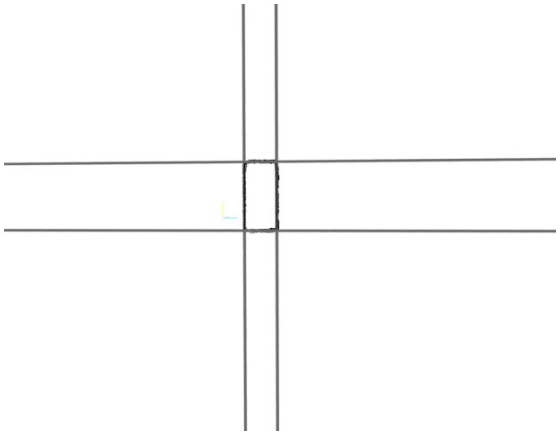
Local regularity: orthogonal and parallel orientation. θ

Parallel orientation: $\theta_i \approx \theta_j \pm 0,\ \pi,\ 2\pi$ when

Orthogonal orientation: $\theta_i \approx \theta_j \pm \frac{\pi}{2},\ \frac{3\pi}{2}$; when





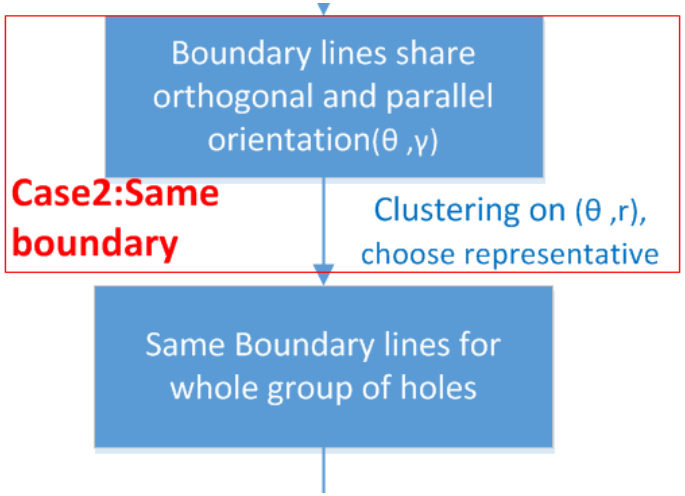


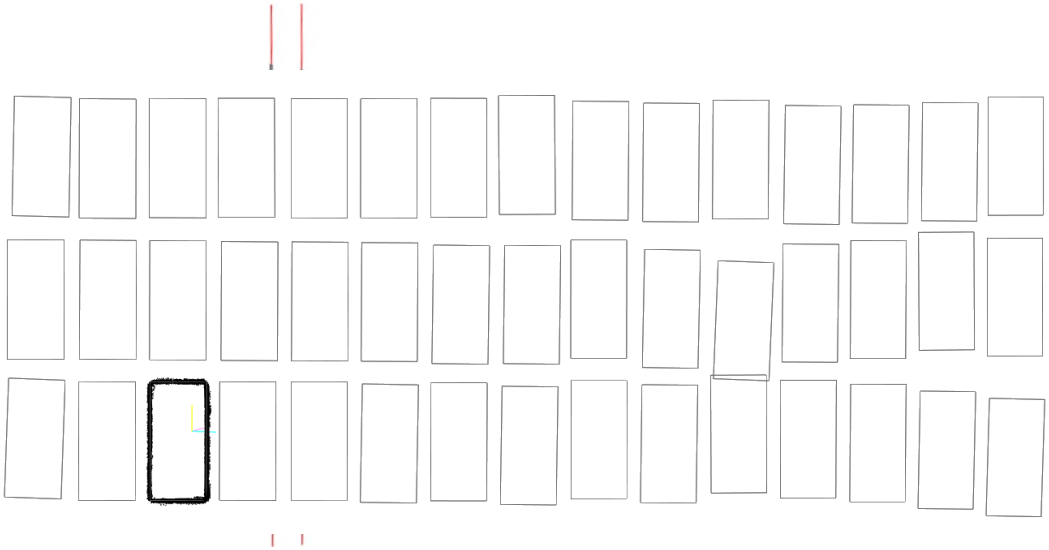
r≥ 0 and θ in the interval (−π, π]

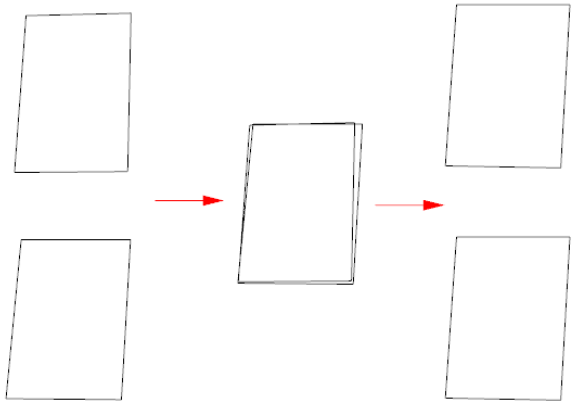
The procedures of regularity identification and application: Procedures(1)– Detail

Same boundary: (r, θ)

Same boundary regularity when: $(r_i, \theta_i) \approx (r_j, \theta_j)$





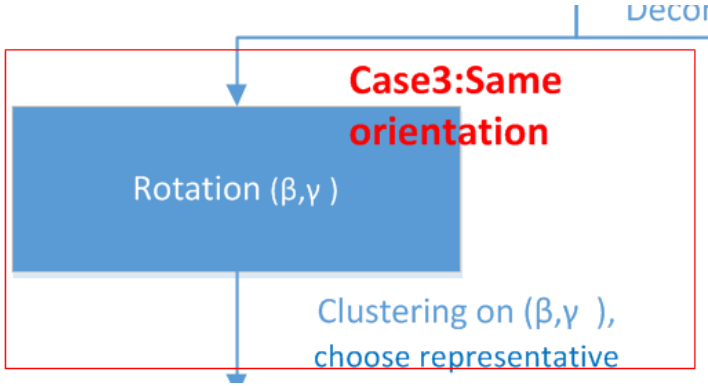


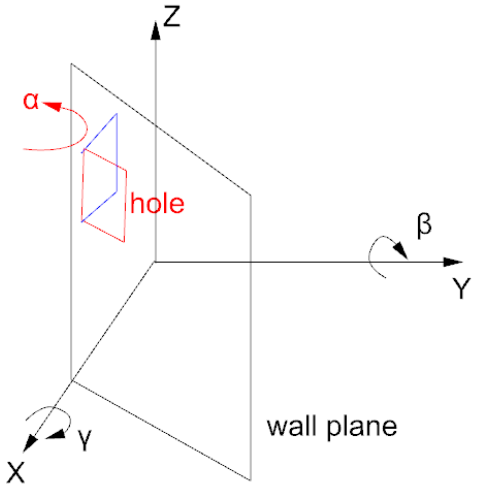
The procedures of regularity identification and application: Procedures(1)– Detail

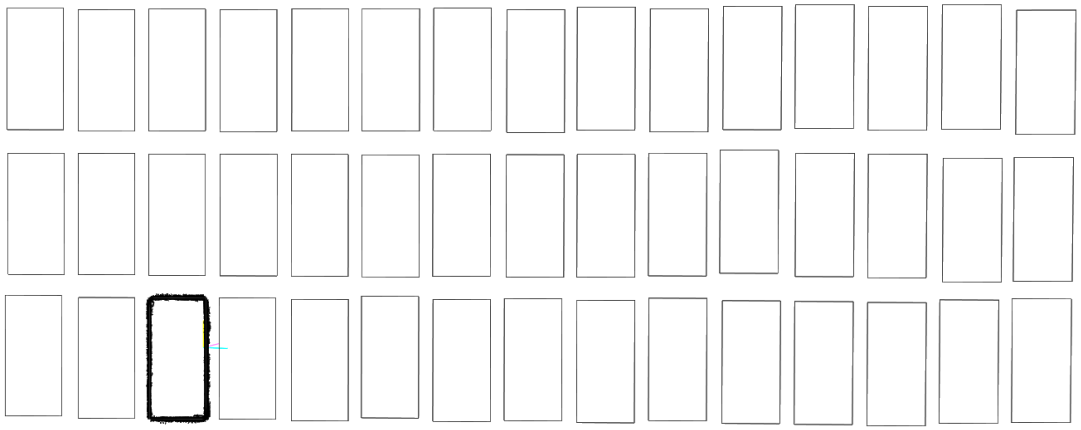
$$M = \begin{pmatrix} R & T \\ 0 & 1 \end{pmatrix}$$

Same orientation:

Same orientation regularity when: $(\beta_i, \gamma_i) \approx (\beta_j, \gamma_j)$







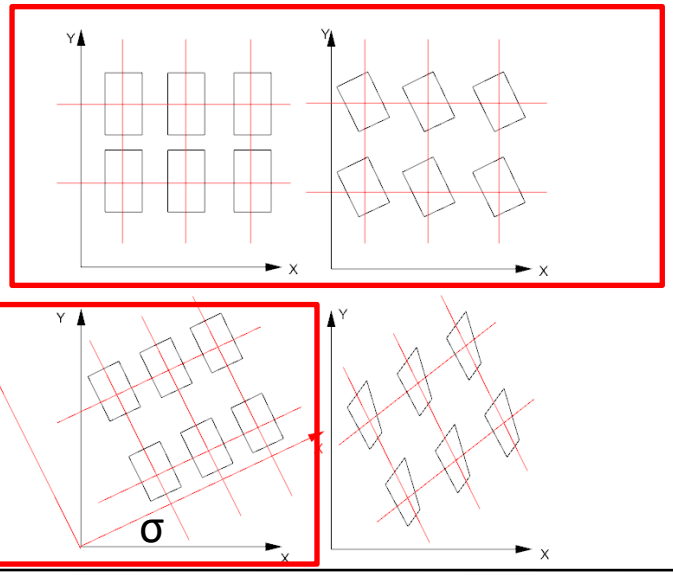
The procedures of regularity i application: Procedures(1)– Detail

$$M = \begin{pmatrix} R & T \\ 0 & 1 \end{pmatrix}$$

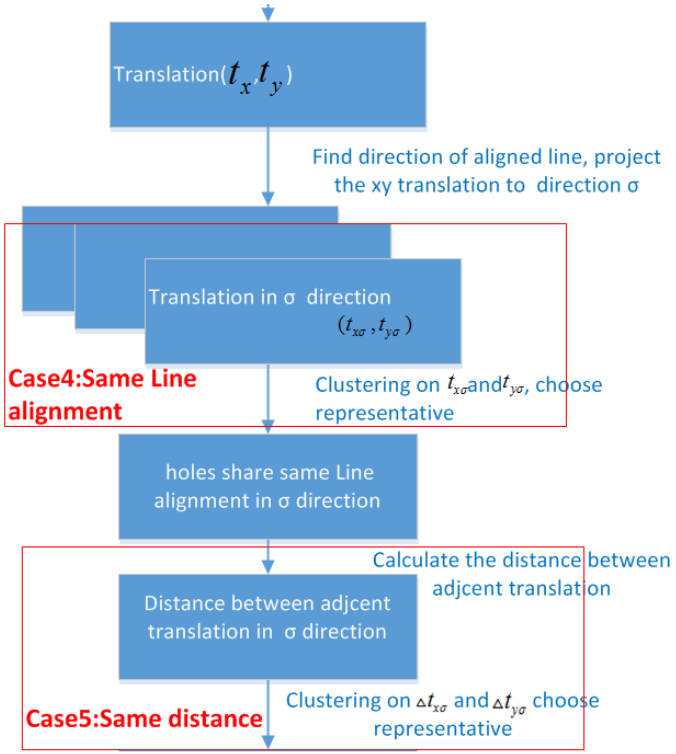
Translation in 2D: (t_x, t_y)

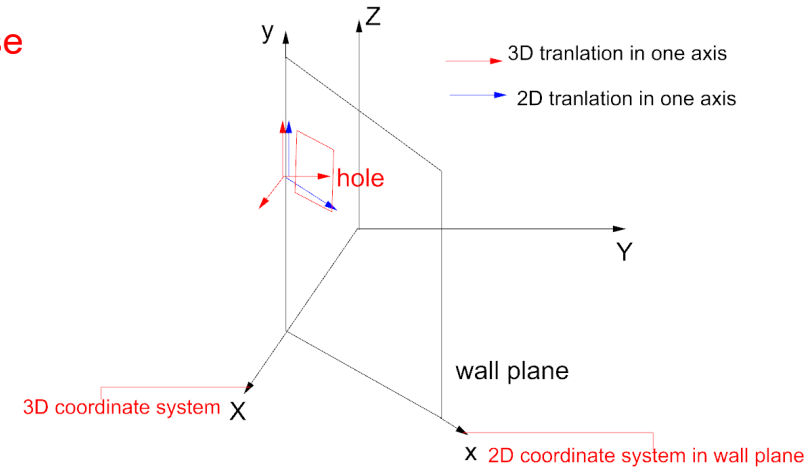
Aligned orientation: σ

Translation in σ direction: $(t_{x\sigma}, t_{y\sigma})$



Common case

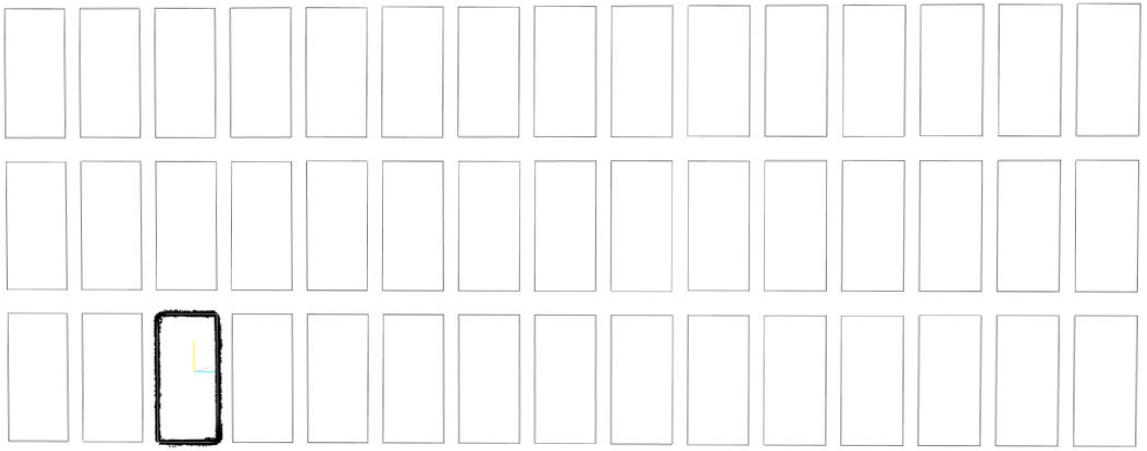


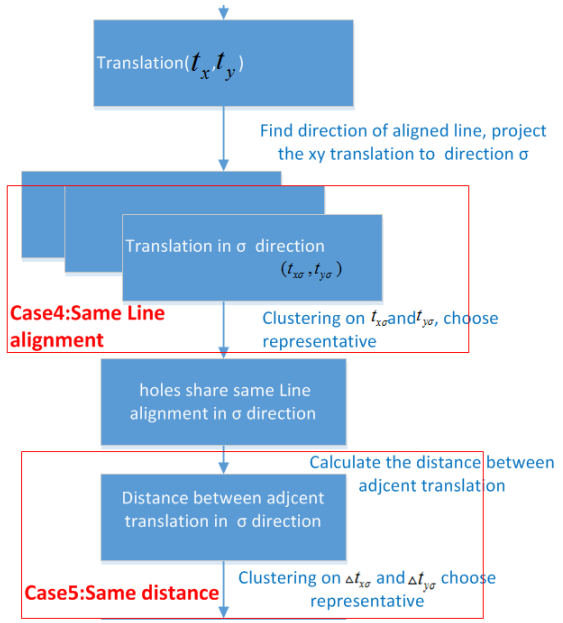


The procedures of regularity identification and application: Procedures(1)– Detail

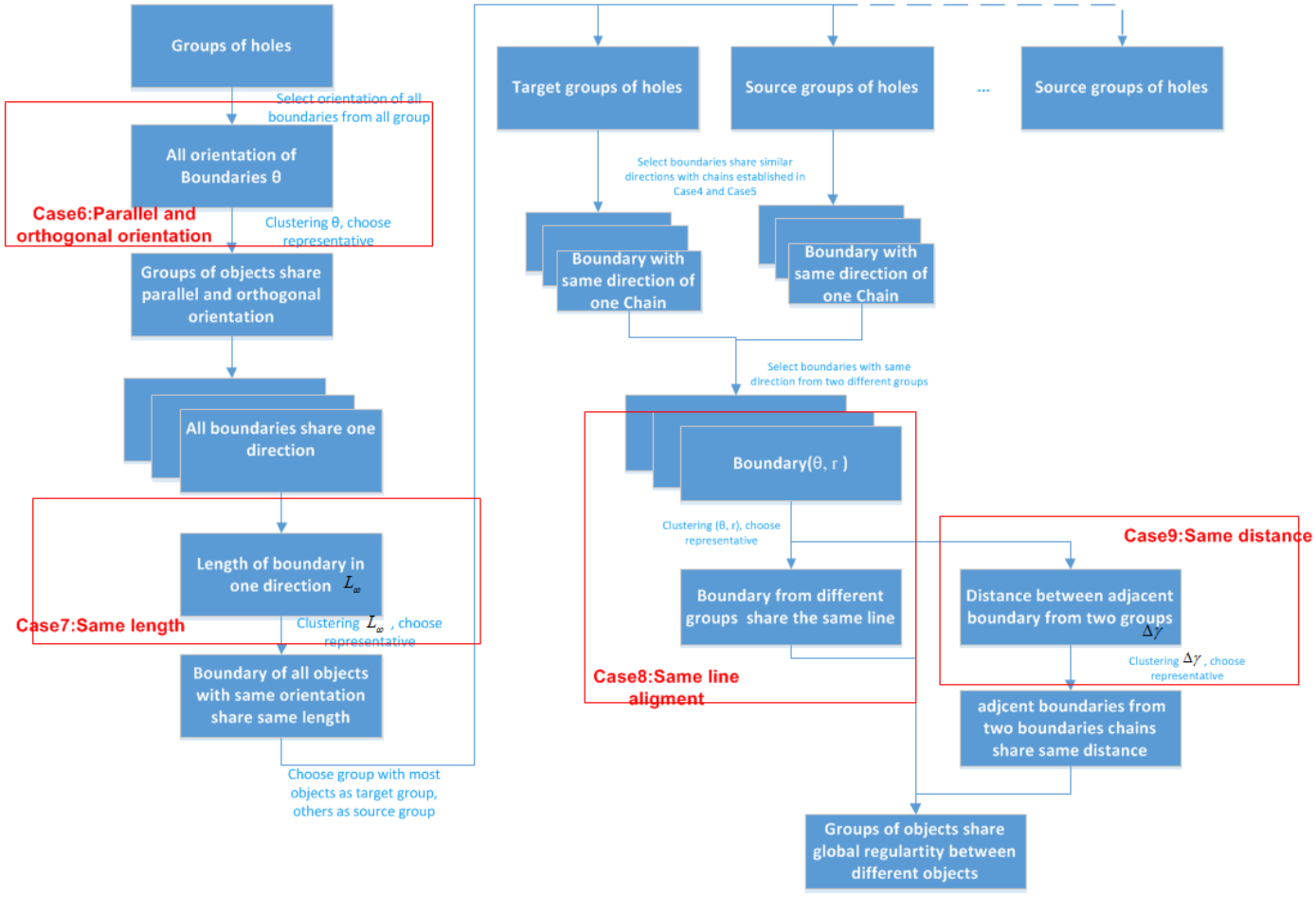
Line alignment regularity $t^{i}_{x\sigma} \approx t^{j}_{x\sigma}$ or $t^{i}_{y\sigma} \approx t^{j}_{y\sigma}$

Distance between objects regularity when: $\Delta t_{x\sigma}{}^{ij} \approx \Delta t_{x\sigma}{}^{jk}$, or $\Delta t_{y\sigma}{}^{ij} \approx \Delta t_{y\sigma}{}^{jk}$



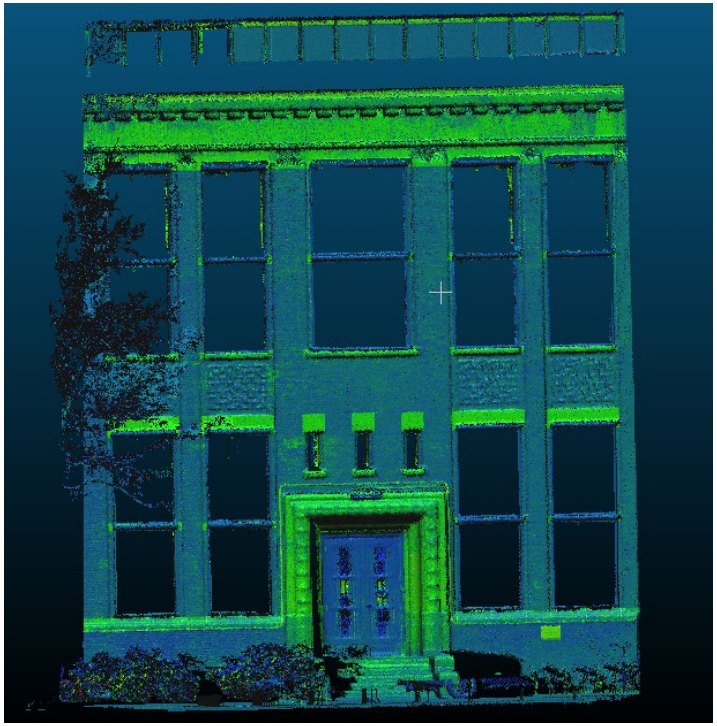


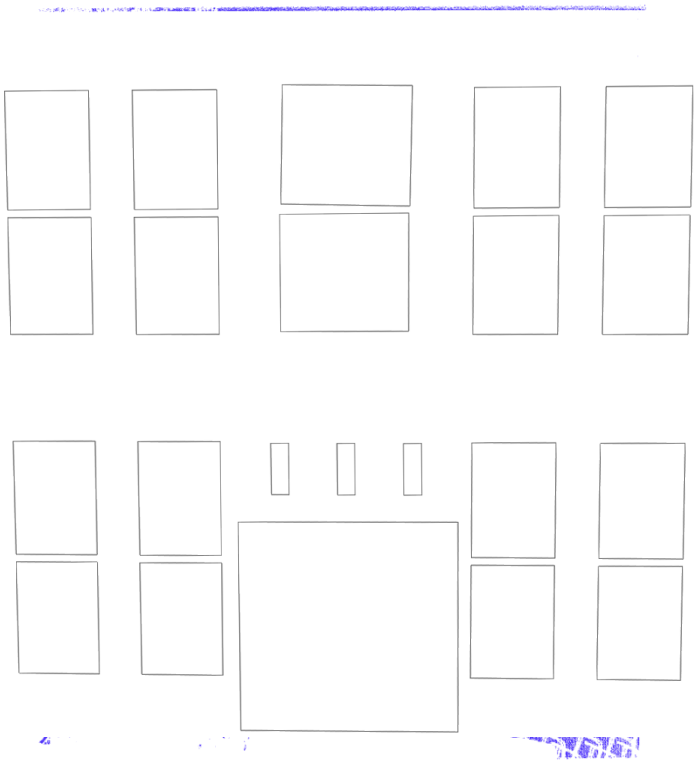
The procedures of regularity identification and application:Procedures(2)



The procedures of regularity identification and application:Procedures(2)

Façade point cloud from Faculty of Architecture and Built Environment (BK)

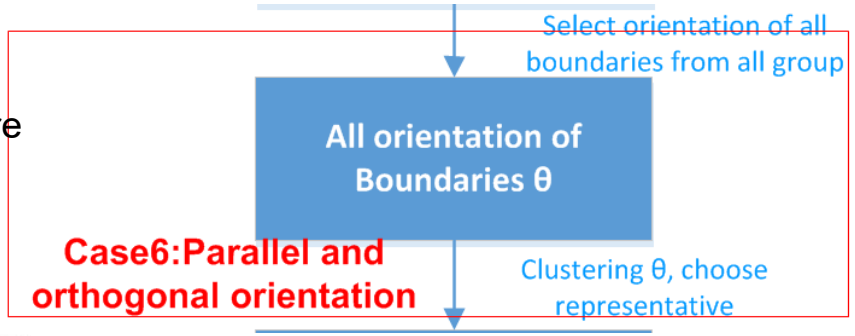


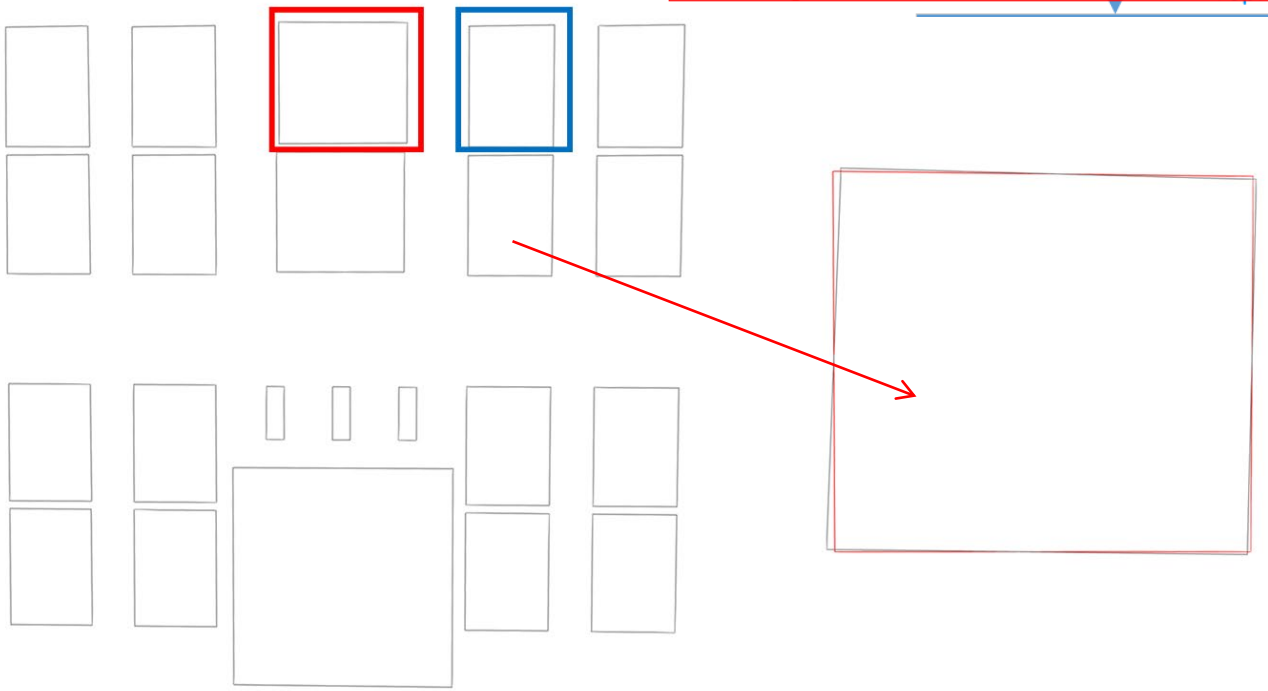


The procedures of regularity identification and application:Procedures(2)

Parallel and orthogonal orientation:

- All orientations of boundary from all groups are considered
- The regularity identification and application is the same with local regularity.





The procedures of regularity identification and application:Procedures(2)

Same length: L_ω

- Lengthes of boundary share a same direction from all groups are clustered respectively .

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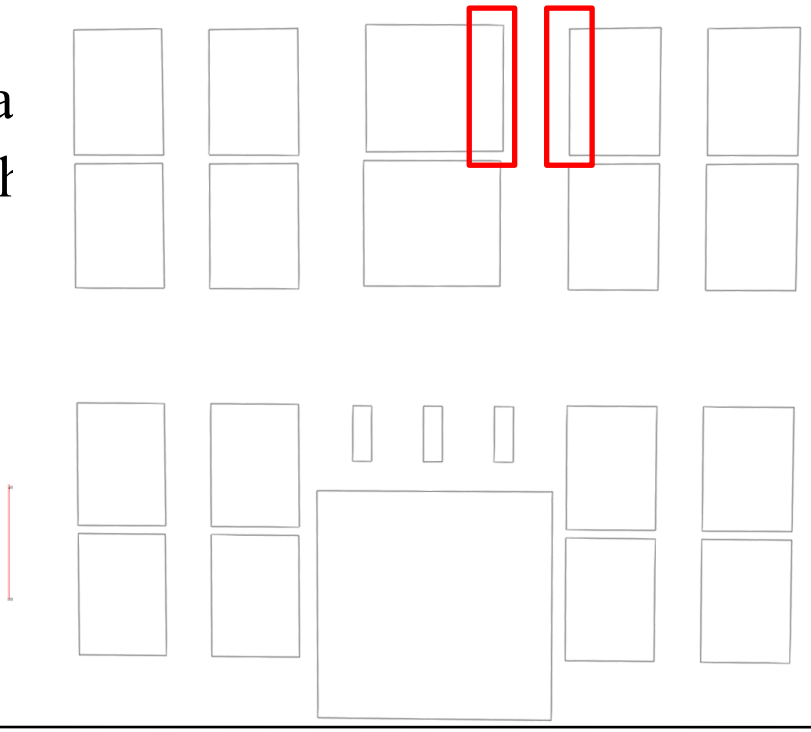
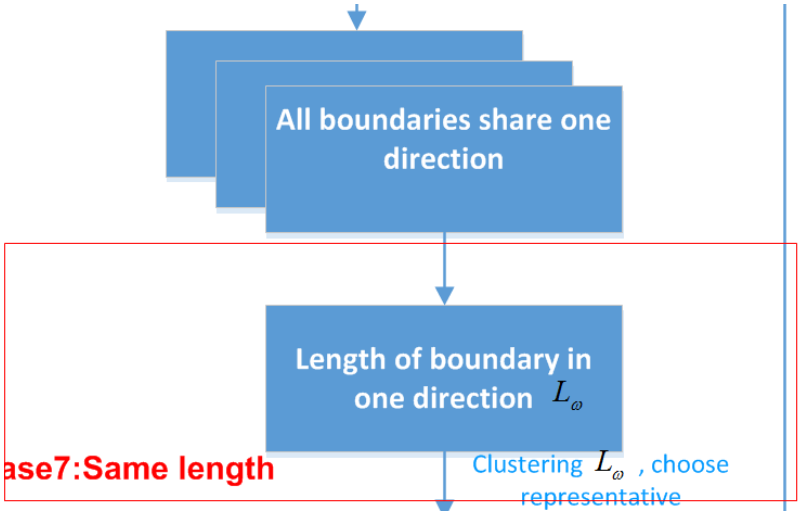
wł



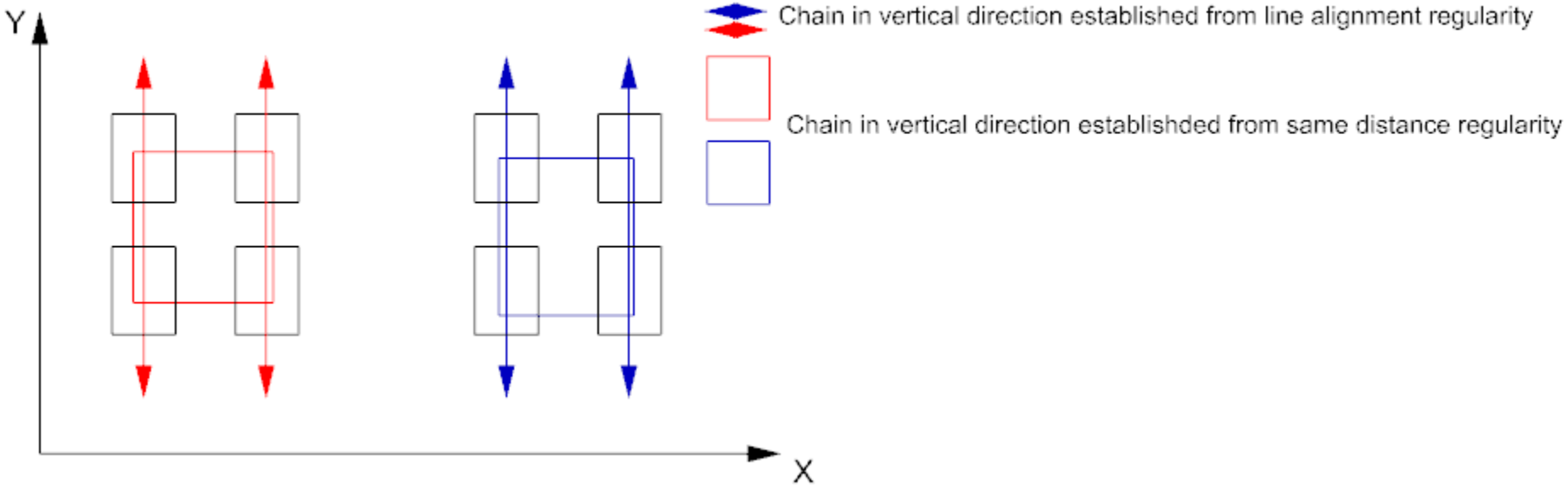


The procedures of regularity identification and application:Procedures(2)

Position regularities: preserve the chains established in previous position regularities among similar objects

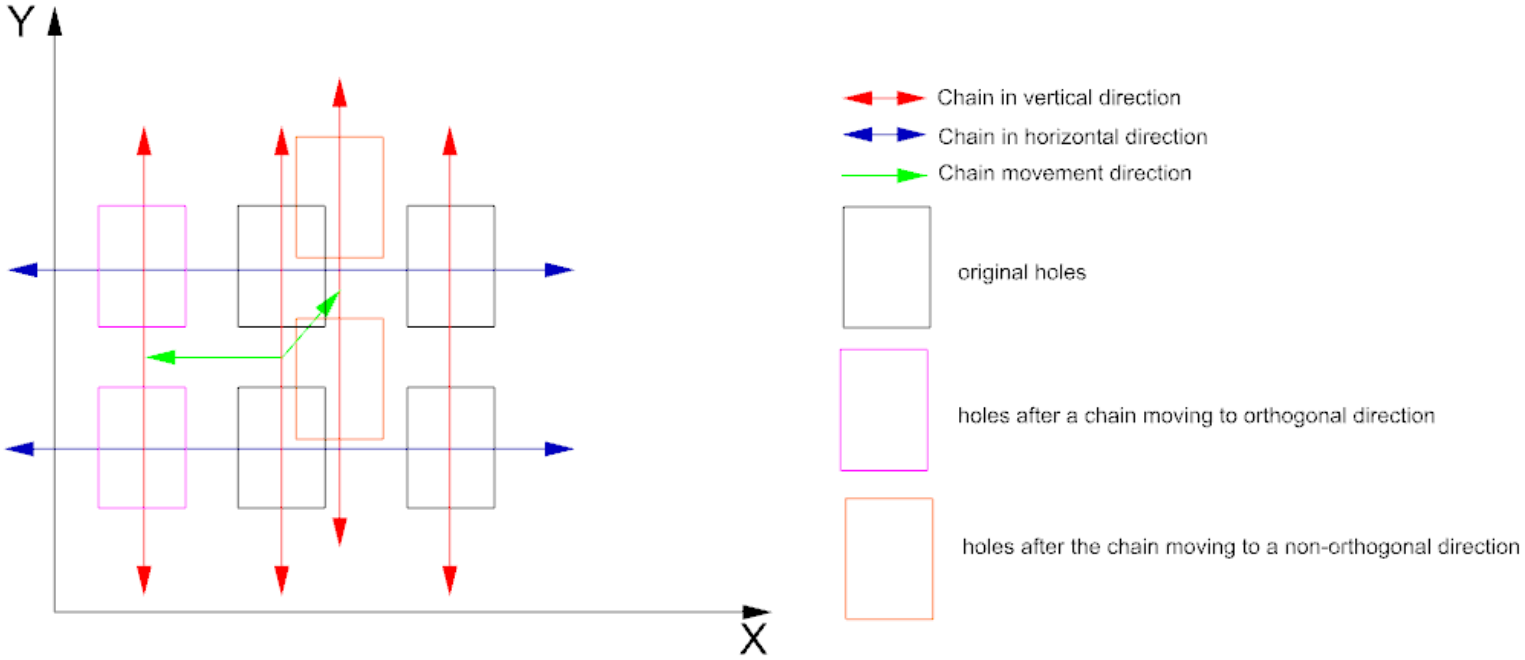
Same line alignment among similar objects

Same distance among similar objects



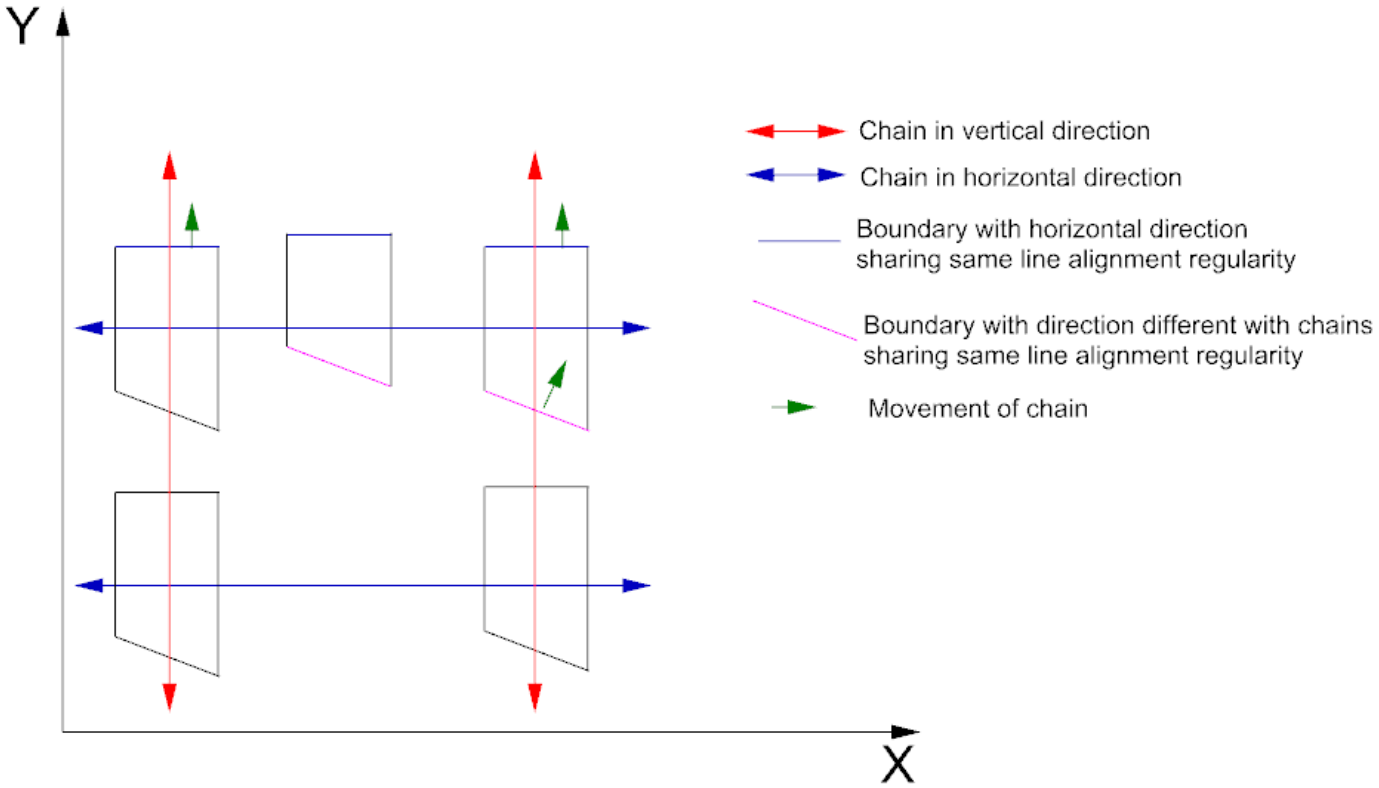
The procedures of regularity identification and application:Procedures(2)

Chains are restrianed to move to its orthogonal direction



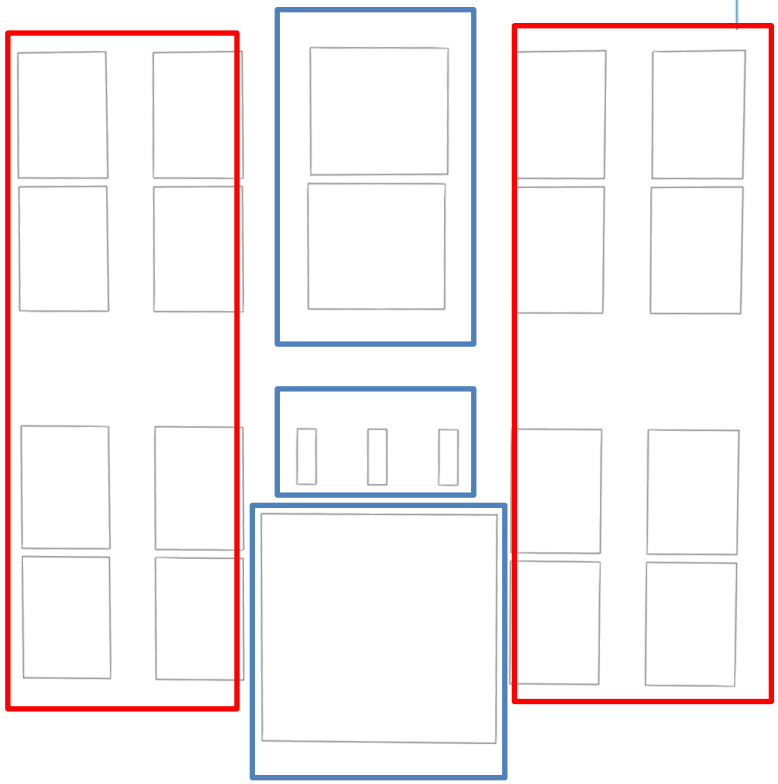
The procedures of regularity identification and application:Procedures(2)

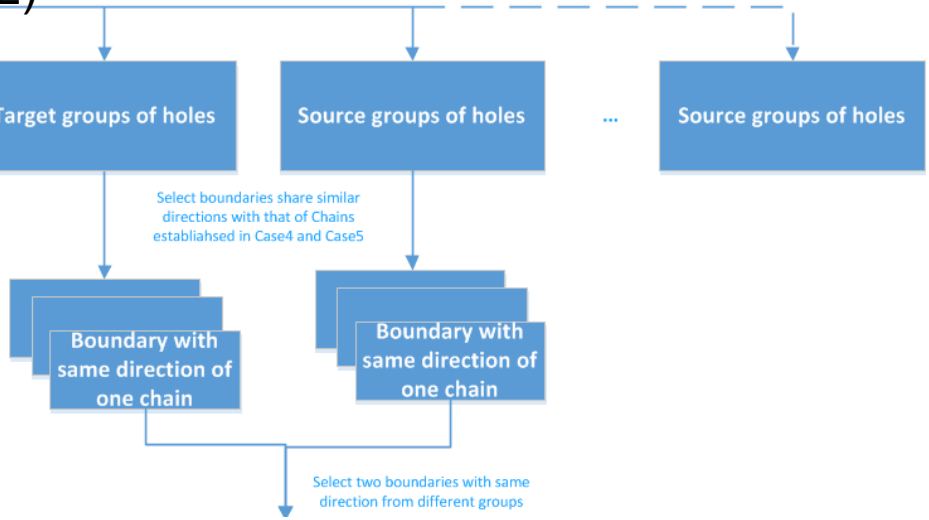
Only Boundaries with similar direction with Chains to taken into account for position regularites



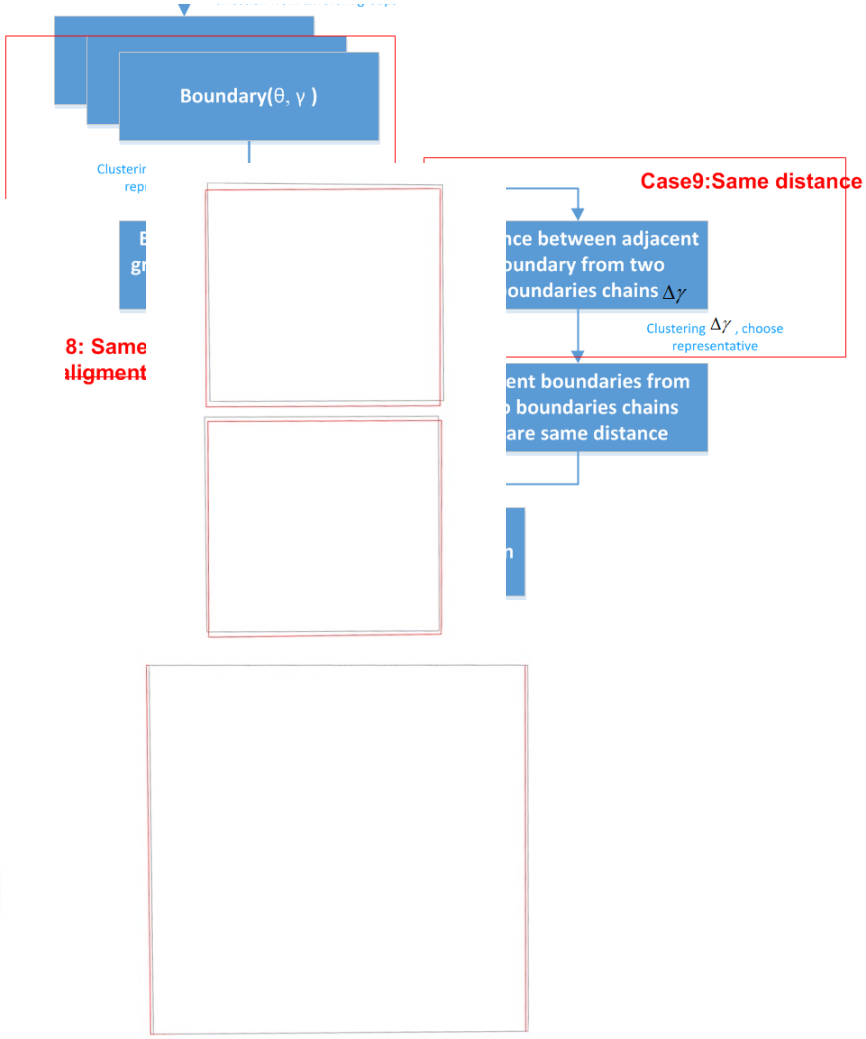
The procedures of regularity identification and application:Procedures(2)

The regularities are found between prominent group (Target)and one of other groups(Source) each time





The procedures of regularity identification and application:Procedures(2)

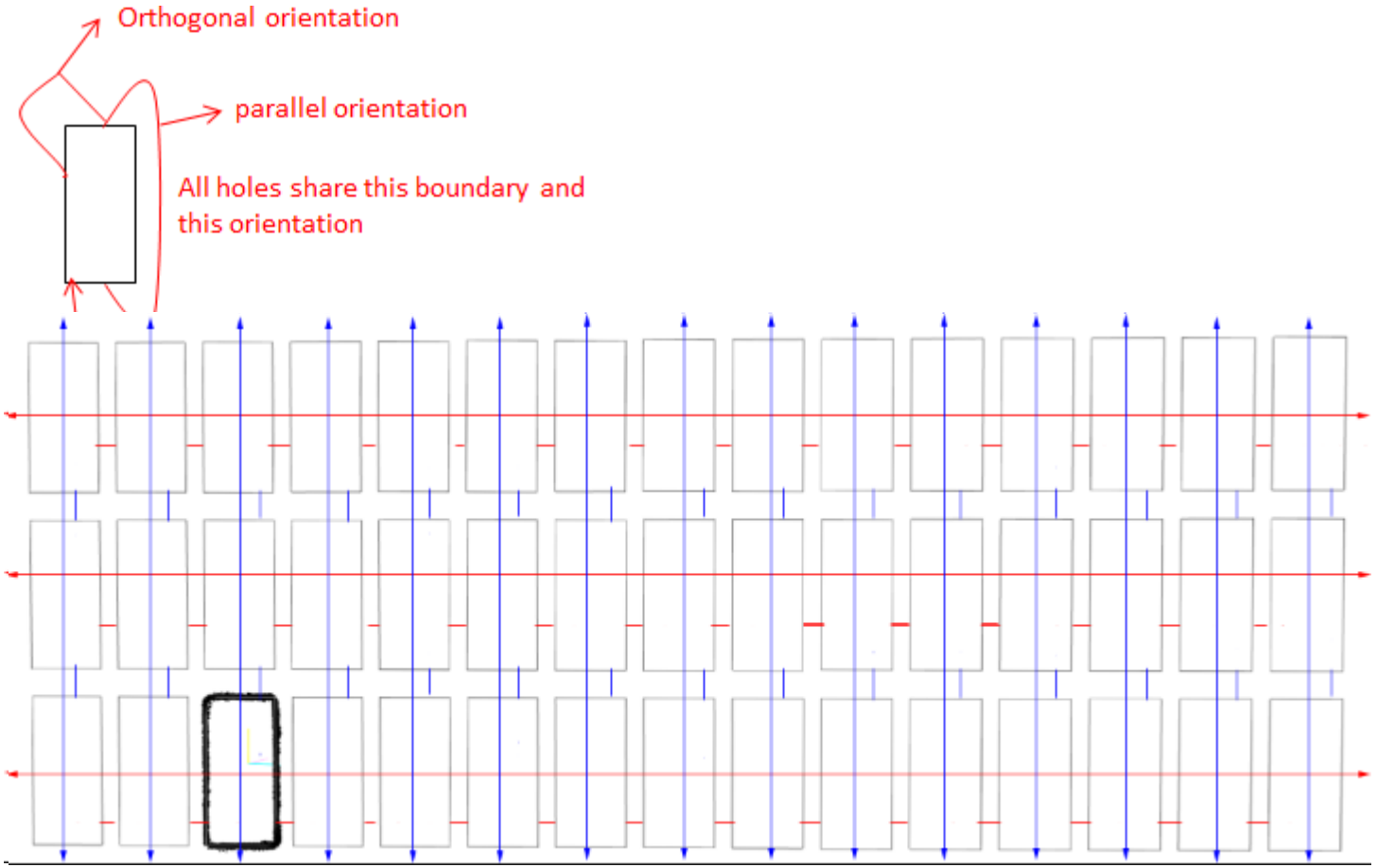


Quality analysis

- Effects of provided procedure for applying regularity
- Match with original point cloud

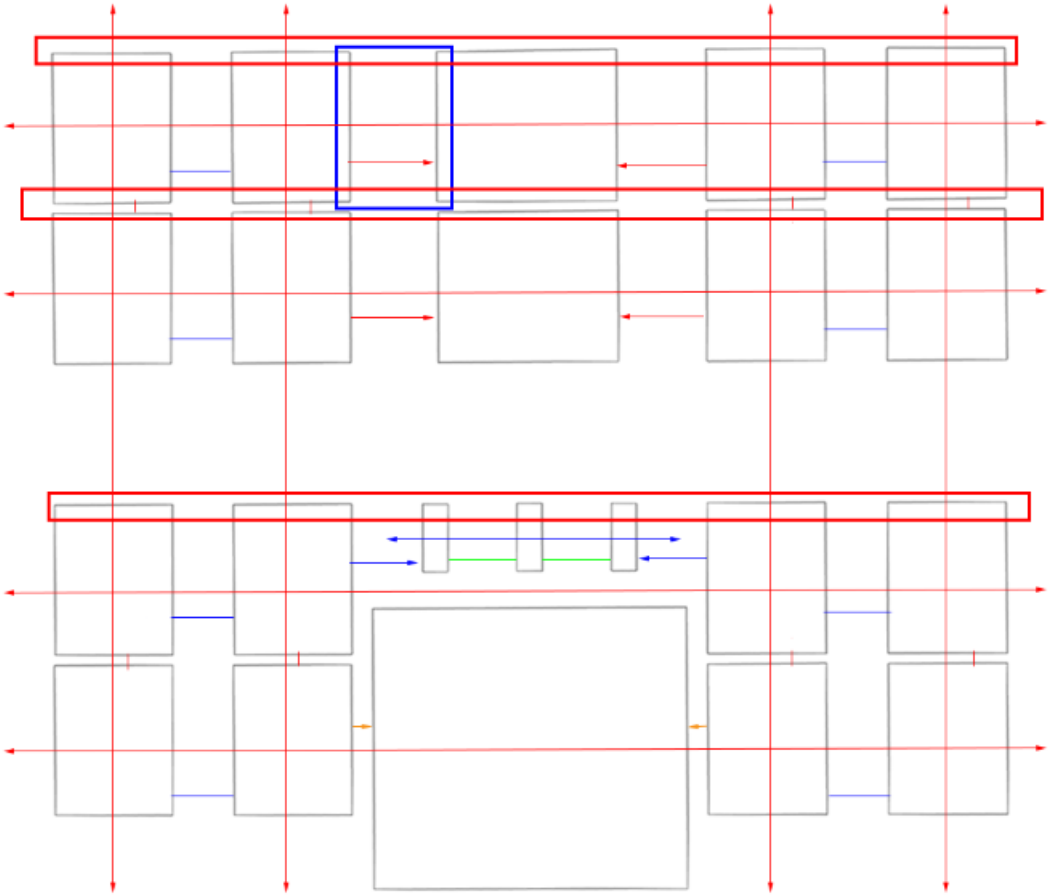
Quality analysis

- Effects of provided procedure for applying regularity
  - TN Facade(Case1-Case6)



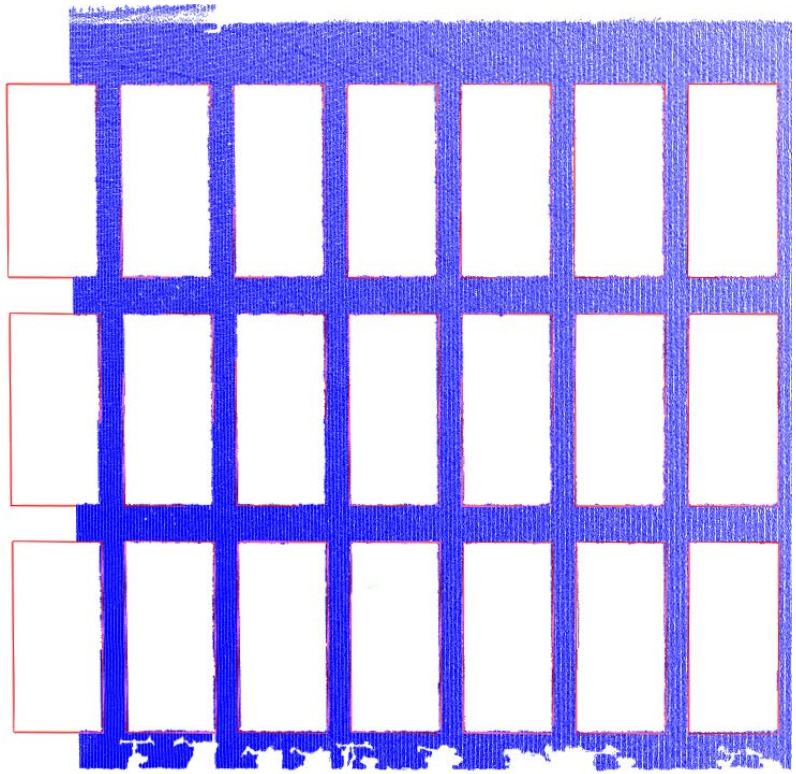
Quality analysis

- Effects of provided procedure for applying regularity
  - BK Facade(Case1-Case9)



Quality analysis

- Match with original point clouds



Conclusion and future work

Conclusions:

Hole extraction
- Rasterization approach
- Robust to various density, noise
- No loss information of edge

Local and global regularities identification and application
- Provide 9 cases of regularities to explore
- Feature and clustering method to extract regularities
- ICP to find different groups of similar holes
- Register points and Transformation matrices
- RANSAC line fitting to find the boundary lines
- Chains to preserve the established connections

Quality
- Procedures provided works fine with these two datasets
- Good match with original point cloud
- Improve results from noise, various densities and imperfectness of algorithms

Conclusion and future work

Future work:

- The regularities of whole façade: including extrusions, intrusions, doors. Even for a whole building with several facades
- Special cases of regularities can be also applied: orientations of similar objects share orthogonal orientations. The similar objects shares mirror reflection regularity. Position regularities are explored among all groups
- Occlusion problem needs to be fixed. For example, ICP can not identify partially matched objects
- Thresholds need to be limited and set adaptively. The relations between thresholds can be derived in order to reduce number of threshold

Appendix

Thresholds

Step		TN	BK
Wall extraction			
	RANSAC plane fitting	DistanceThreshold=0.1m	DistanceThreshold=0.1m
Hole extraction			
	Rasterization	Resolution=0.05m	Resolution=0.05m
First procedure of regularity			
	ICP	Iteration times =20 The maximum distance between closest pairs=0.005m	Iteration times =20 The maximum distance between closest pairs=0.005m
	RANSAC line fitting	RansacDisThreshold=0.005m Minimum number of points in model=points*0.005	RansacDisThreshold=0.005m Minimum number of points in model=points*0.005
	Local regularity-Case1	Clustering cut-off value =0.05(2.8°)	Clustering cut-off value =0.05(2.8°) One incomplete holes: Clustering cut-off value =0.1(5.7°)
	Same boundary regularity-Case2	Clustering cut-off value ==0.05	Clustering cut-off value =0.05
	Orientation regularity-Case3	Clustering cut-off value ==0.05(2.8°)	Clustering cut-off value ==0.05(2.8°)
	Position regularity (2 types)-Case4, Case5	Clustering cut-off value ==0.10m	Clustering cut-off value ==0.15m
Second procedure of regularity			
	Orthogonal and parallel regularity-Case6	Clustering cut-off value =0.05(2.8°)	Clustering cut-off value =0.05(2.8°)
	Length regularity-Case7	Clustering cut-off value =0.05m	Clustering cut-off value =0.05m

Appendix

	Algorithm	Source
Segmentation	RANSAC plane fitting	PCL
Hole extraction		
	Dilation and erosion	Supervisor
	Connected components labeling	Supervisor
Regularities		
	Hierachical Clustering	ALGLIB
	ICP	PCL
	RANSAC Line fitting	PCL

Questions?