

Mathematical morphology directly applied to point cloud data

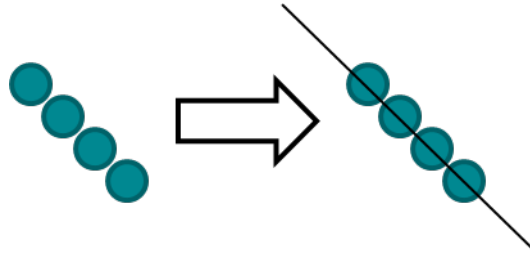
Jesús Balado Frías

Faculty of Architecture and the Built Environment, GIS Technology Section.

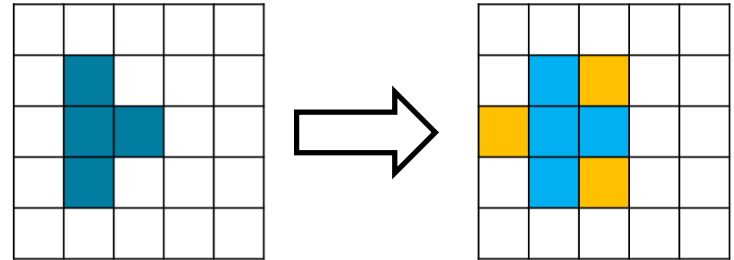
NCG Seminar Point Clouds

04/06/2020

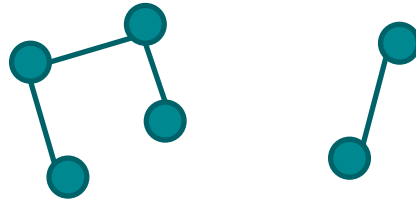
Image to point cloud processing



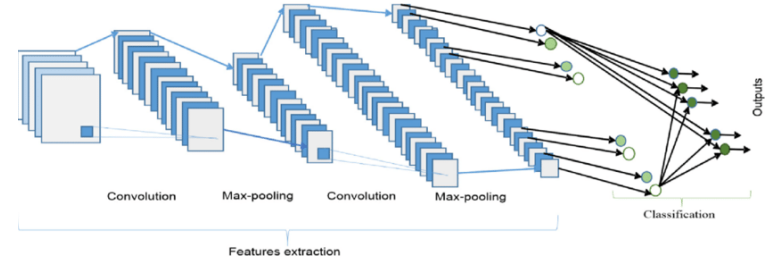
Hough transform



Region growing



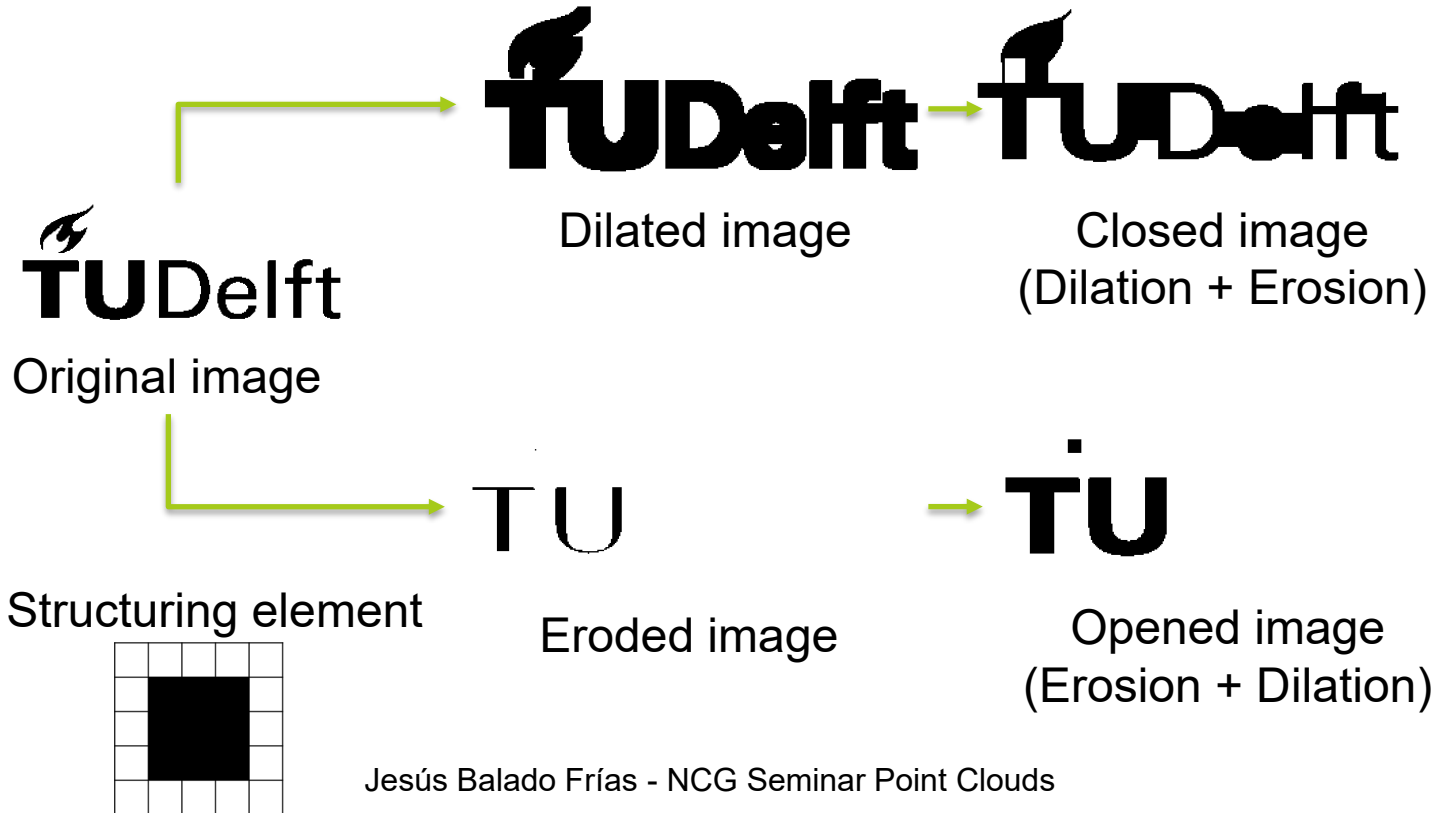
Connected Components



Convolutional Neural Networks

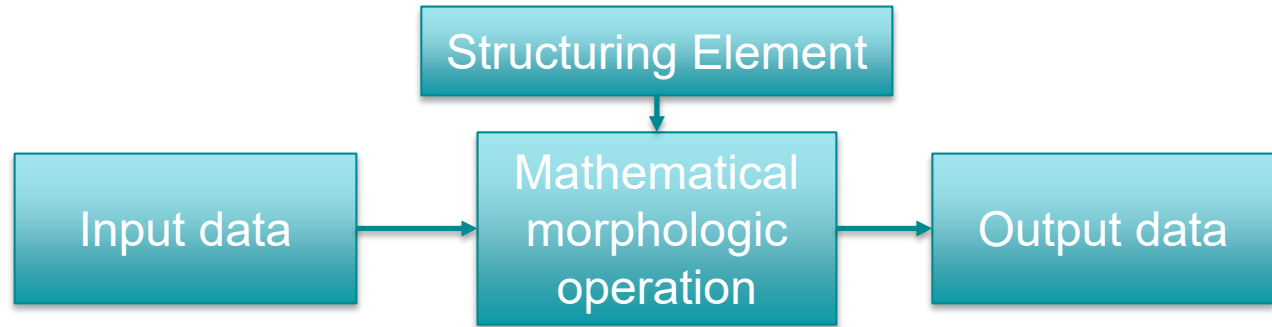
Source: 10.3390/electronics8030292

Mathematical Morphology



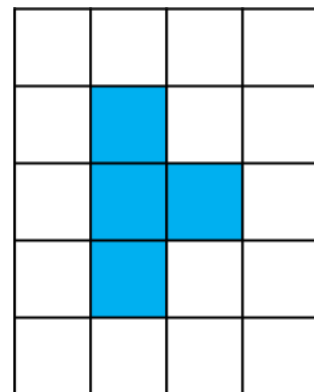
Objective

- Design morphological operations directly applicable to 3D vector data:
 - Point cloud Structuring Element (SE) design
 - Morphological dilation design
 - Morphological erosion design



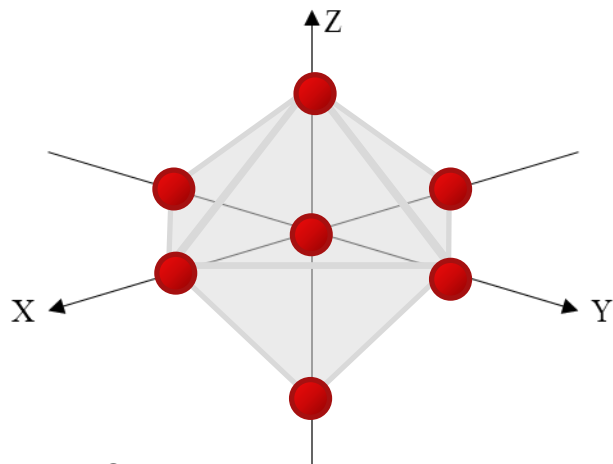
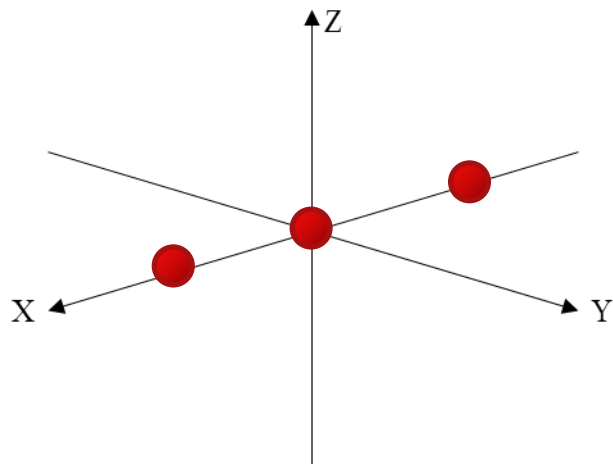
Overview: problems to solve

- Data type:
 - 2D raster \rightarrow 3D vector
- Binary mathematical morphology:
 - Pixel value $\rightarrow \exists$ or \nexists points
- Comparison SE with input data
 - Pixel to pixel \rightarrow Point to point + threshold
 - Threshold based on point density



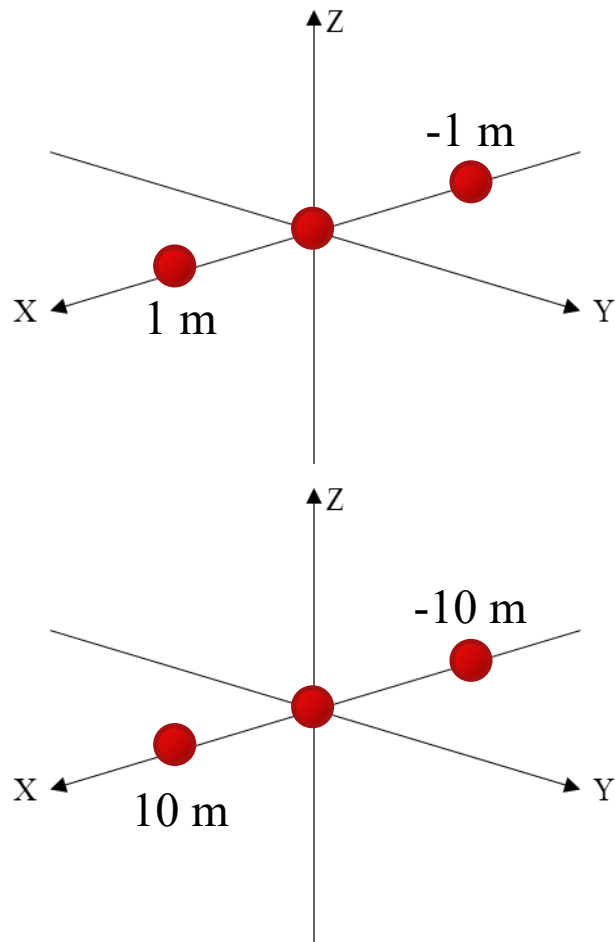
Structuring element

- Main characteristics:
 - Shape



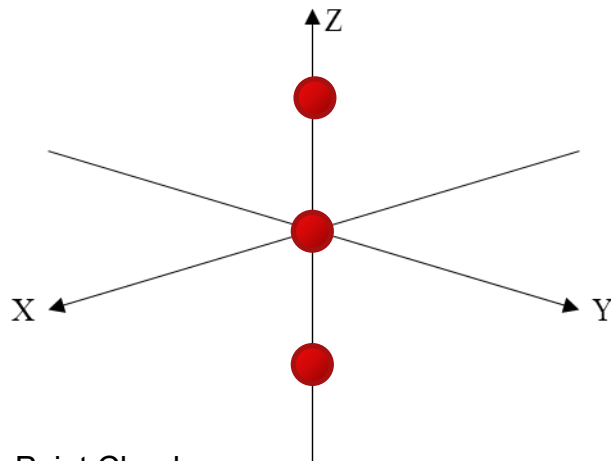
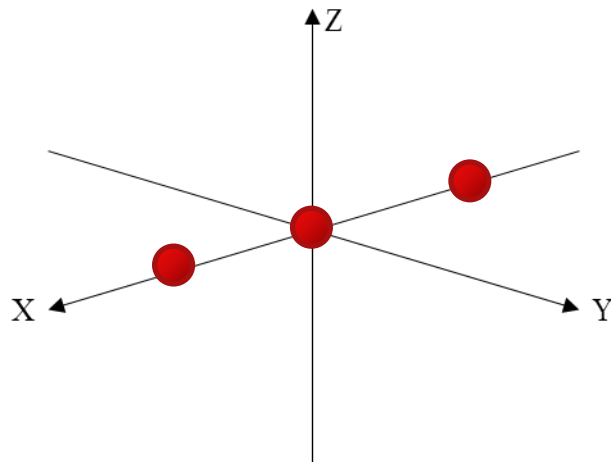
Structuring element

- Main characteristics:
 - Shape
 - Size



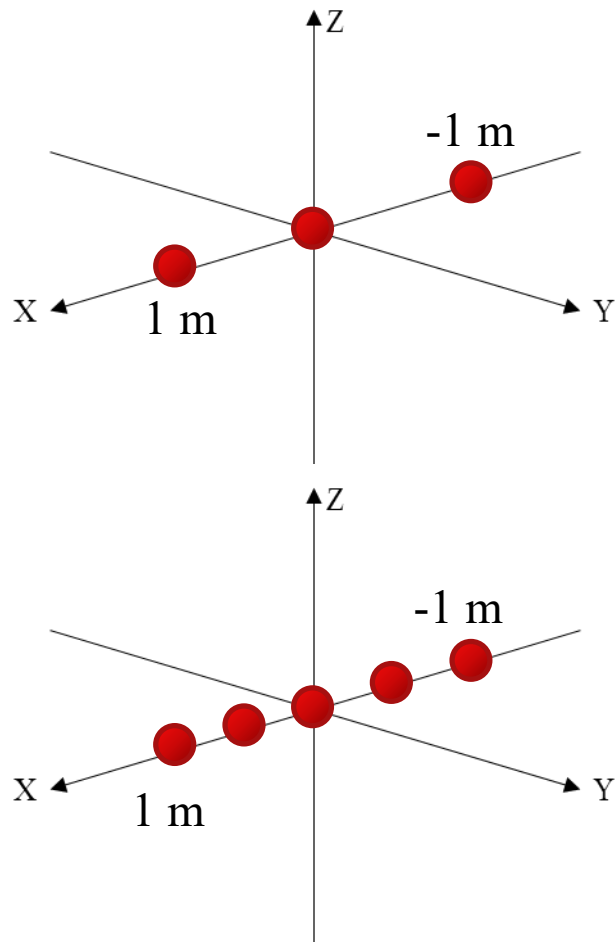
Structuring element

- Main characteristics:
 - Shape
 - Size
 - Orientation



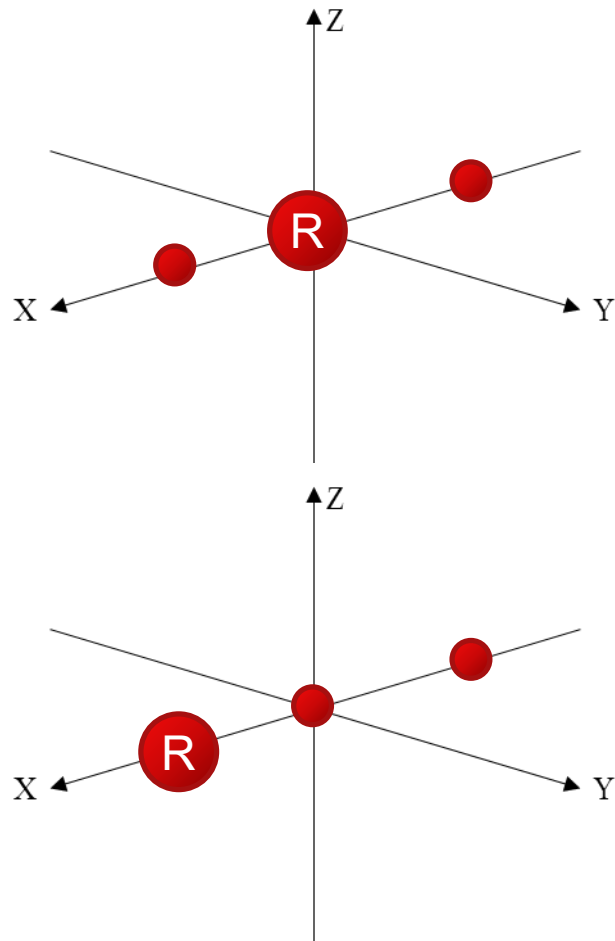
Structuring element

- Main characteristics:
 - Shape
 - Size
 - Orientation
 - Density

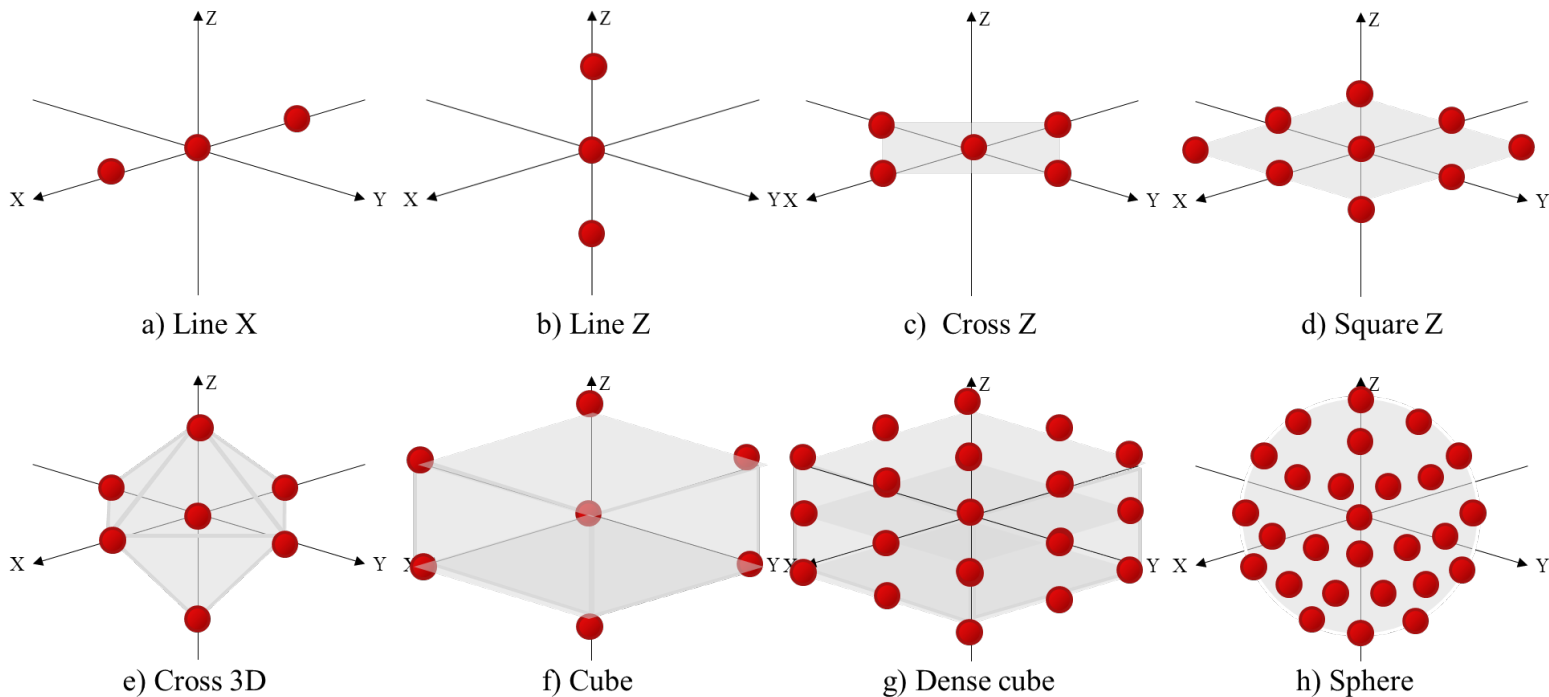


Structuring element

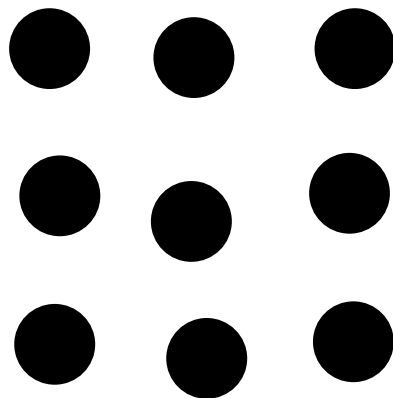
- Main characteristics:
 - Shape
 - Size
 - Orientation
 - Density
 - Reference point



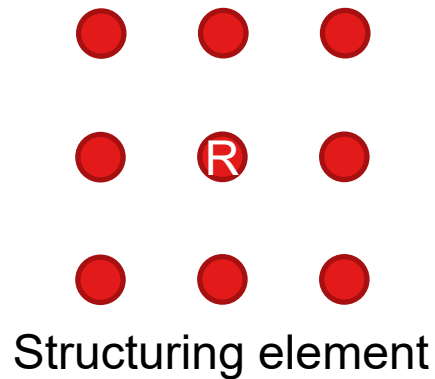
Structuring element



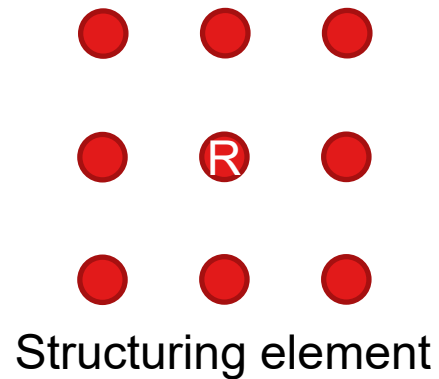
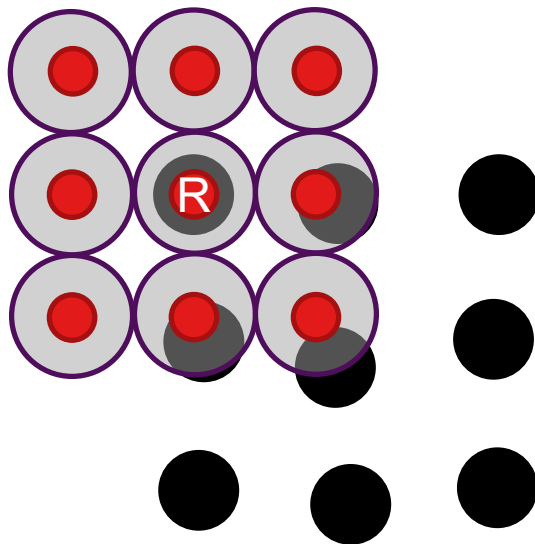
Morphological dilation



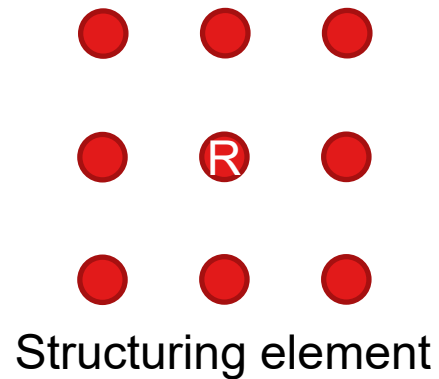
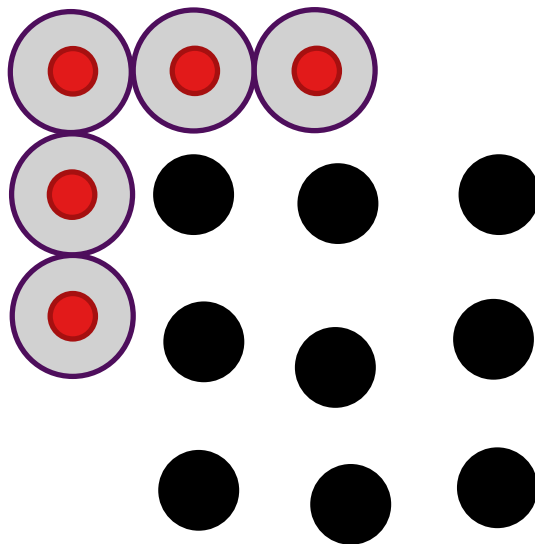
Input point cloud



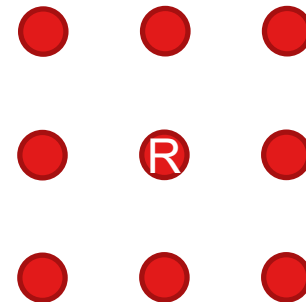
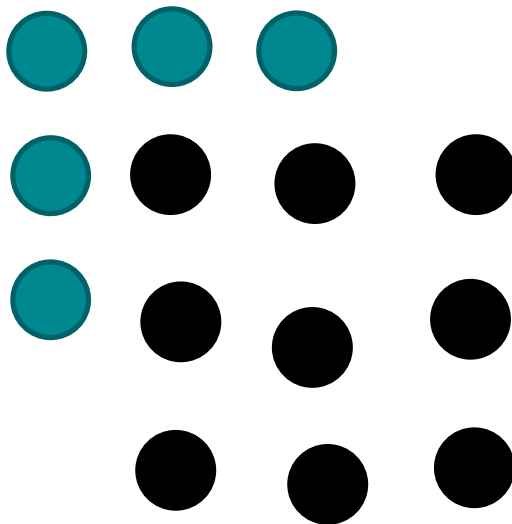
Morphological dilation



Morphological dilation

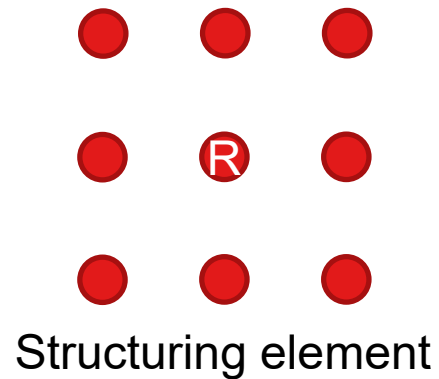
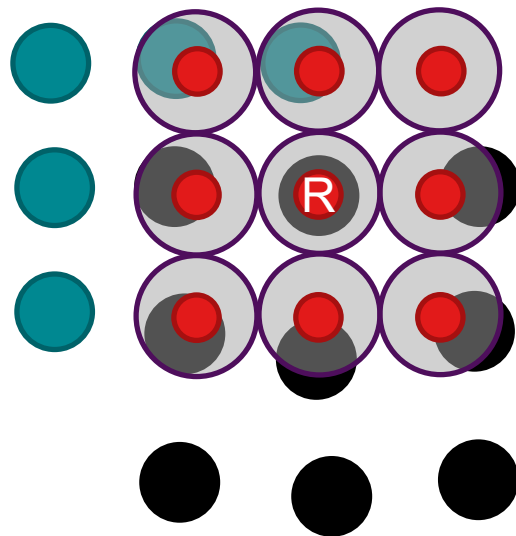


Morphological dilation

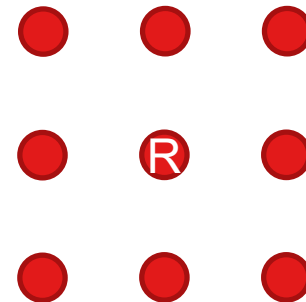
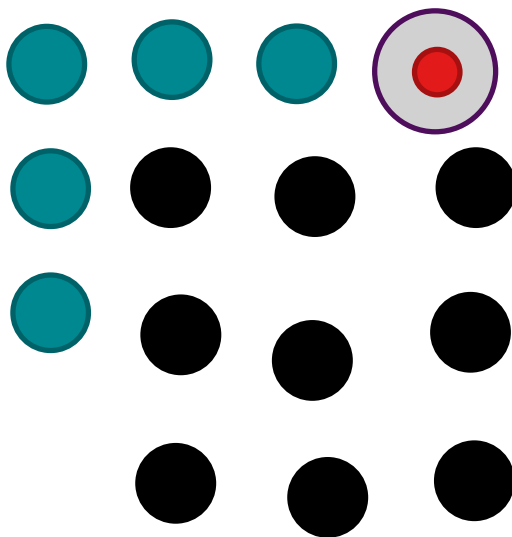


Structuring element

Morphological dilation

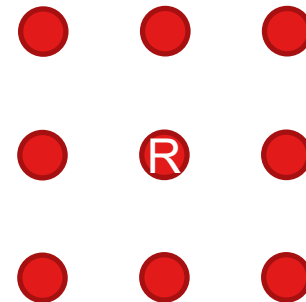
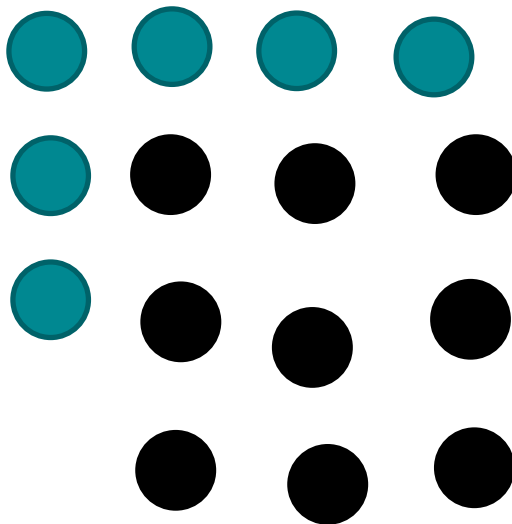


Morphological dilation



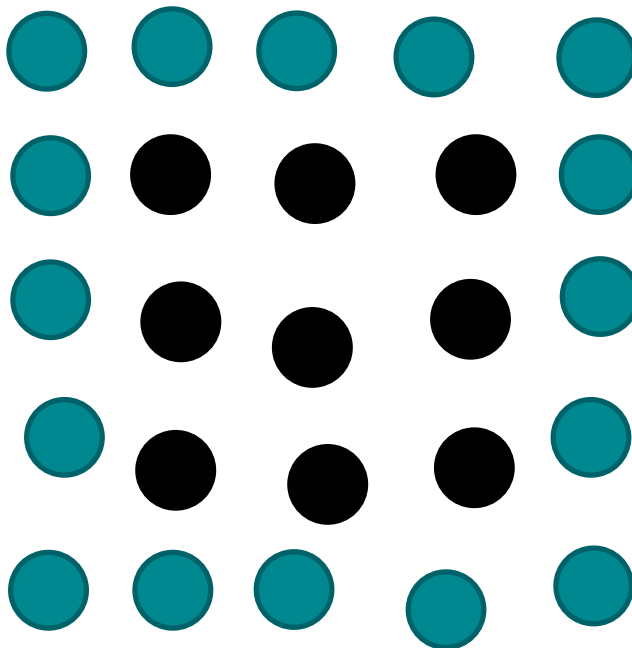
Structuring element

Morphological dilation

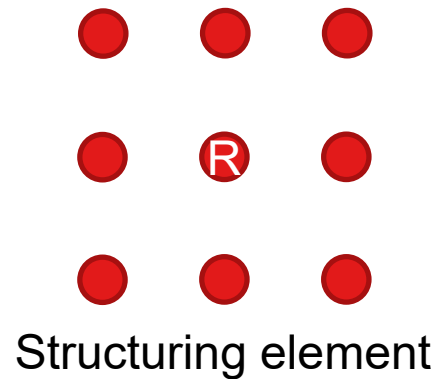


Structuring element

Morphological dilation

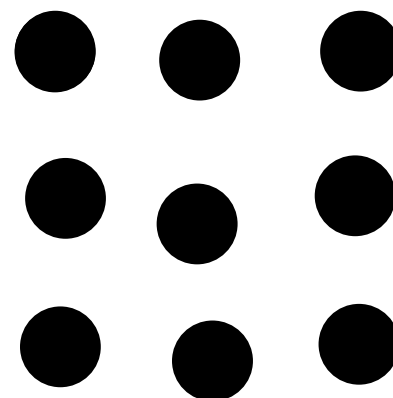
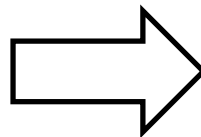
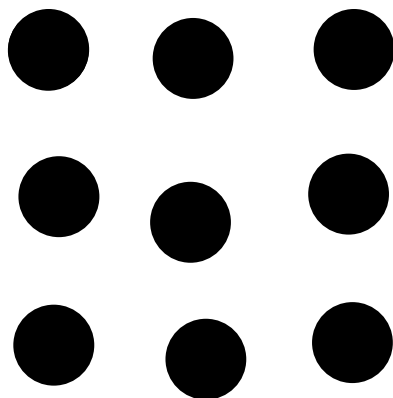
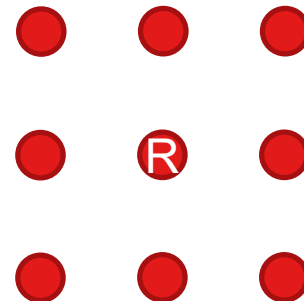


Dilated point cloud



Morphological erosion

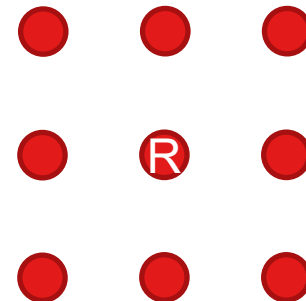
Structuring element



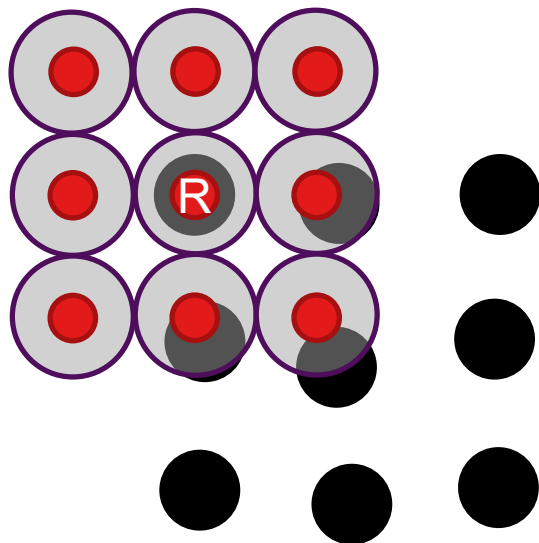
Input point cloud

Copy

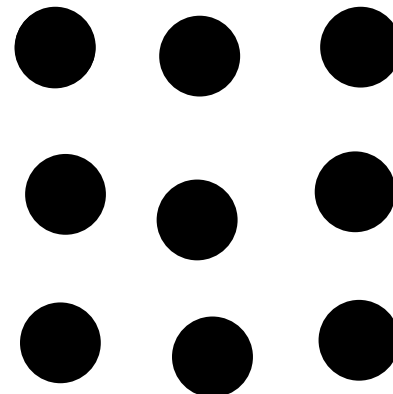
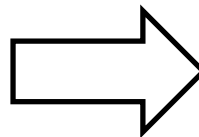
Morphological erosion



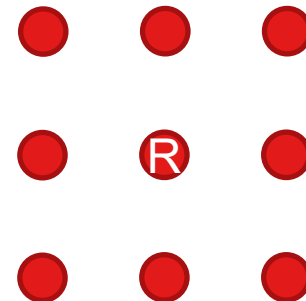
Structuring element



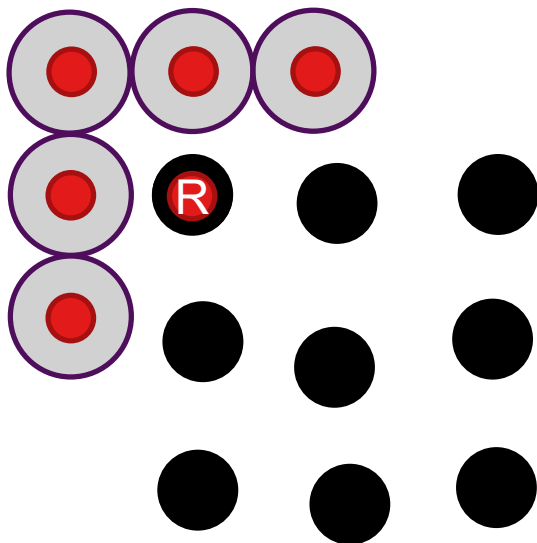
Input point cloud



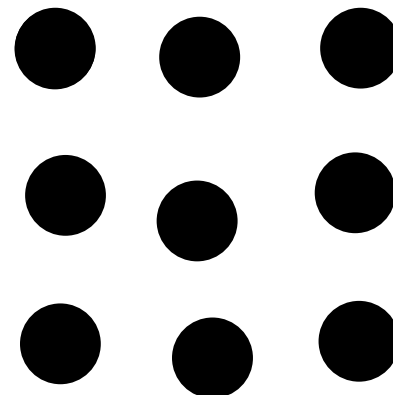
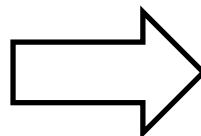
Morphological erosion



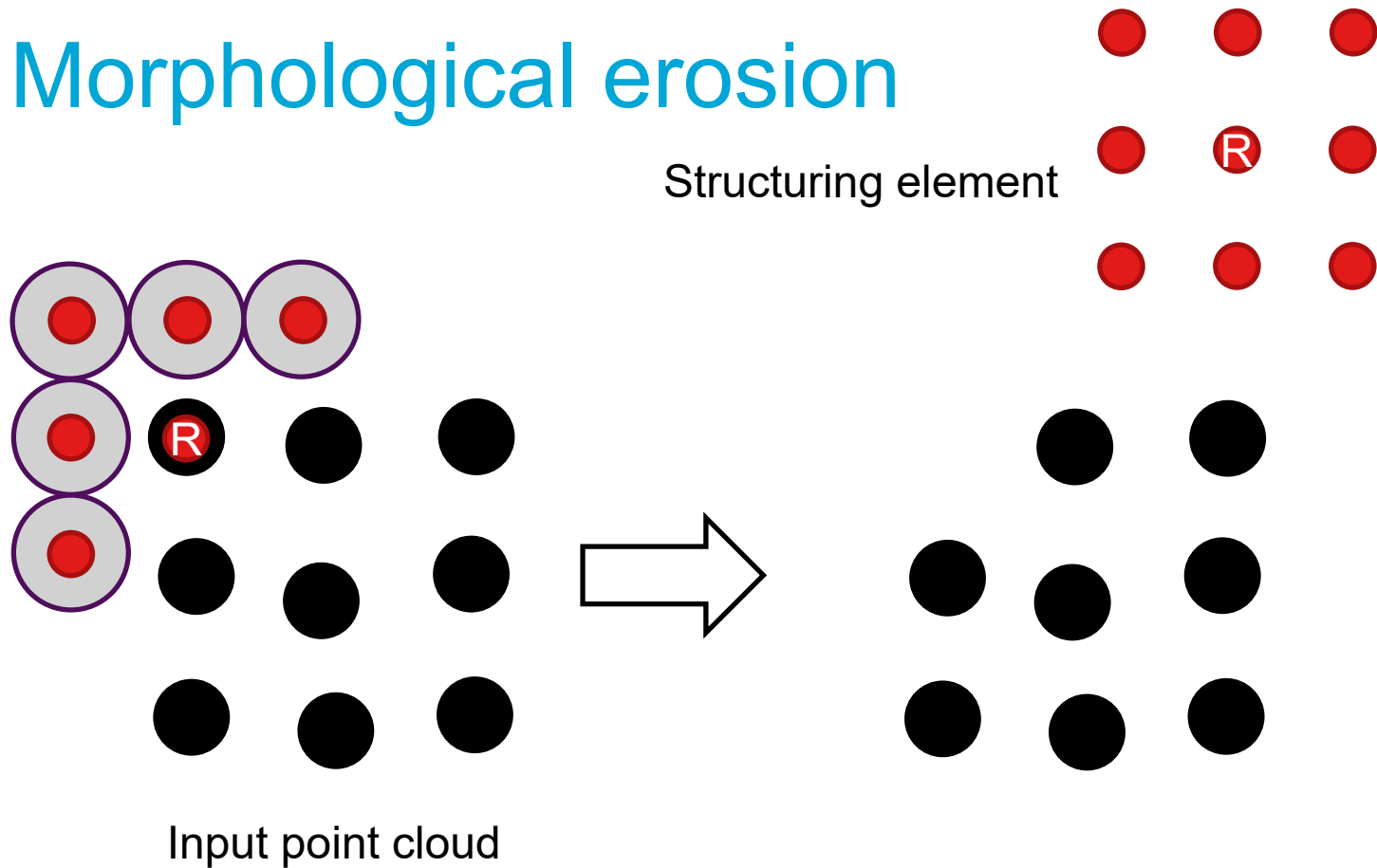
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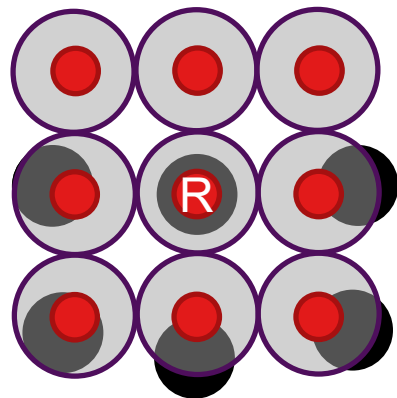
Input point cloud



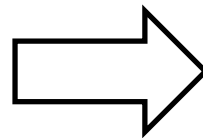
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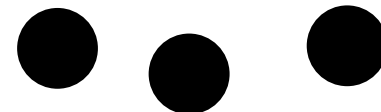
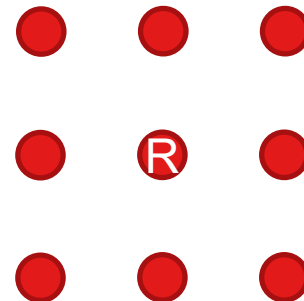
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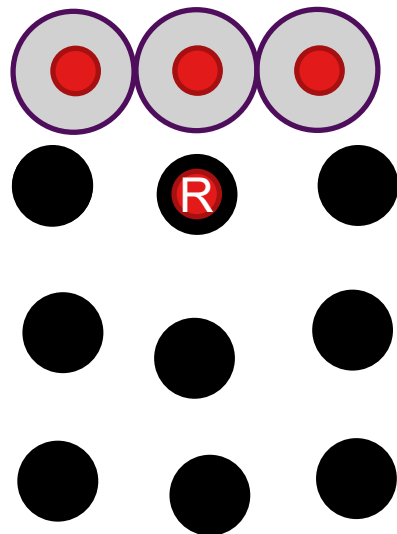
Input point cloud



Structuring element

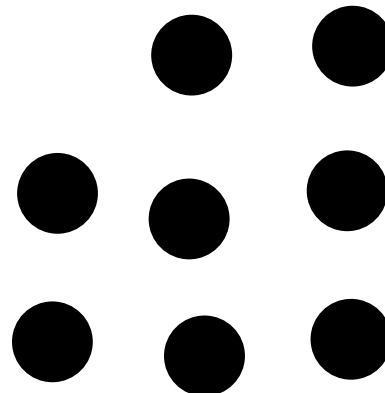
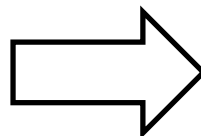
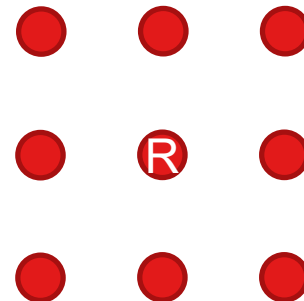


Morphological erosion

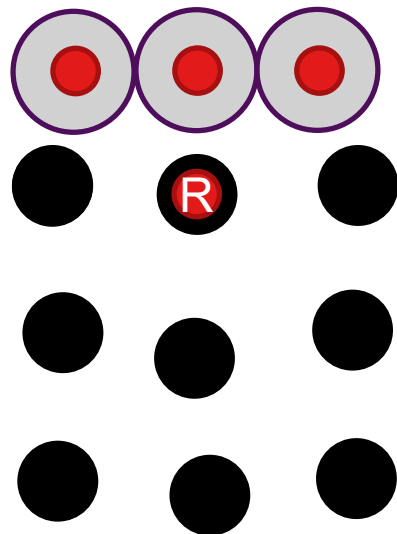


Input point cloud

Structuring element

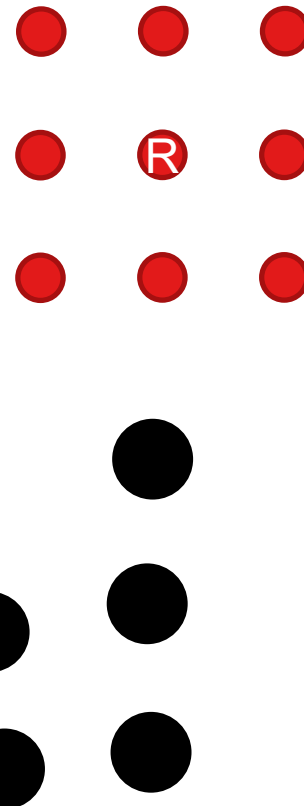


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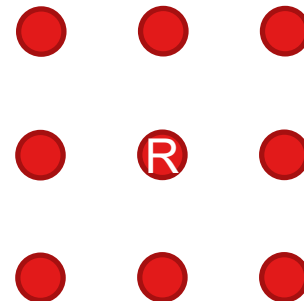


Input point cloud

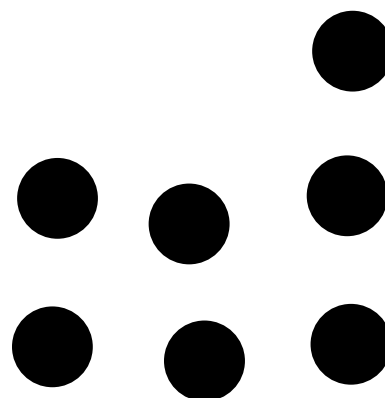
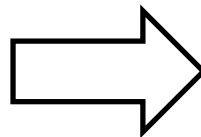
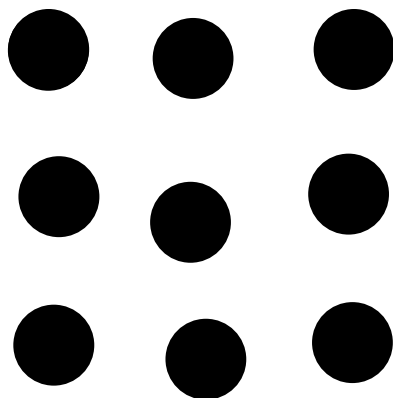
Structuring element



Morphological erosion

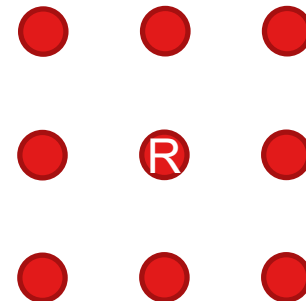


Structuring element

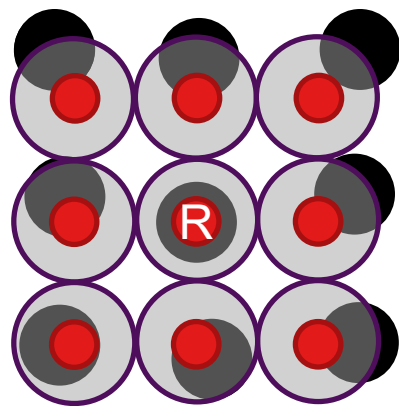


Input point cloud

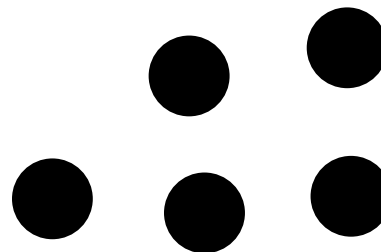
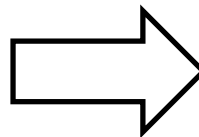
Morphological erosion



Structuring element

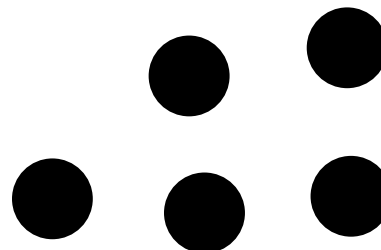
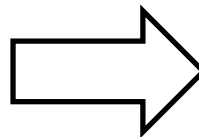
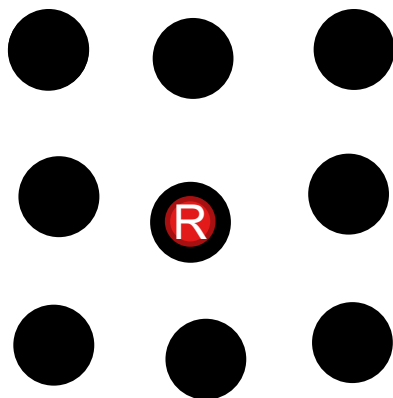
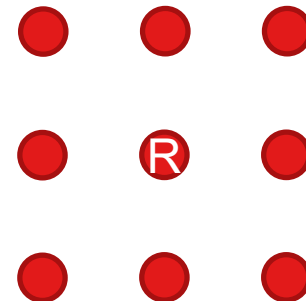


Input point cloud



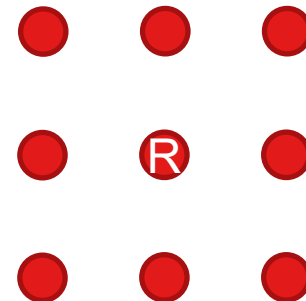
Morphological erosion

Structuring element

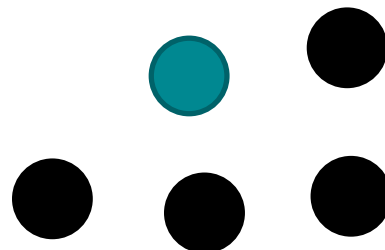
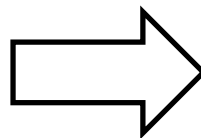
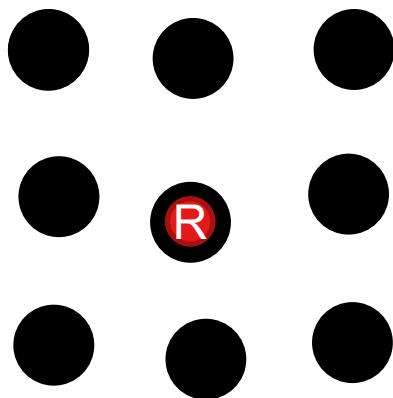


Input point cloud

Morphological erosion

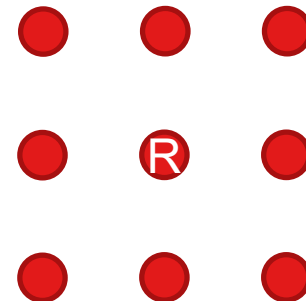


Structuring element

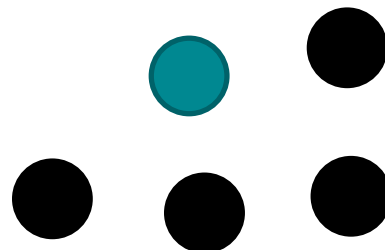
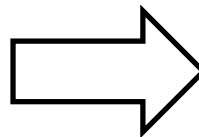
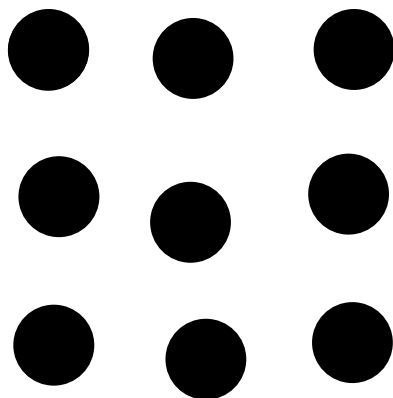


Input point cloud

Morphological erosion

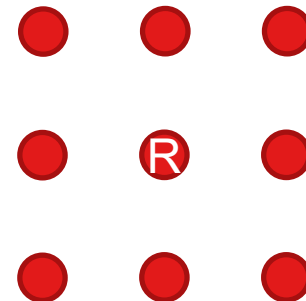


Structuring element

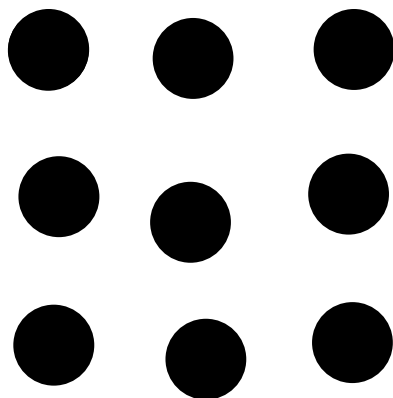


Input point cloud

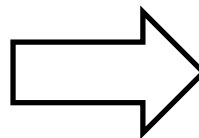
Morphological erosion



Structuring element

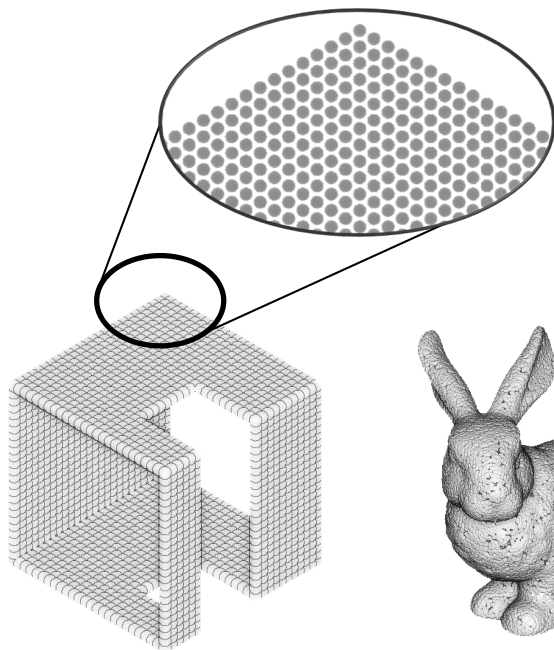


Input point cloud

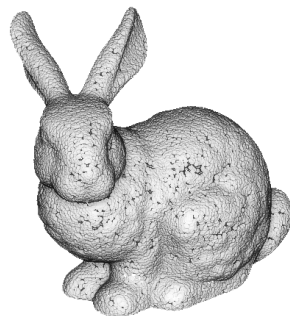


Eroded point cloud

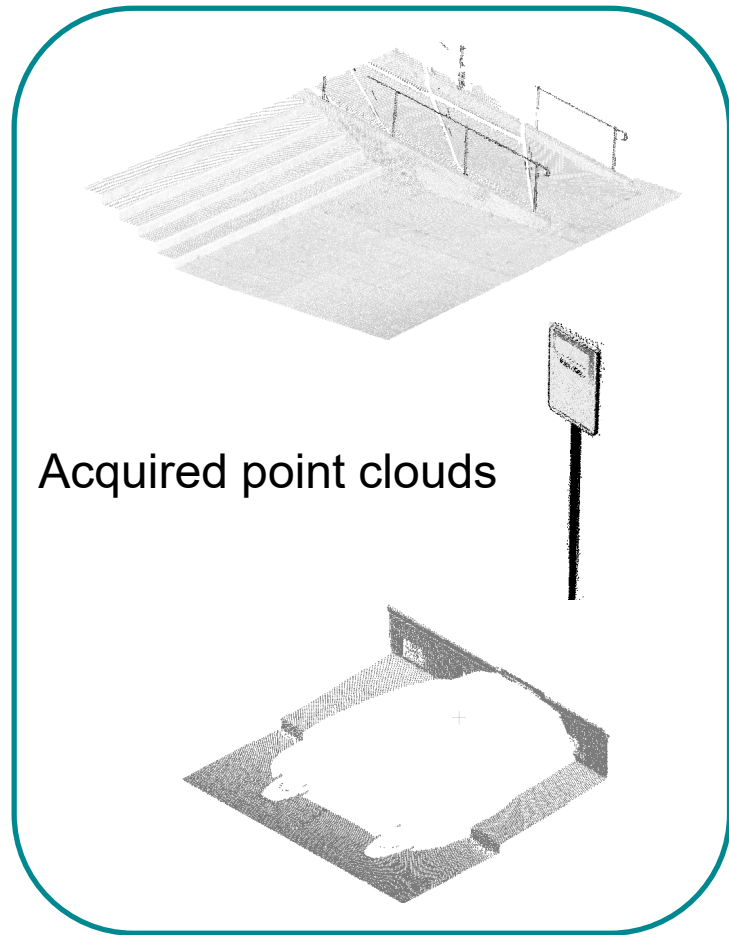
Case studies



Artificial
point cloud

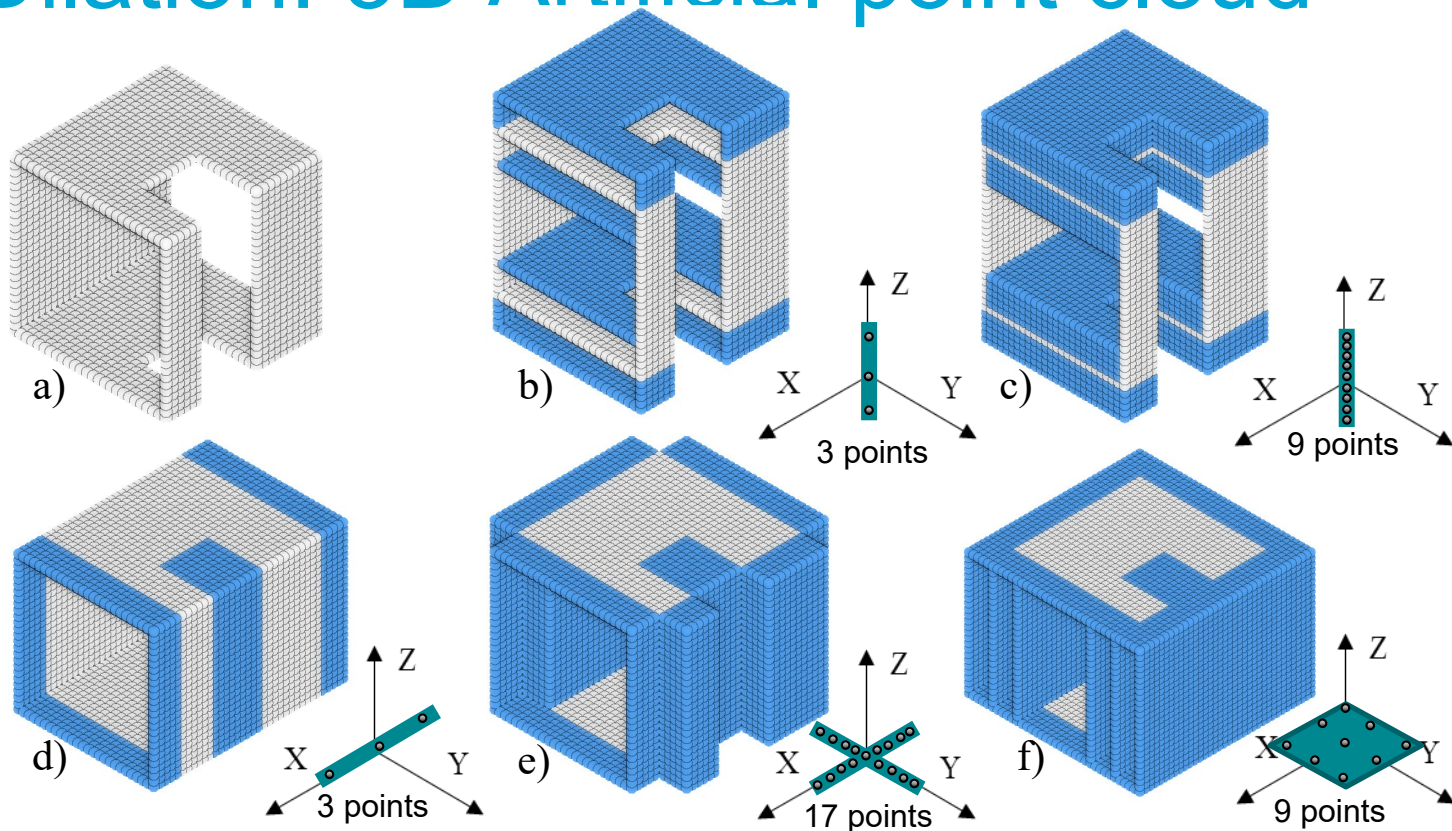


3D model
point cloud

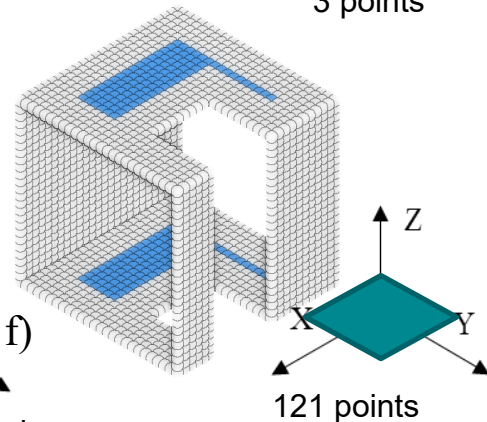
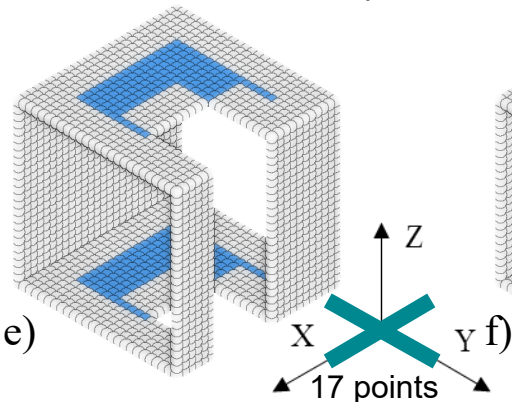
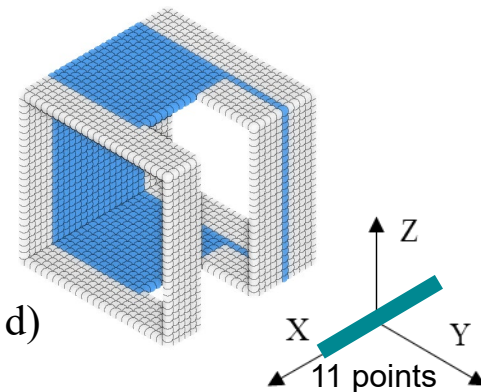
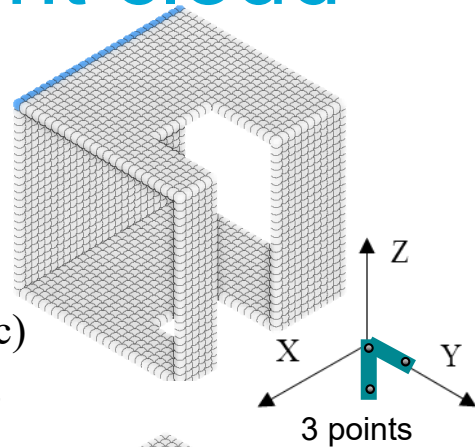
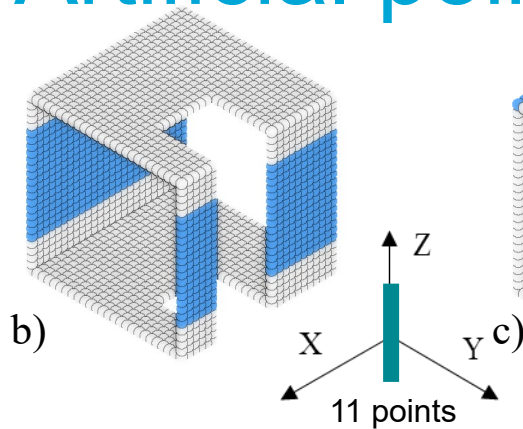
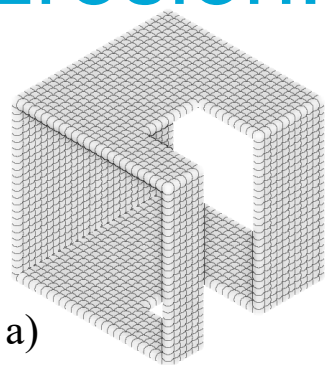


Acquired point clouds

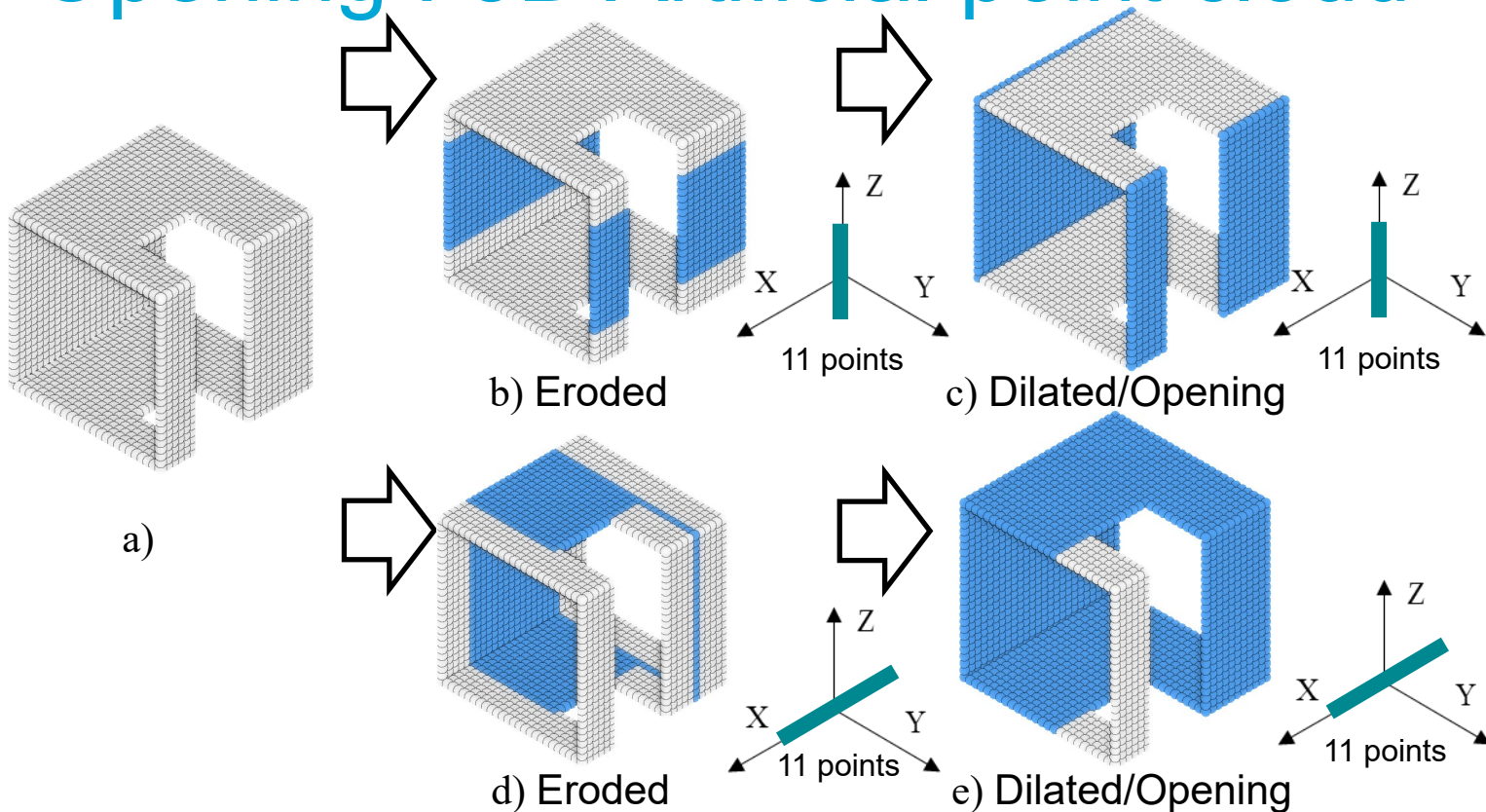
Dilation: 3D Artificial point cloud



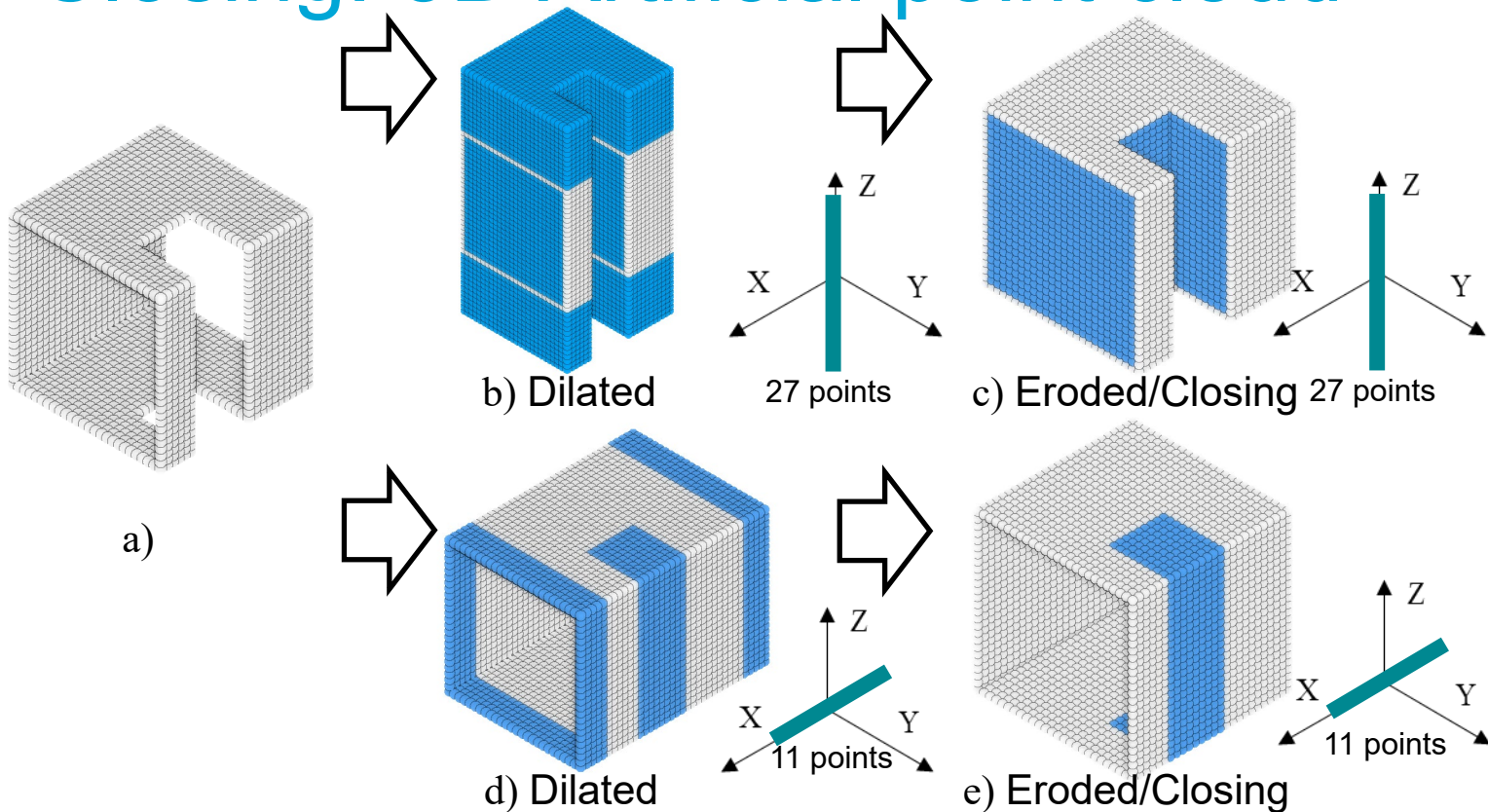
Erosion: 3D Artificial point cloud



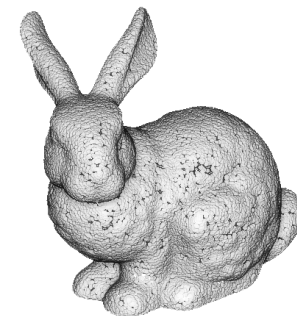
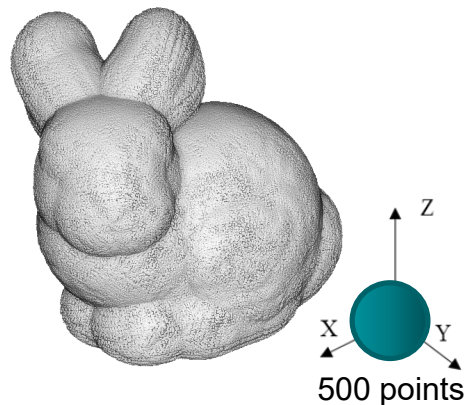
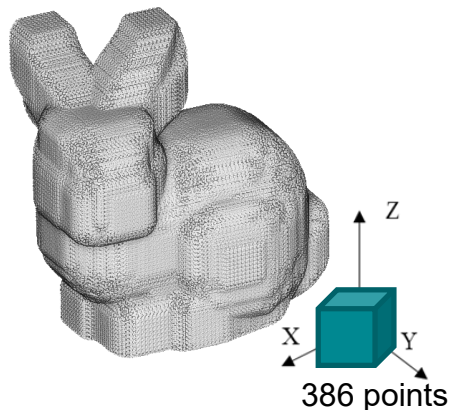
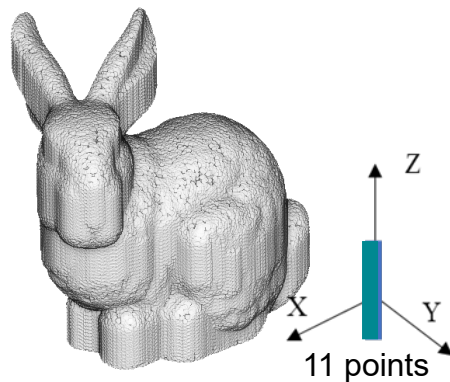
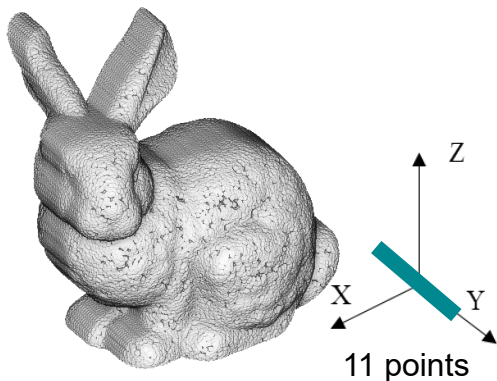
Opening : 3D Artificial point cloud



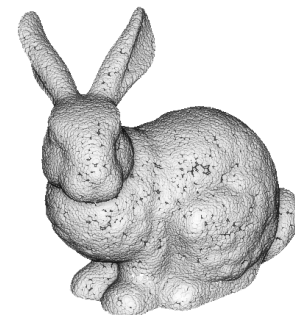
Closing: 3D Artificial point cloud



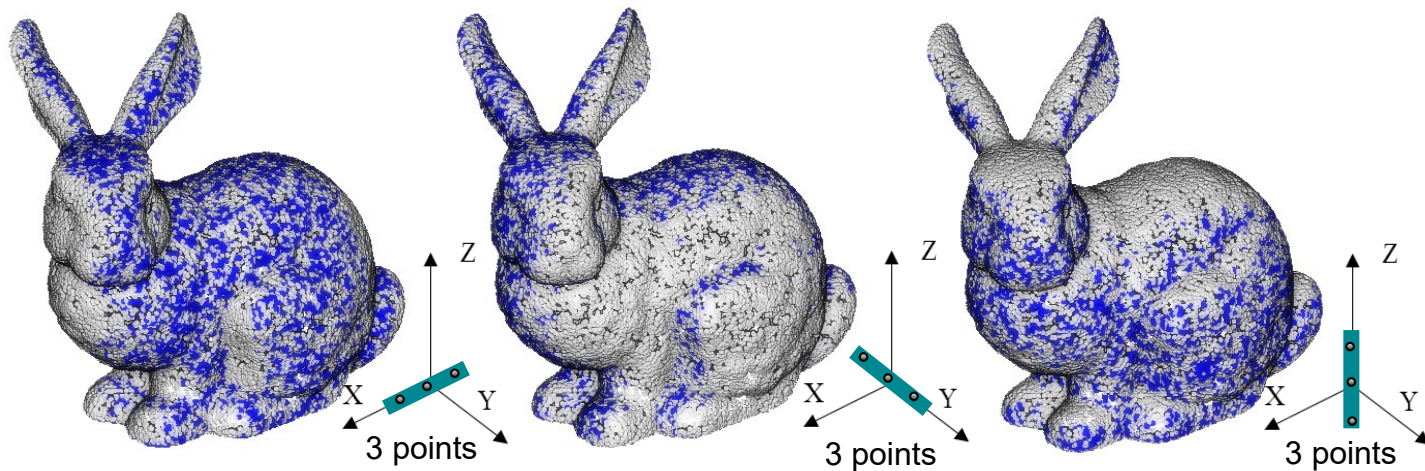
Stanford Bunny: Dilation



Stanford Bunny: Erosion

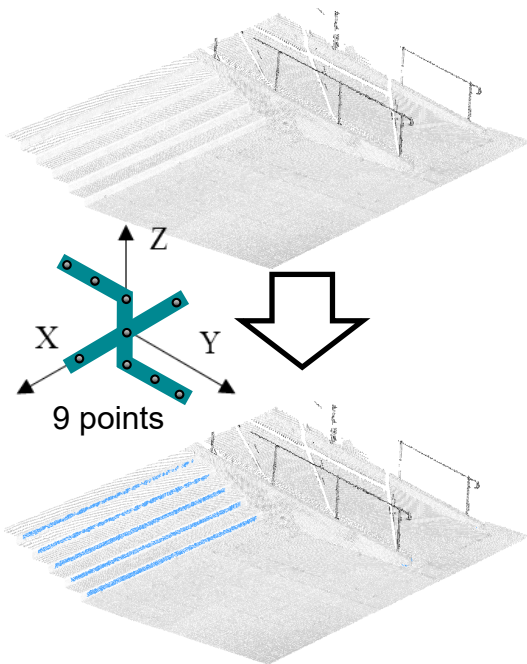


Input data



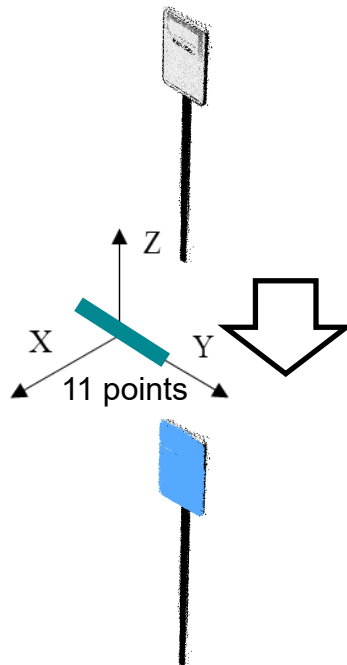
Application

Detection



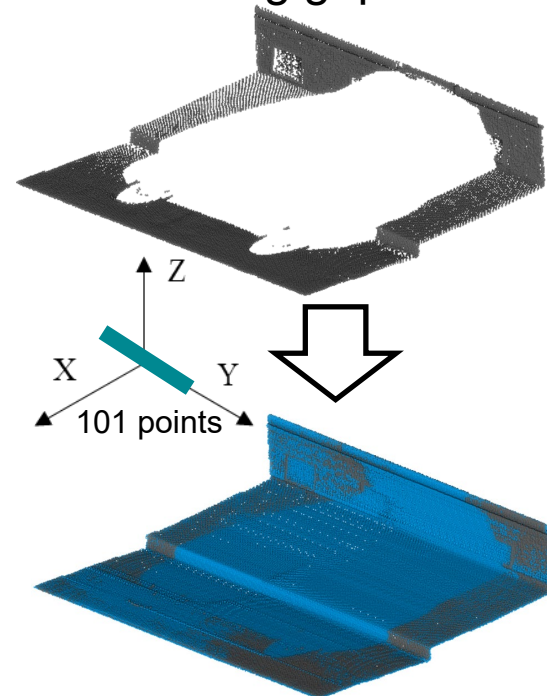
Erosion

Segmentation



Opening

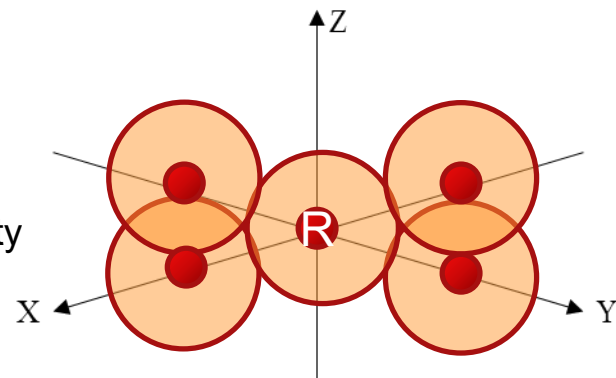
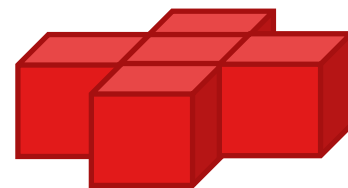
Filling gaps



Closing

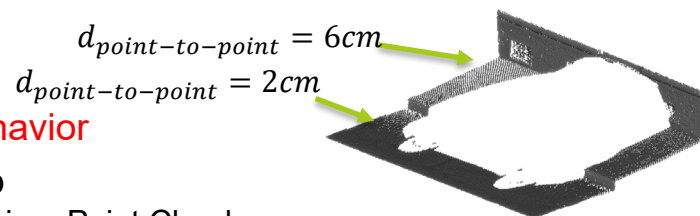
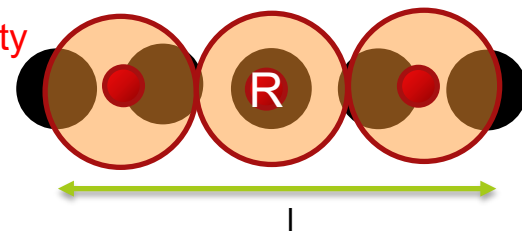
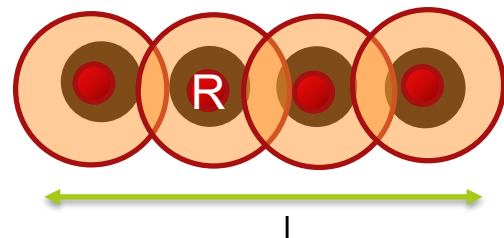
Calculation of coincidence between SE and input point cloud

- SE as polygon
 - Convert the SE to a 3D polygon
 - Check if points of input cloud are regularly distributed on the polygon
 - How to consider if the points are uniformly distributed?
- Distance point to point with threshold
 - Existence of nearby points is searched on sphere
 - The sphere radius is based on point density



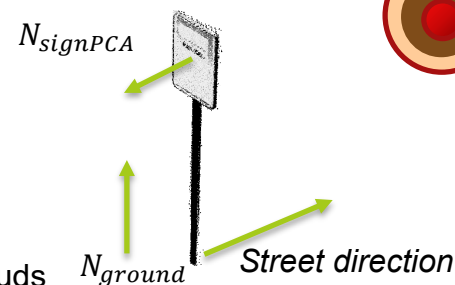
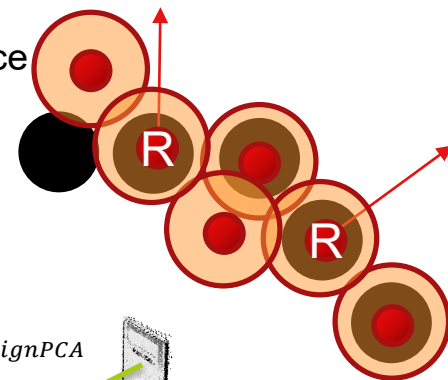
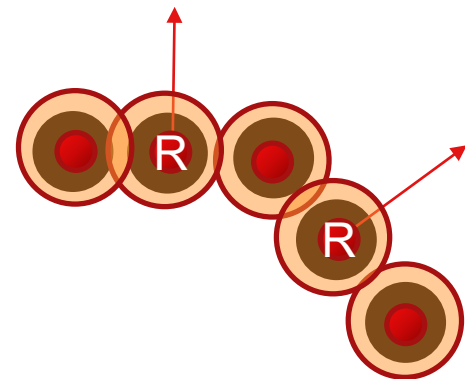
SE point density

- Adaptable to local point density
 - Number of point in SE variable
 - Estimate local point density
 - Per iteration, generate SE according local density
 - **Slower computation**
 - More robust against point density changes
 - **Difficulty in distinguishing gaps vs low point density**
- Fixed
 - Number of point in SE fixed
 - Similar than image processing
 - SE defined before the first iteration
 - Fast computation
 - **Large variations affect to algorithm behavior**
 - Low point density is considered as gap



SE orientation

- Adaptable to point cloud local curvature
 - Estimate normal
 - **Slower computation**
 - Rethink SE design
 - The SE is defined by a normal that fits the point surface
 - **Some applications shown would not be feasible**
- Fixed
 - Similar than image processing
 - Fast computation
 - SE more easy to design
 - **The SE orientation has to be known in advance**
 - More applications (shape detections)



Conclusion

- The principles of the mathematical morphology have been adapted from image to point clouds
- The method is simple and easy to implement
- Common point cloud processing problems can be treated: shape detection, segmentation, and gap filling

Mathematical morphology directly applied to point cloud data

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NCG Seminar Point Clouds

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