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Building extraction

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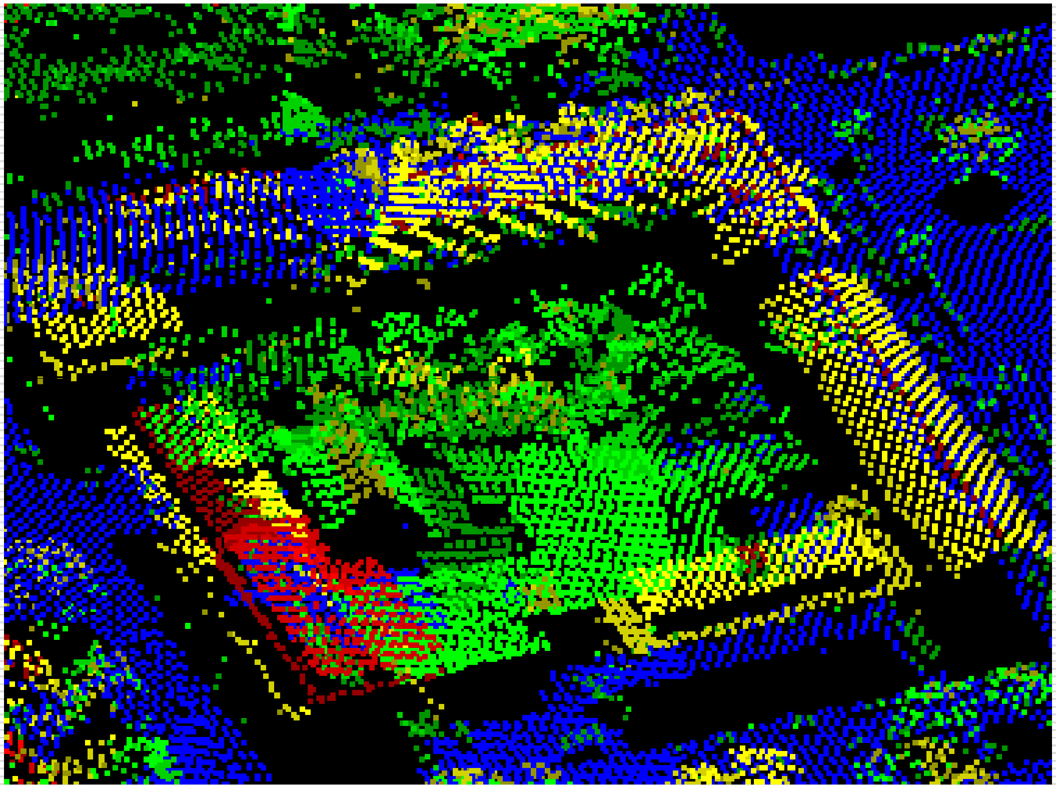
Why building extraction?

- Update GIS database
- 3D city model
- Map making
- Revenue collection
- Change detection
- Disaster management

Where are buildings in the point cloud?

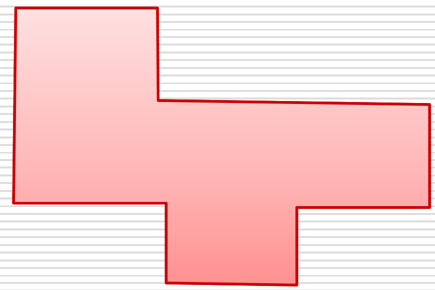


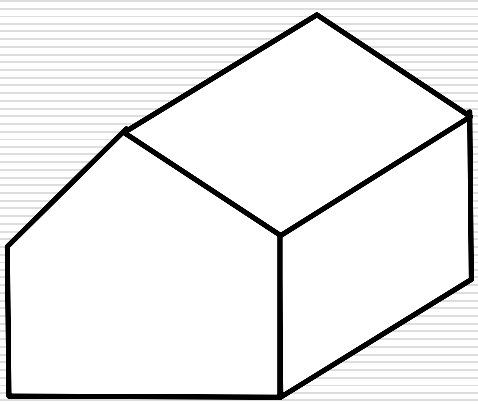
Manual interpretation !

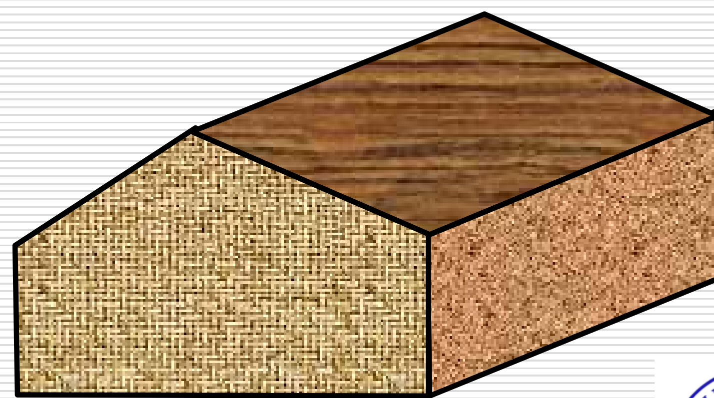
How a computer knows that a group of point cloud is actually for a building?

Desired outcome

- Plan
- Height
- 3D vector model
- 3D vector model with texture







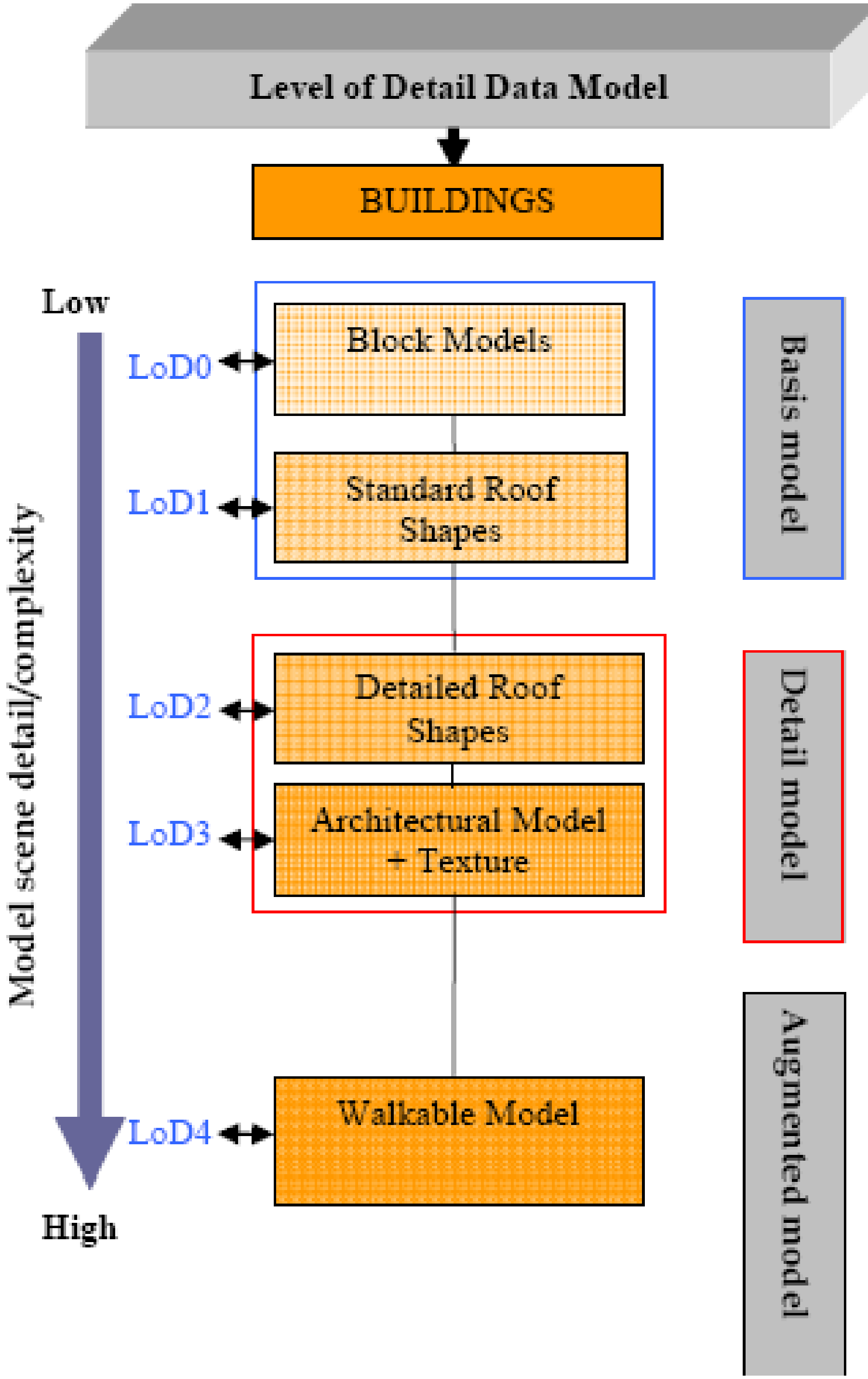
Why difficult ?

- In LiDAR data no other but geometric information in the form of sparse points
- Geometry alone can separate from natural features, e.g., trees but not from the artificial features, e.g., tanks or double decker bus
- The buildings may be simple and very complex
- There are errors in data

Basic concepts…

- Height difference wrt local neighborhood
- Typical shapes different from natural objects
- Made of planar surfaces
- Domain knowledge

Level of detail



Possible approach: Using only laser data

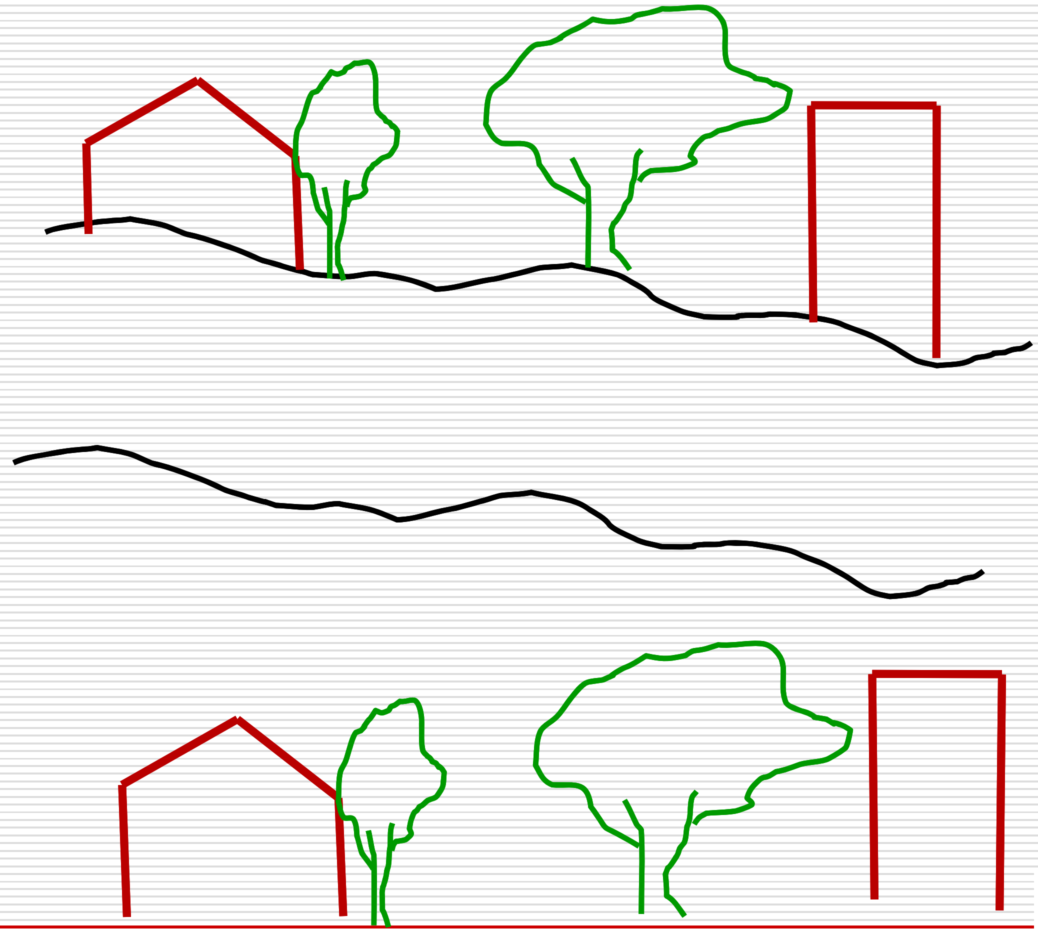
- Based on detection of planes
- Edges using plane intersection or height difference in DSM
- Limitations of using only LiDAR data
  - Confusion in trees and buildings
  - Confusion in grass lands and roads
  - As the only criterion of classification is the height or geometry (plane)

Possible approach: Using laser and other data

- Aerial images
- Satellite images
- Ground plans ???
- Advantages of both data sets

- To eliminate the limitations of laser alone

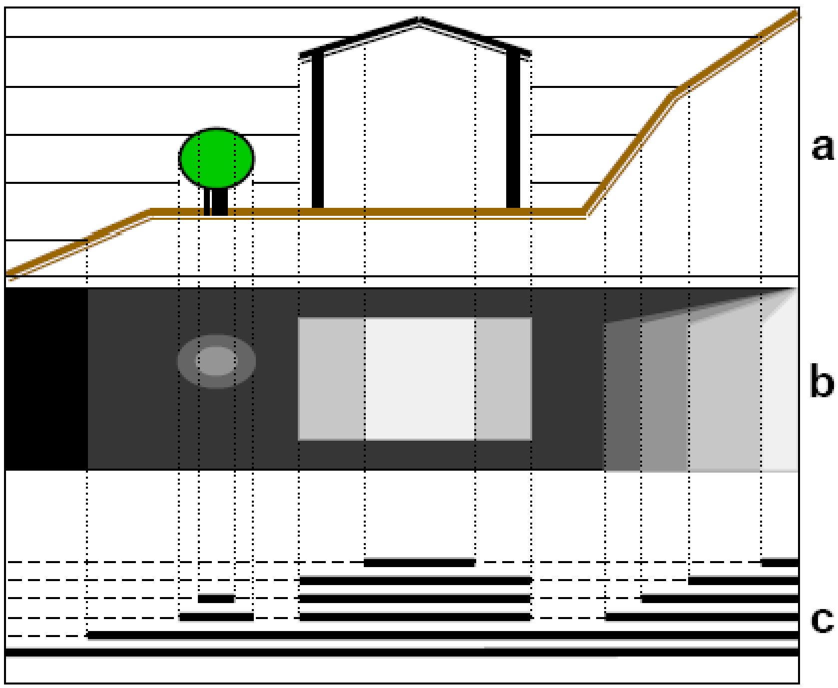
DSM, BEM and nDSM

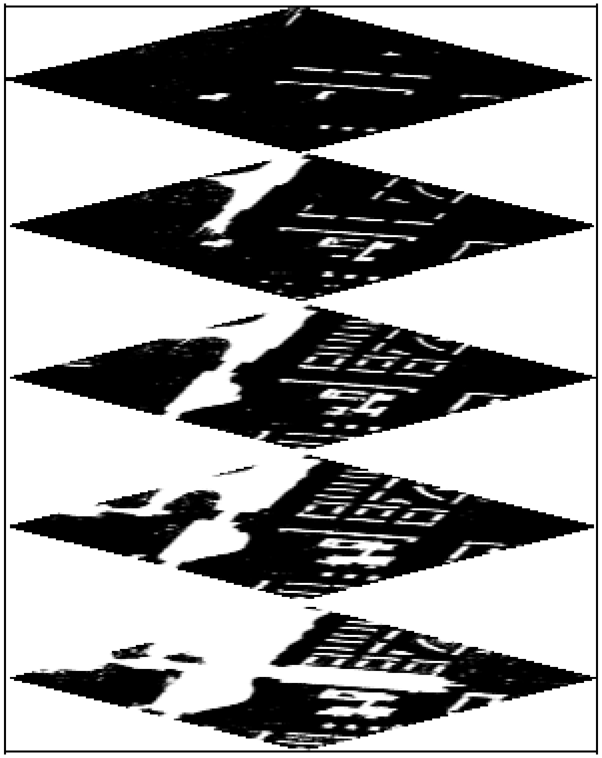


Approach: Using thresholded nDSM

- Generate BEM (DTM)
- Find normalized DSM = DSM – DTM
- This normalized DSM shows the variation of only above ground objects, as terrain slope has been eliminated.
- Threshold normalized DSM at different heights.
- The irregular shapes corresponds to trees while regular shapes corresponds to buildings.
- A process of eliminating trees and retaining buildings leads to finding outlines of buildings.
  - Morphological operators
  - Texture analysis
- Find planes and model and group

Approach: Concept of horizontal profiles





The size and CG location of building will not change much in comparison to other items, as we slice upwards.

Building identification by variation in size and location of CG of blobs

$$\Delta_{Size} = (Size_i - Size_{i+1}) / Size_i$$

$$\Delta_{Location} = \sqrt{((X_{i+1} - X_i) + (Y_{i+1} - Y_i))^2}$$

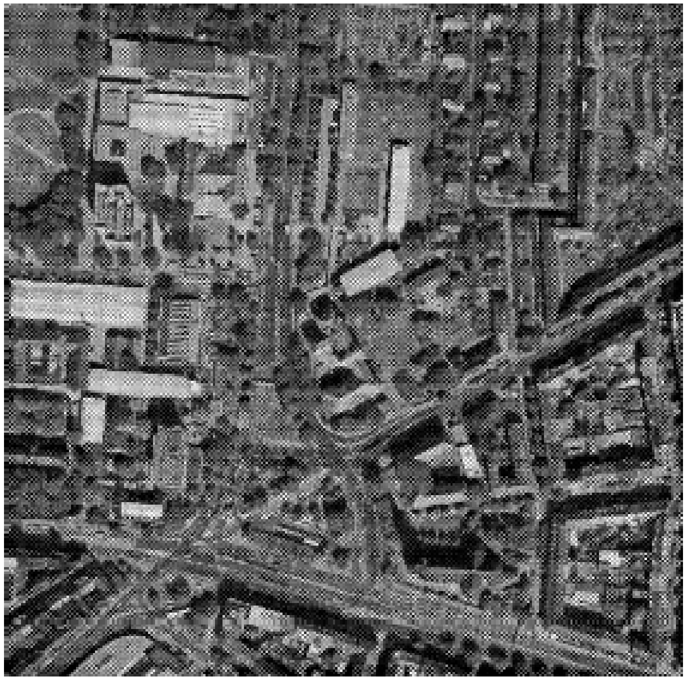
$$S = \begin{cases} Building, & \Delta_{Size} < T_{Size} \wedge \Delta_{Location} < T_{Location} \\ Else, & \Delta_{Size} \geq T_{Size} \vee \Delta_{Location} \geq T_{Location} \end{cases}$$

+ Domain knowledge, other data

Approach: Classification

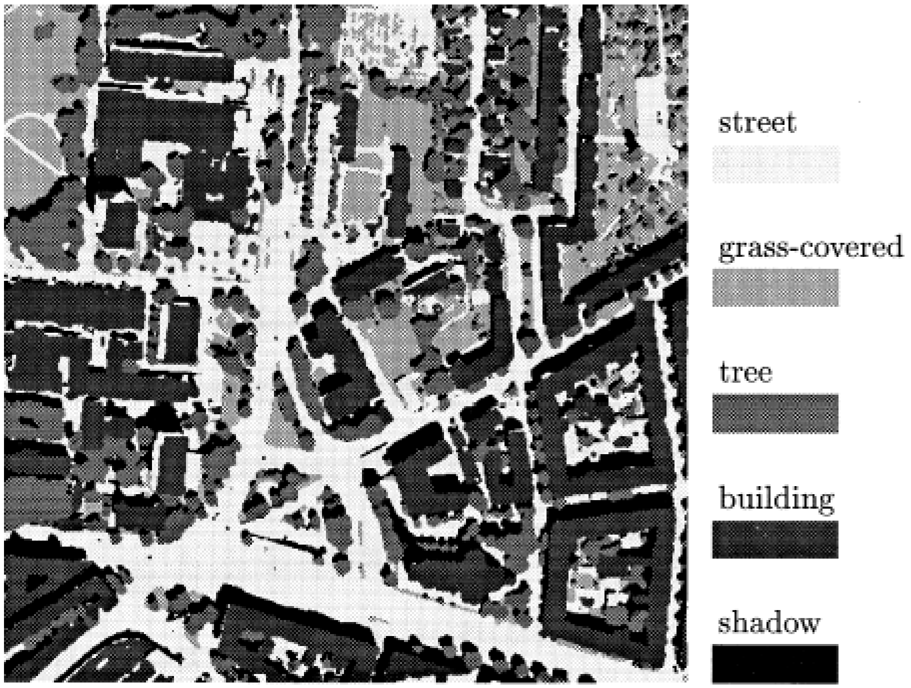
- Using classification of LiDAR DSM and spectral data
- Generate nDSM
- nDSM forms yet another band along with the spectral data for classification
- To discriminate tree from grass, concrete road from concrete roof…as height is also there
- To discriminate building from tree as thematic information is there

- Spectral data: Digital image
- Convert spectral data (digital image) into orthophotograph for registration with the LiDAR data



Classification procedure

- nDSM is considered as one of the bands
- The CIR band used from digital image
- ISODATA classification used for generating clusters

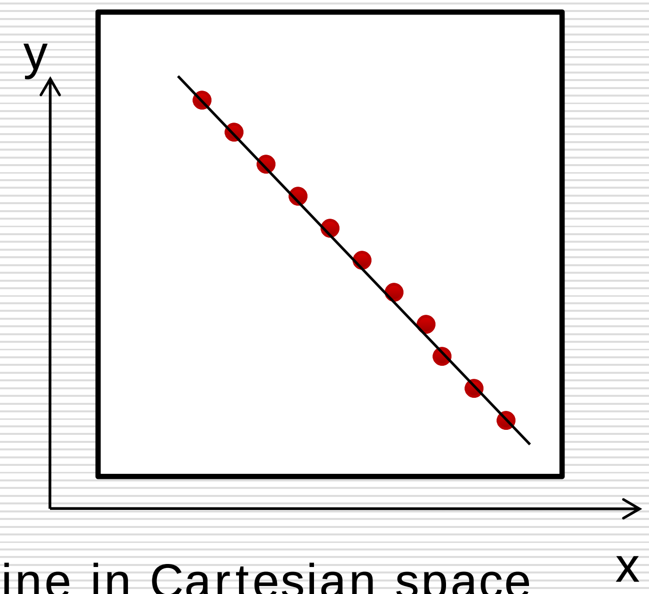


Approach: Using planar surfaces

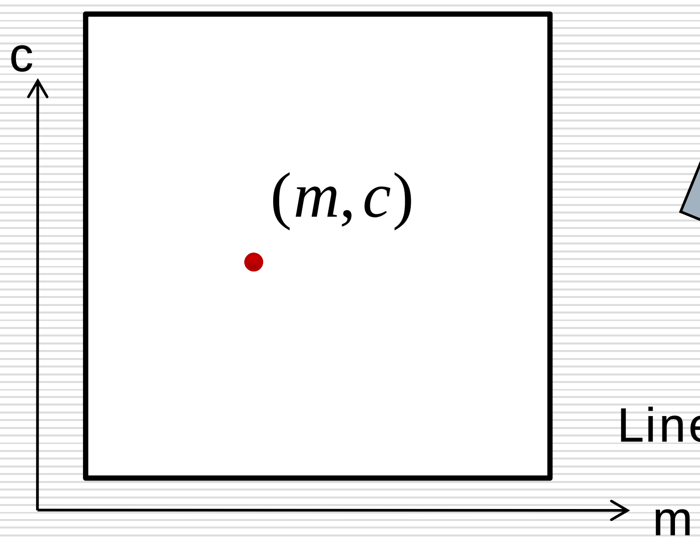
- Buildings are made of planar surfaces
- Locate planes within point cloud
- Intersect planes to determine edges
- Use local height variation to distinguish from non-building planes like roads, grounds etc.

Hough transform 2D

$$y = mx + c$$

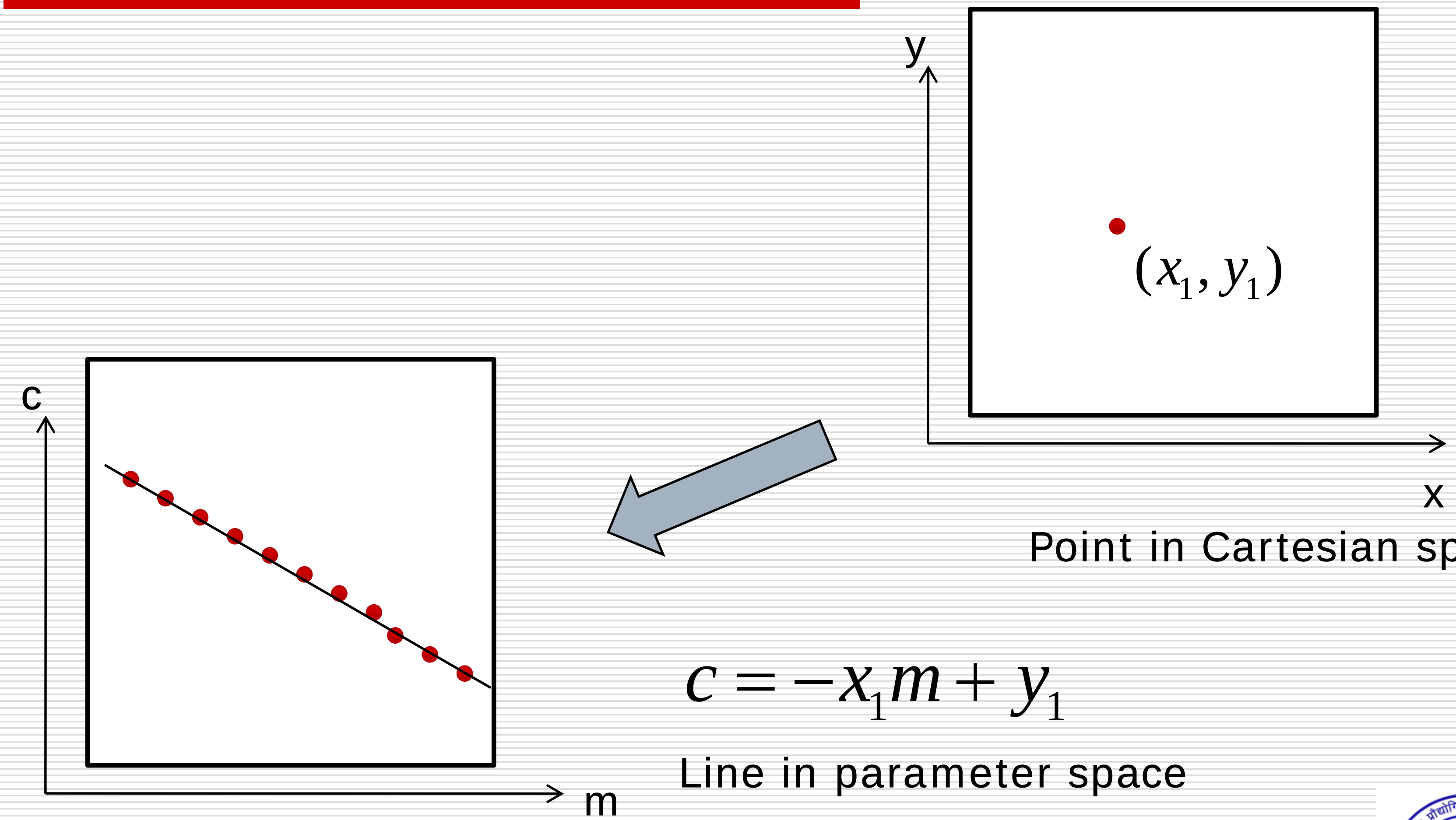


Line in Cartesian space



Line in parameter space

Hough transform 2D

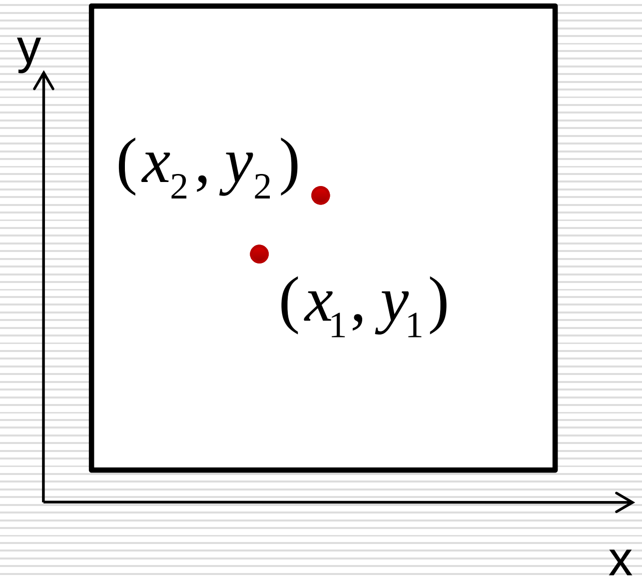


Point in Cartesian space

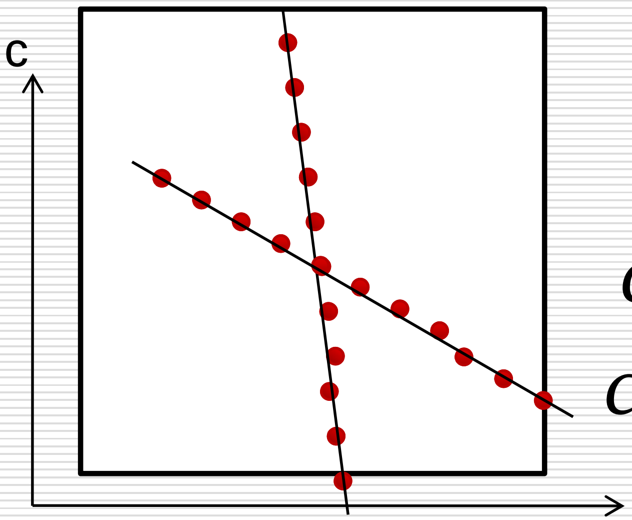
$$c = -x_1 m + y_1$$

Line in parameter space

Hough transform 2D



Point in Cartesian space

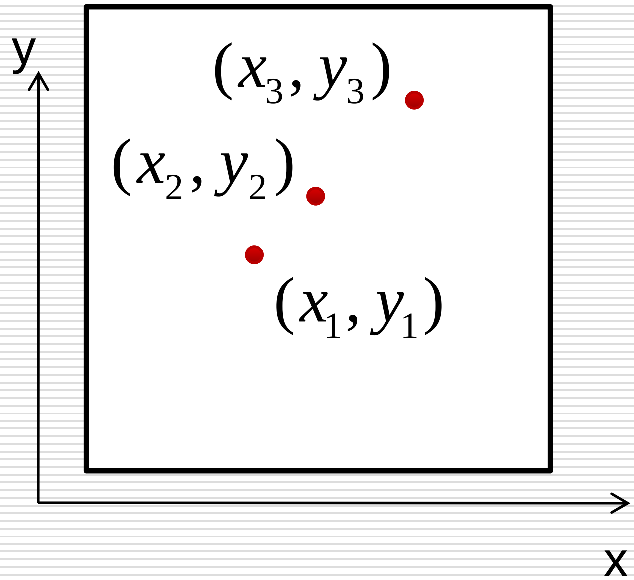


$$c = -x_1 m + y_1$$

$$c = -x_2 m + y_2$$

Line in parameter space

Hough transform 2D

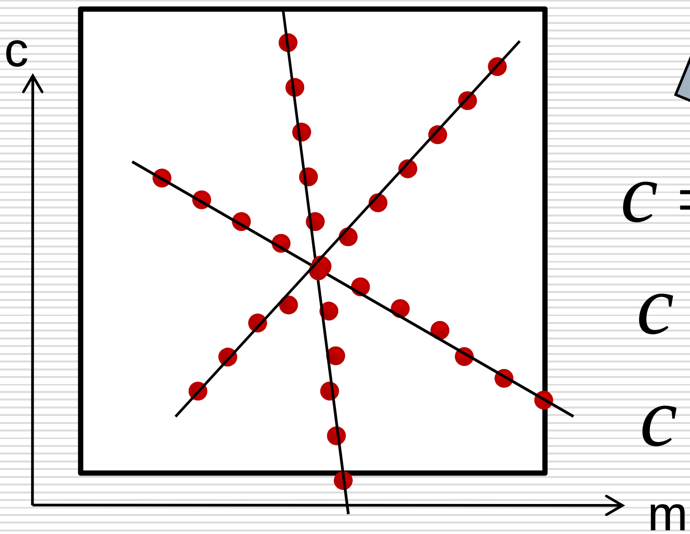


Point in Cartesian space

$$c = -x_1 m + y_1$$

$$c = -x_2 m + y_2$$

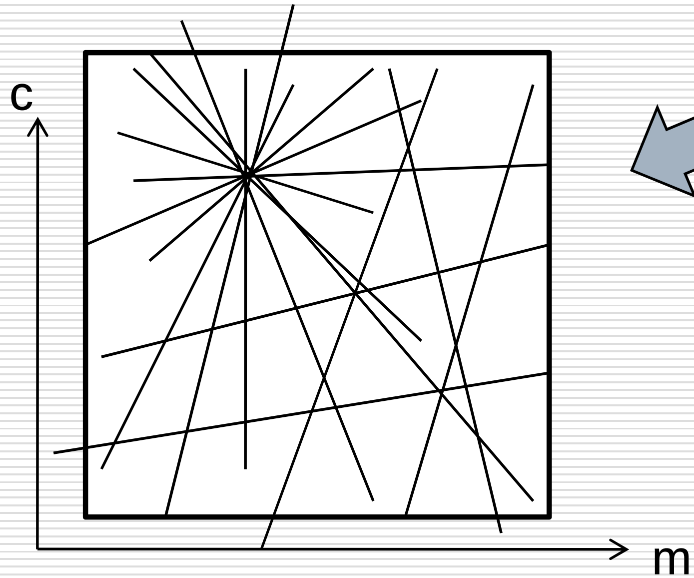
$$c = -x_3 m + y_3$$

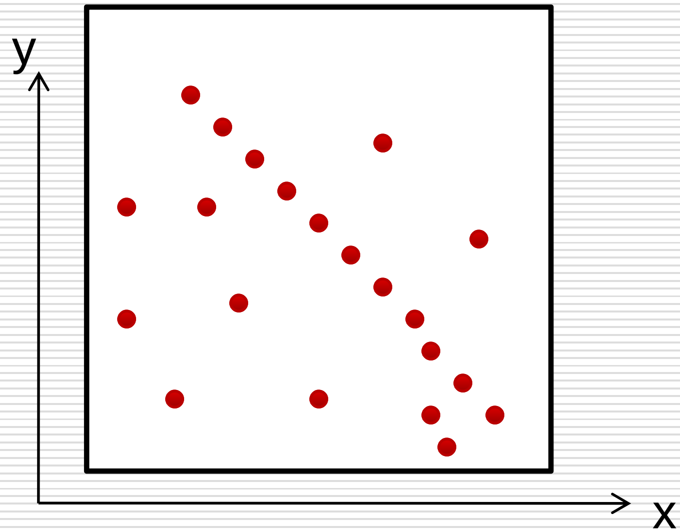


Line in parameter space

Hough transform 2D

Using the above philosophy the parameter space for a set of points will look like:

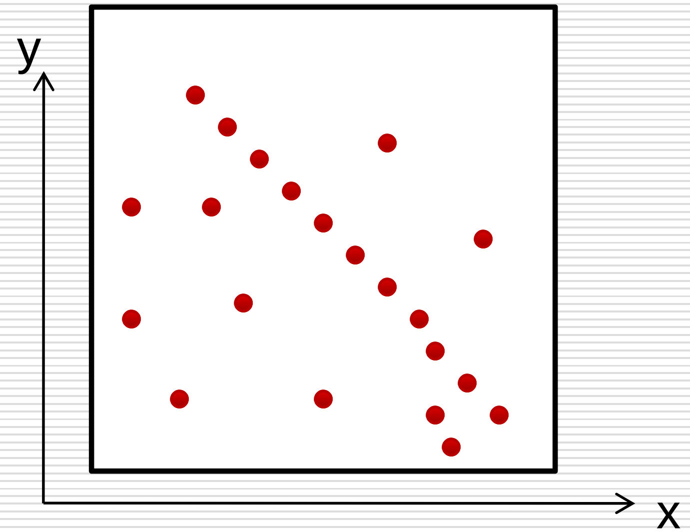




So can we use the density in parameter space to see that for what values of 'm' and 'c' there is a line.

Hough transform 2D

Determine parameters for all possible neighboring pairs.



c

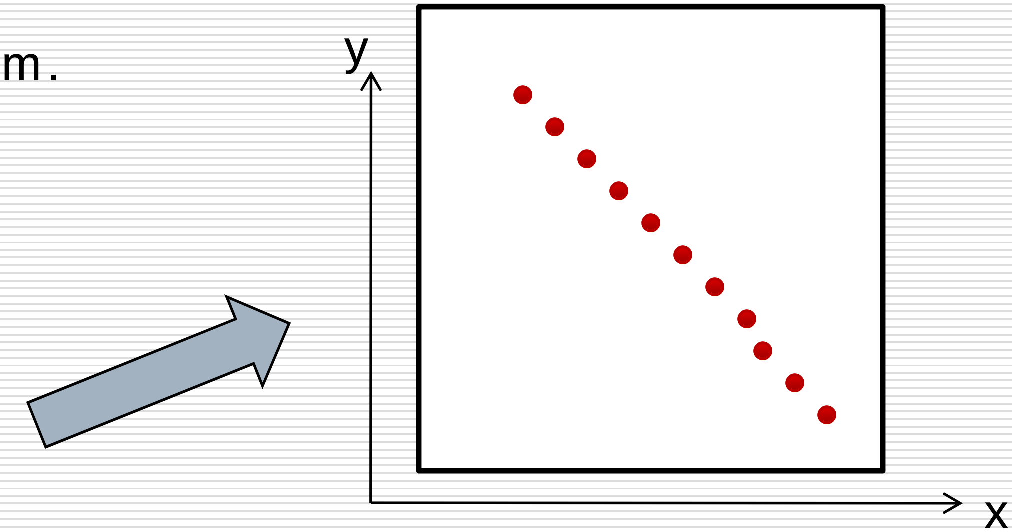
0	5	2	2
1	27	4	3
1	3	1	3
5	2	1	0

m

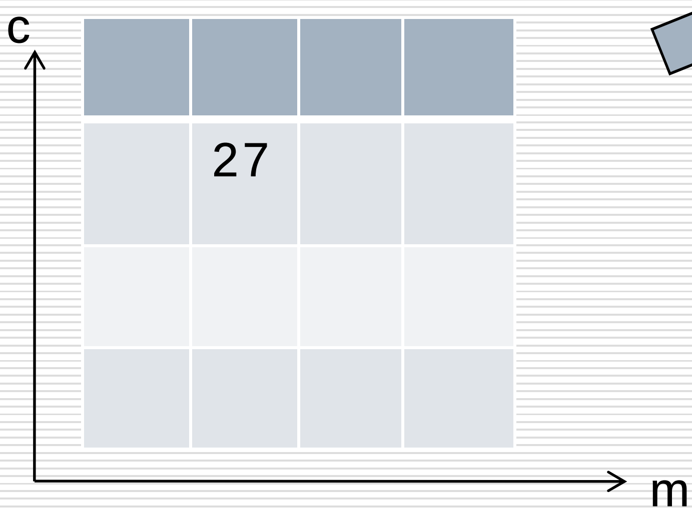
Populate discretized parameter space with the counts of similar ‘m’ and ‘c’.

Hough transform 2D

Threshold the Hough room.

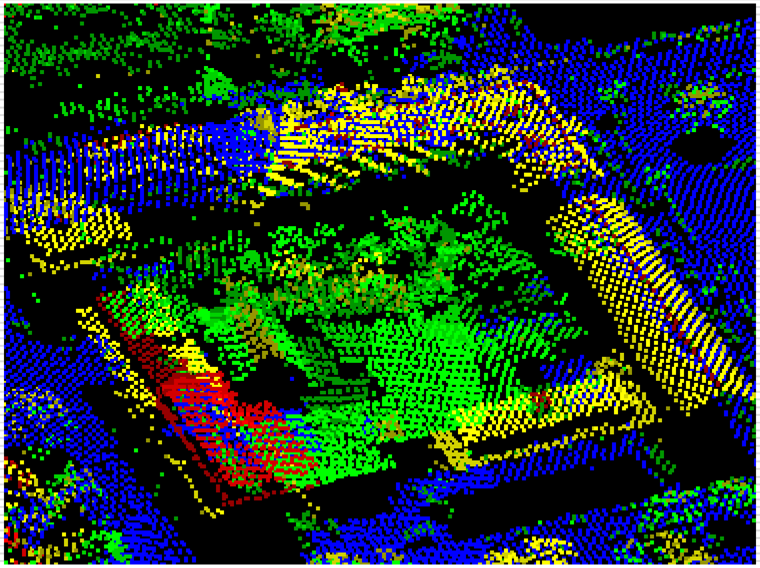


Locate the point-pairs in Cartesian space which have populated the high frequency cell of parameter space.



Hough transform 3D

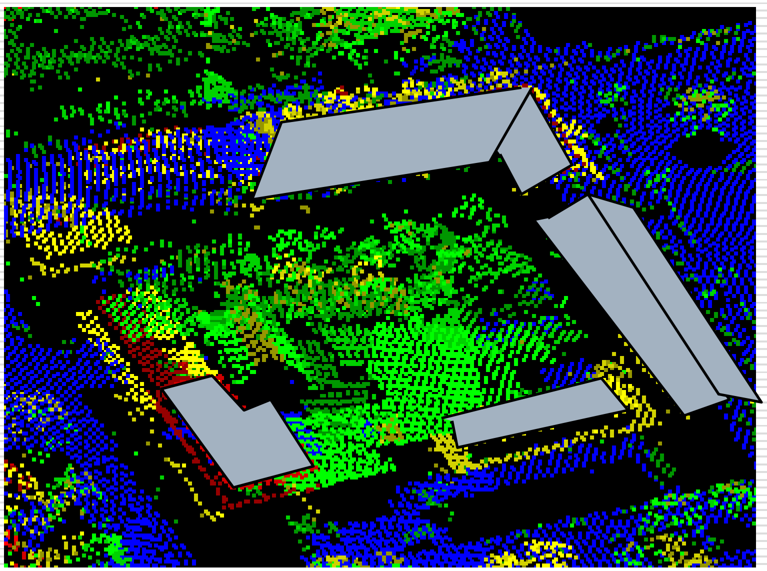
Building planes are in 3D space and need to be detected from 3D LiDAR point cloud.

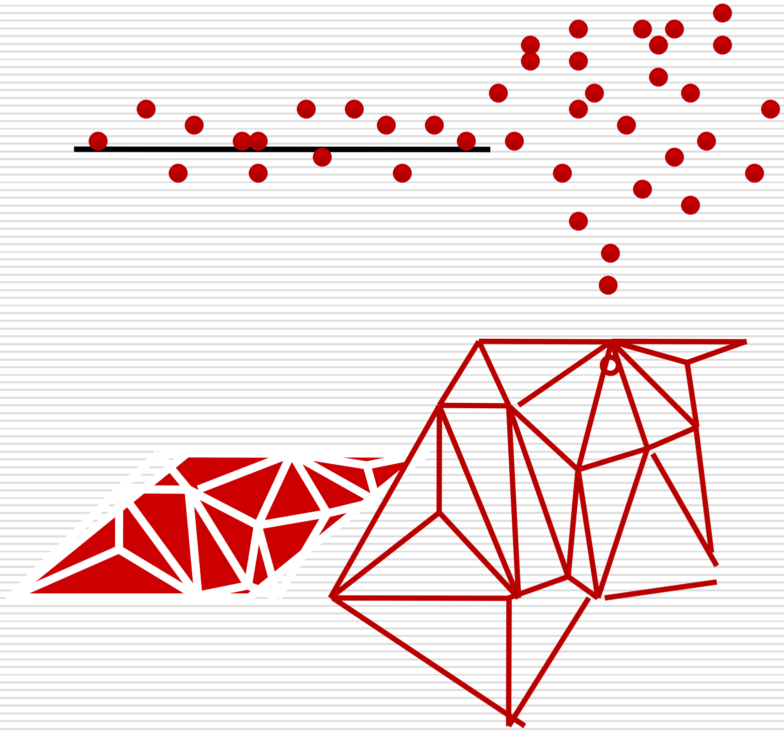


Need to apply Hough transform in 3D

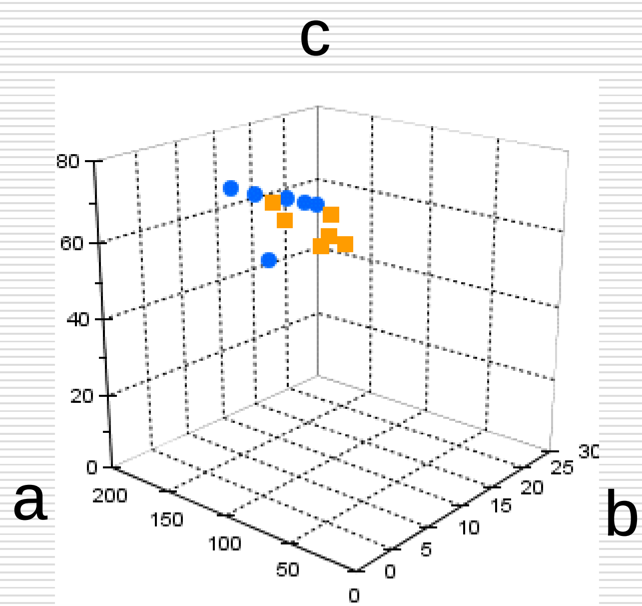
Hough transform 3D

LiDAR data for roof top

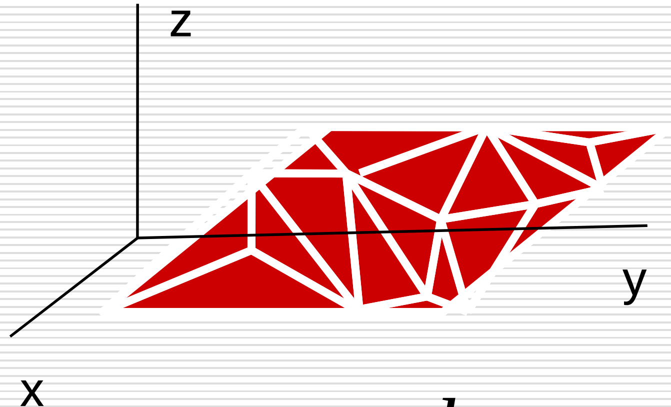




Like the line segments of 2D here triangle is the basic element.



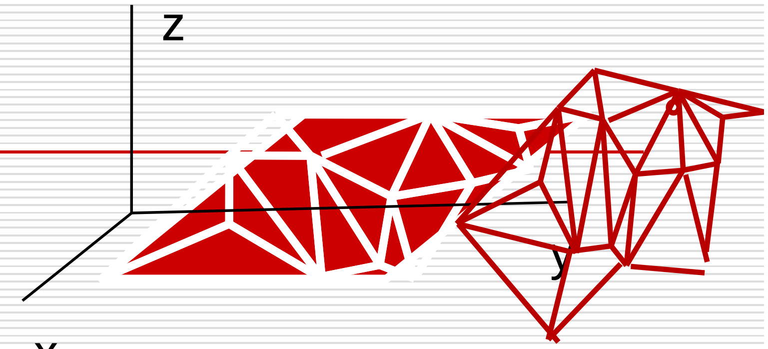
Plane in parameter space



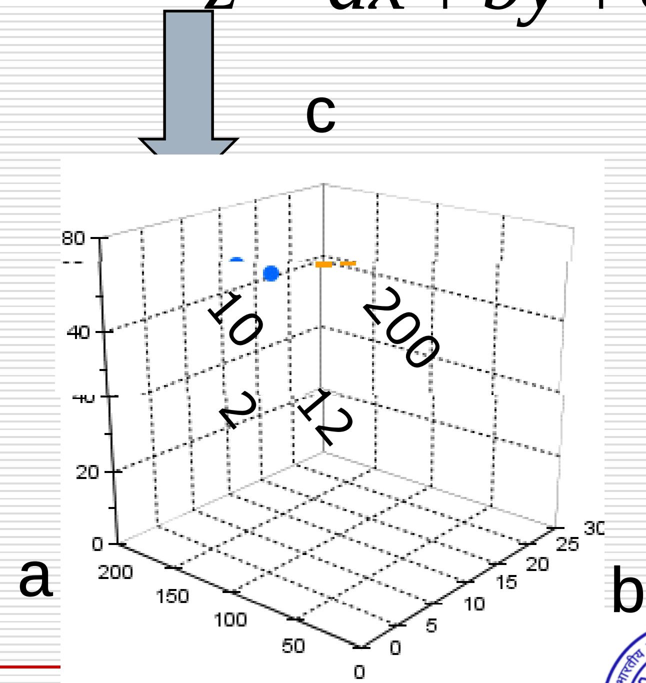
$$z = ax + by + c$$

Planes in Cartesian space

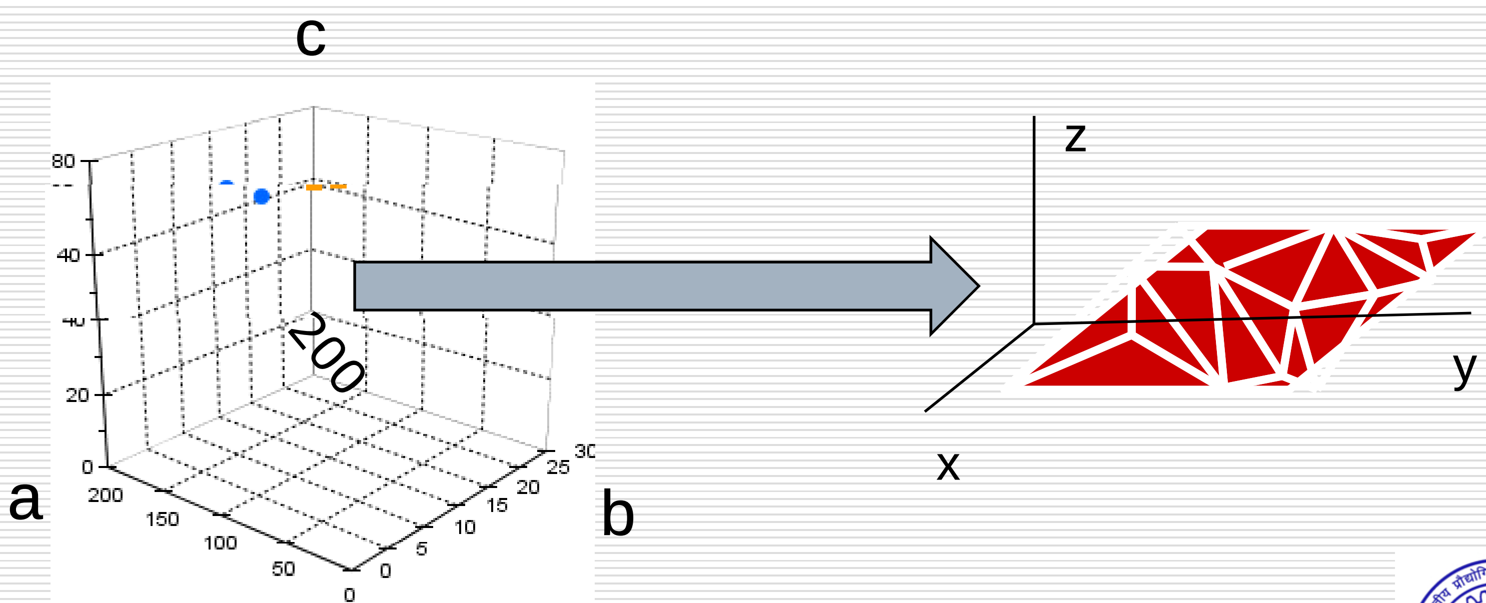
- Create 2D TIN on LiDAR data (x,y)
- Consider height of each vertex
- Determine the parameters (a, b, c) of all planes.
- Populate the 3D Hough room with the count, i.e., how many planes have similar parameters
- Threshold 3D Hough room



$$z = ax + by + c$$



•The triangles for which parameters are nearly same and with high frequency in Hough room



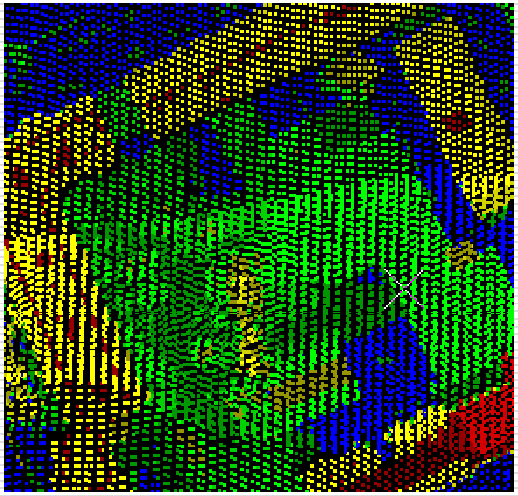
Observations

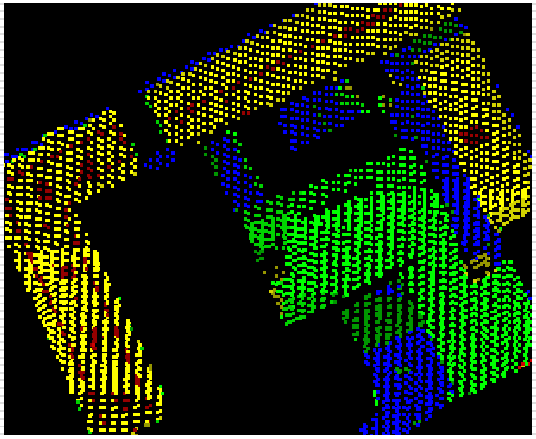
- The result is identification of all LiDAR points that form planar surfaces.
- One Hough room may represent several roof tops...

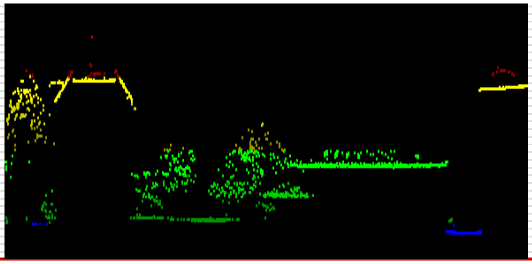
- How is this affected by:
  - The accuracy of data
  - Data density

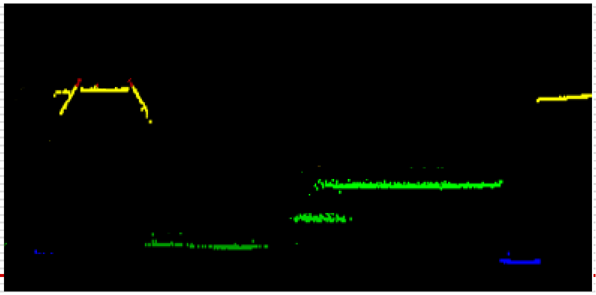
Point classification as planes

- Hough room method classifies LiDAR points as planar surfaces.



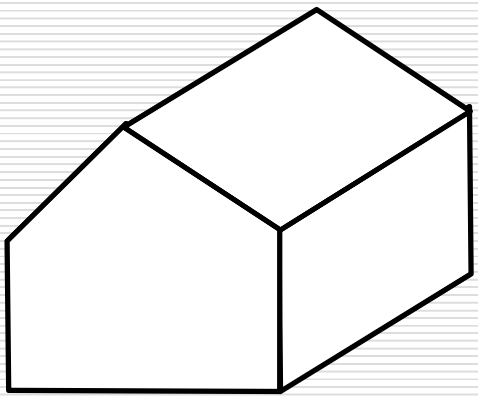


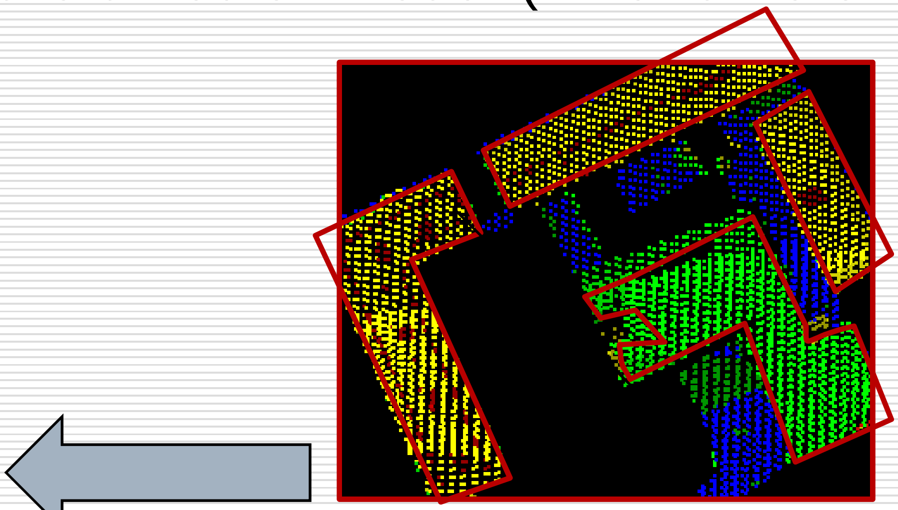


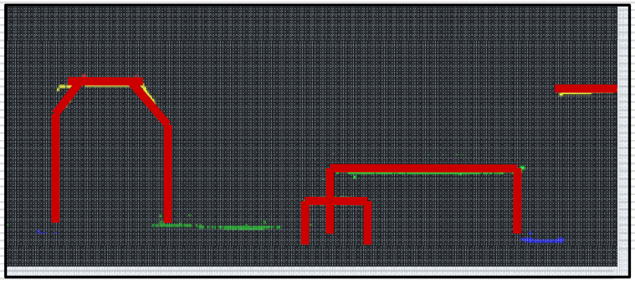


Building modelling

- Required is to generate a vector model (wireframe of building)







Separation of roofs from one major plane (one hough room cell)

•Rasterize the points

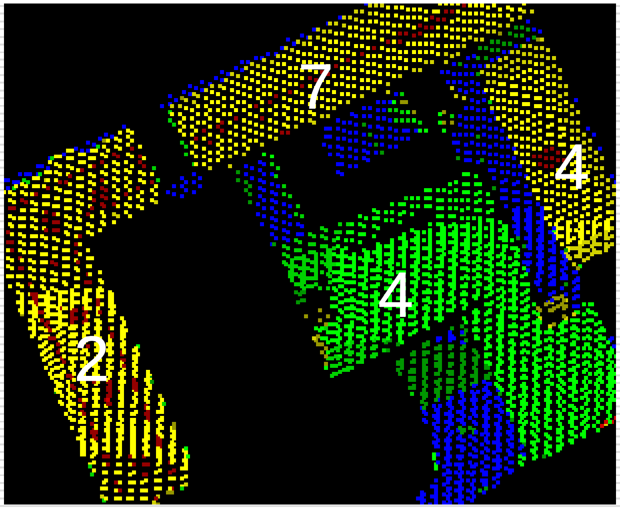
•Use image processing algorithms for blob identification

•Give different IDs to blobs

•Map the blobs back in LiDAR point cloud to give different IDs to different point groups

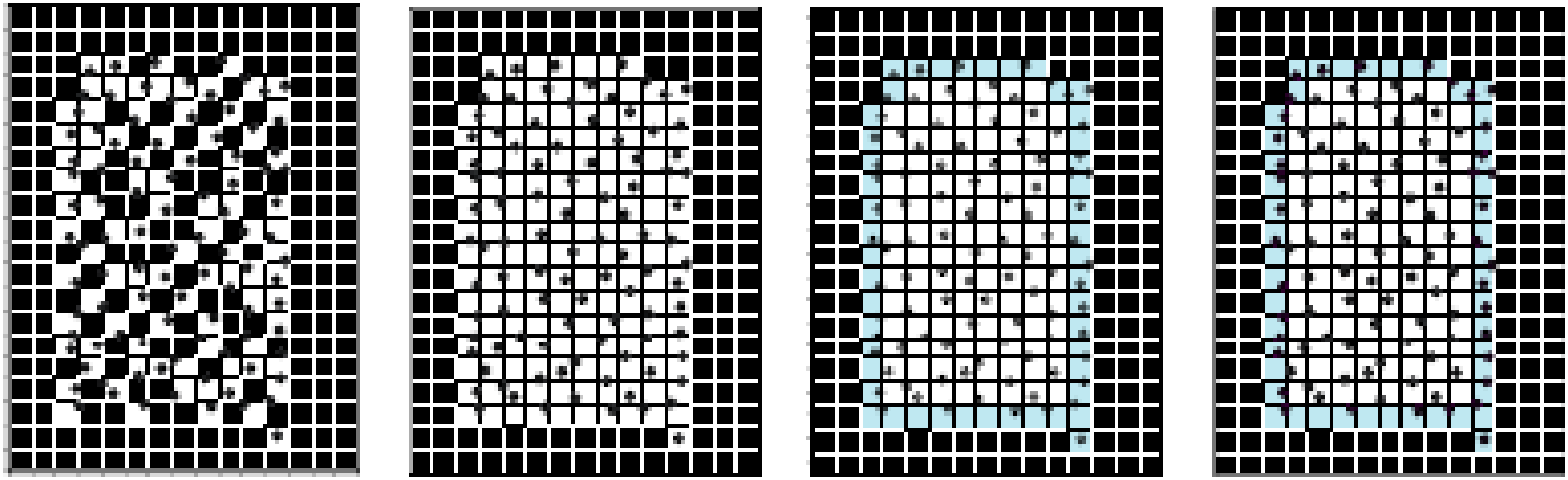
•Remove smaller <threshold planes

•Merge closer groups



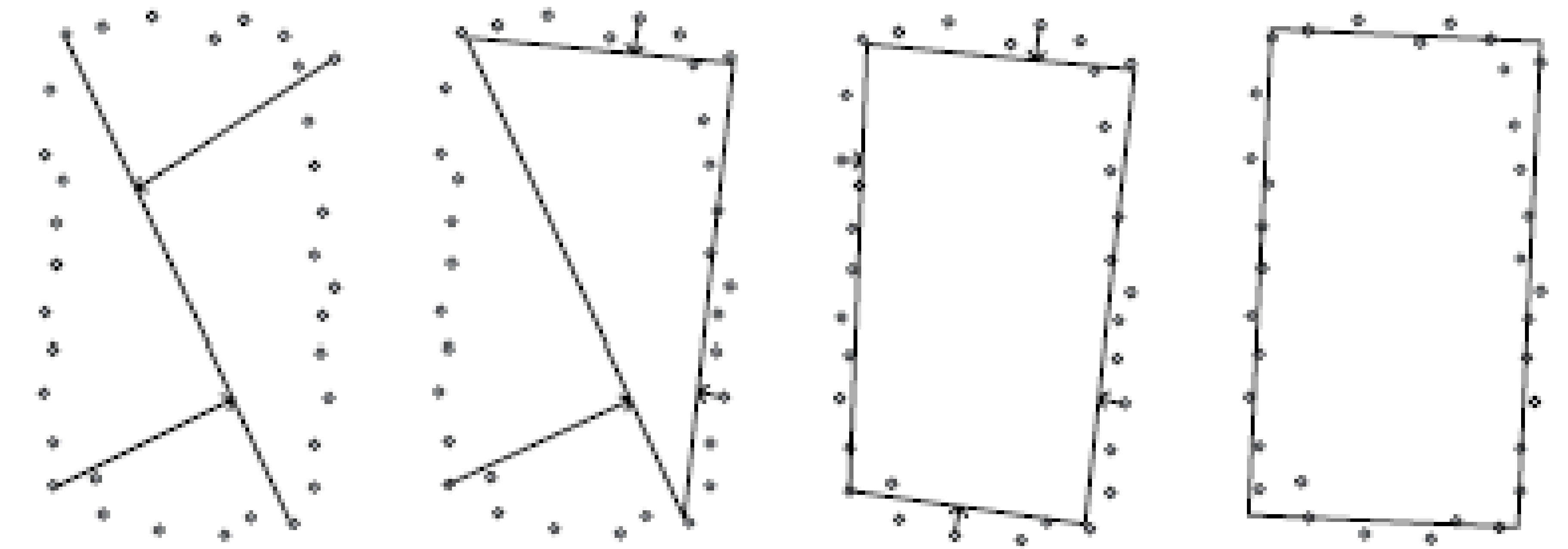
Plane edge identification

- Rasterize point groups
- Morphological closing
- Edge identification



(a) Gridding roof points (b) Morphological Closing on grid to fill holes (c) Application of Bw-boundaries() function (d) Edge points detected

Line fitting to edge data points



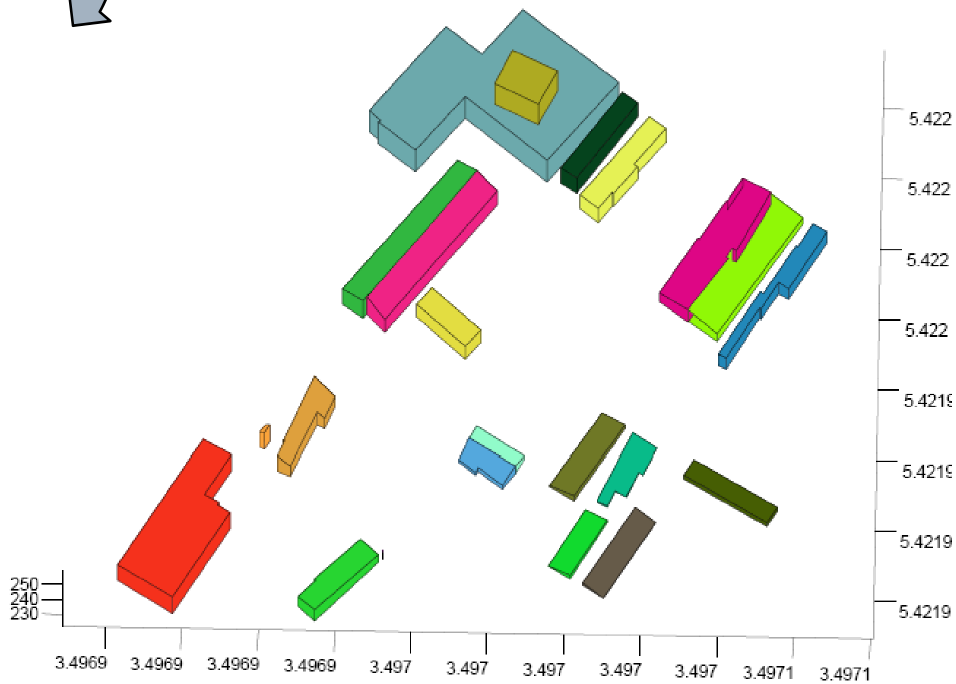
(a) Maximum distance point from line

(b) Joining point at maximum distance

(c) Contour approximation of edge points

(d) Resultant boundary of Line fitting and orthogonalisation

Result



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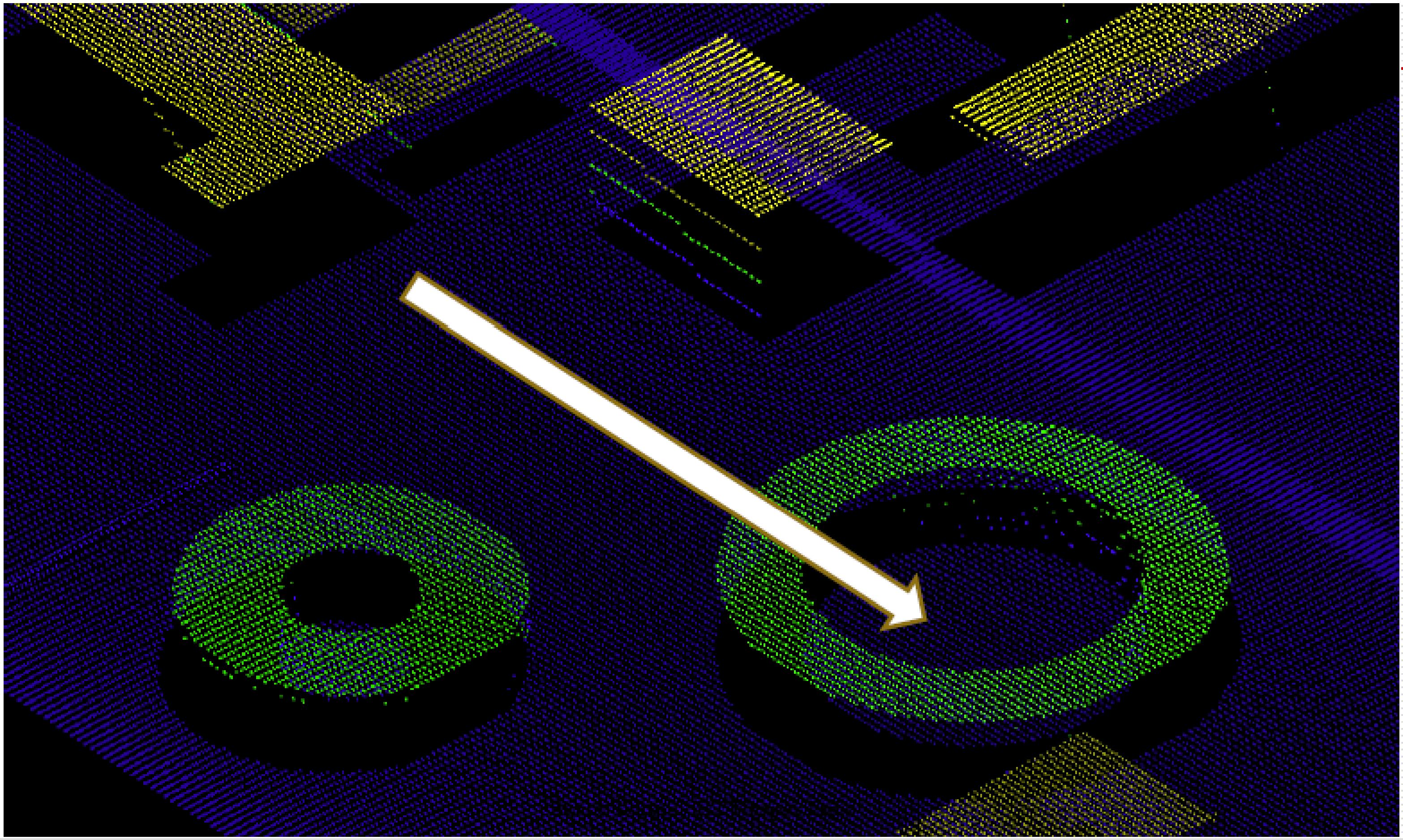

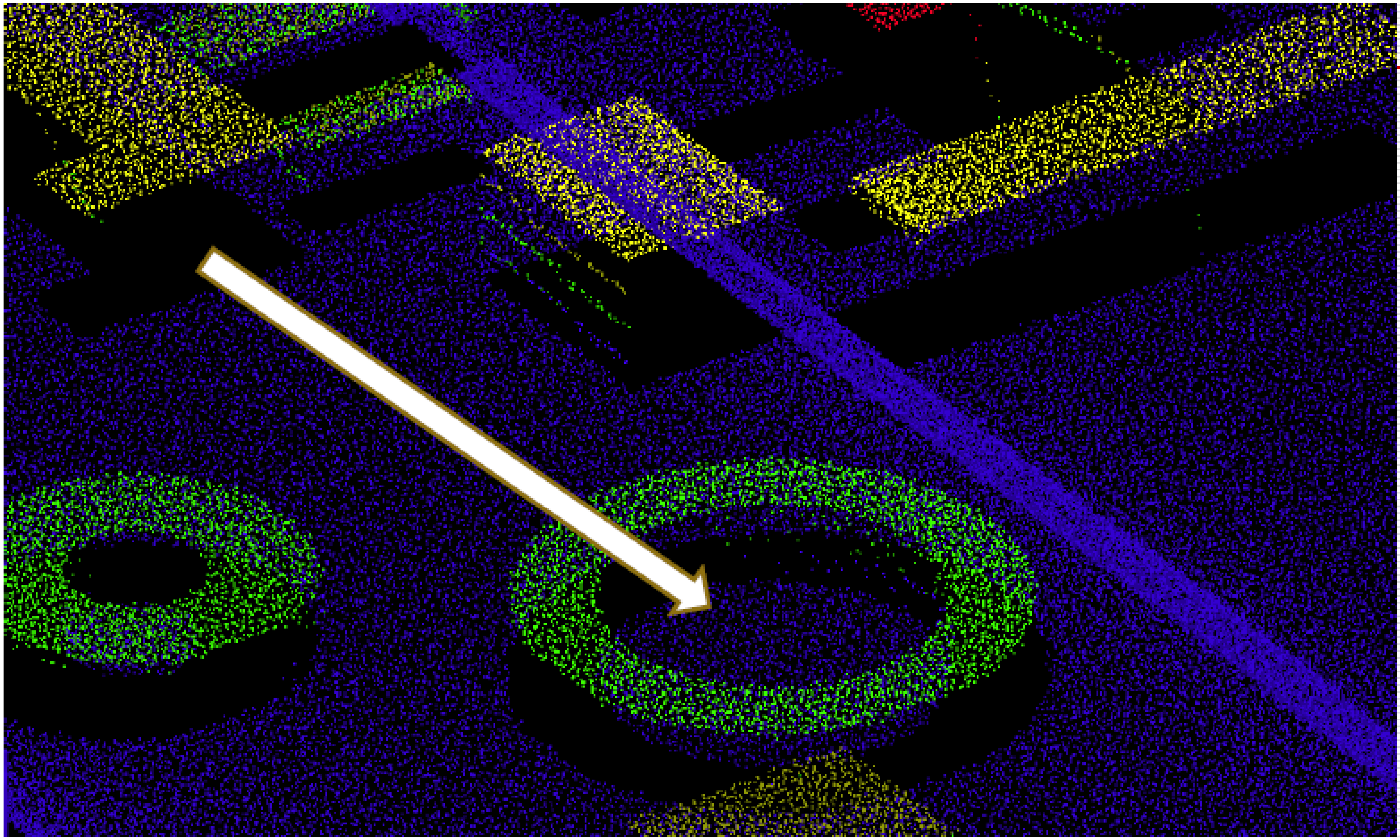

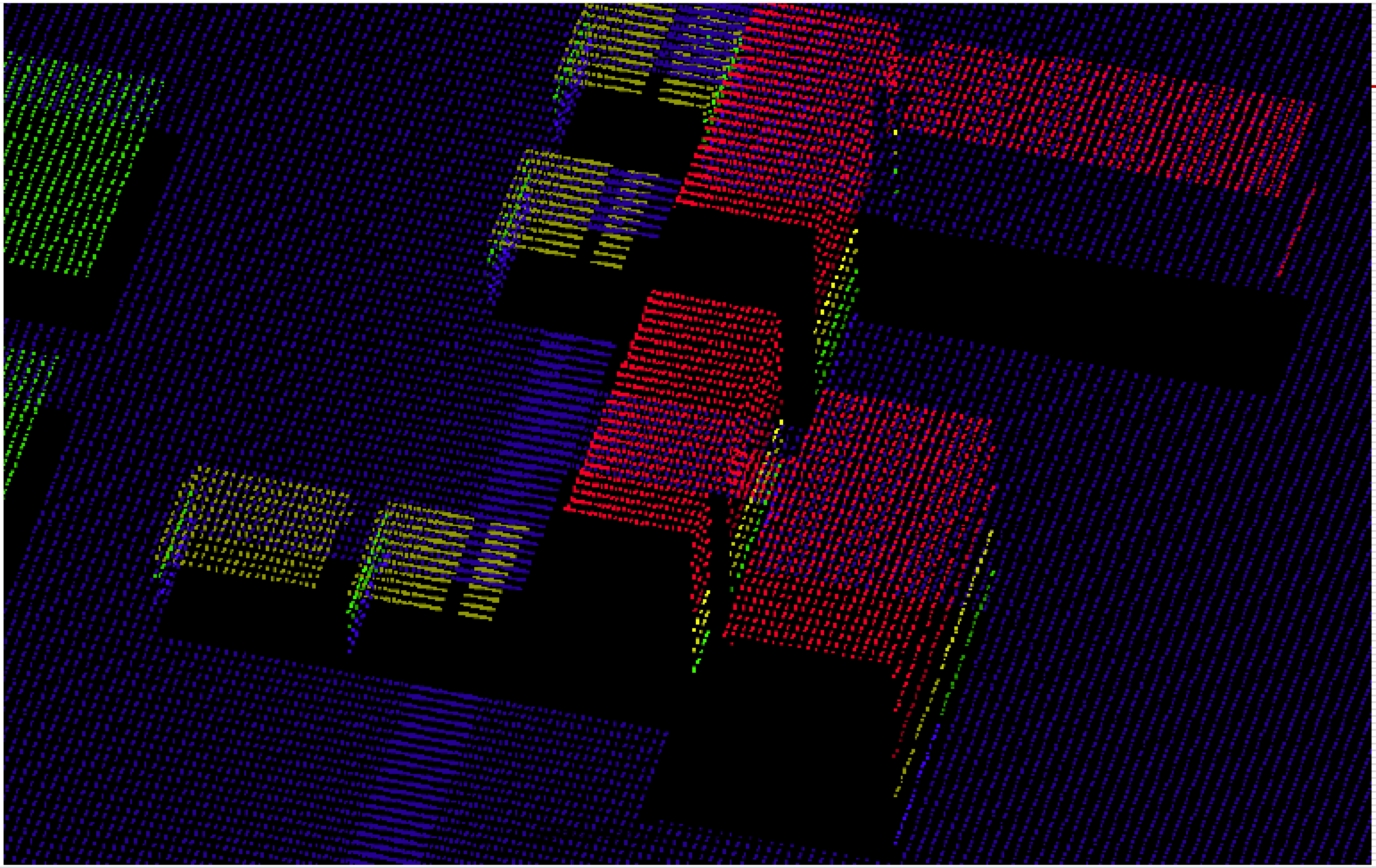

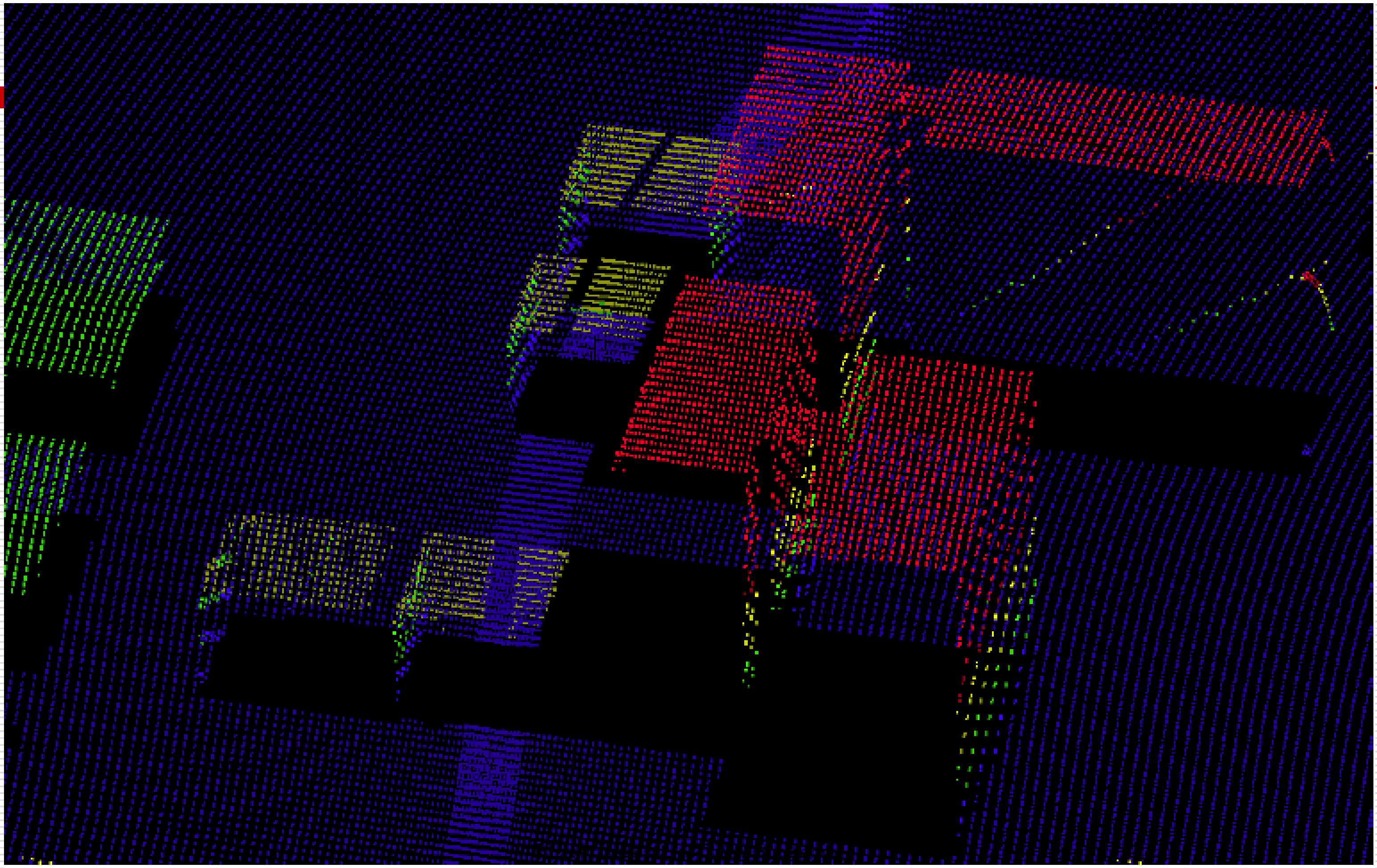

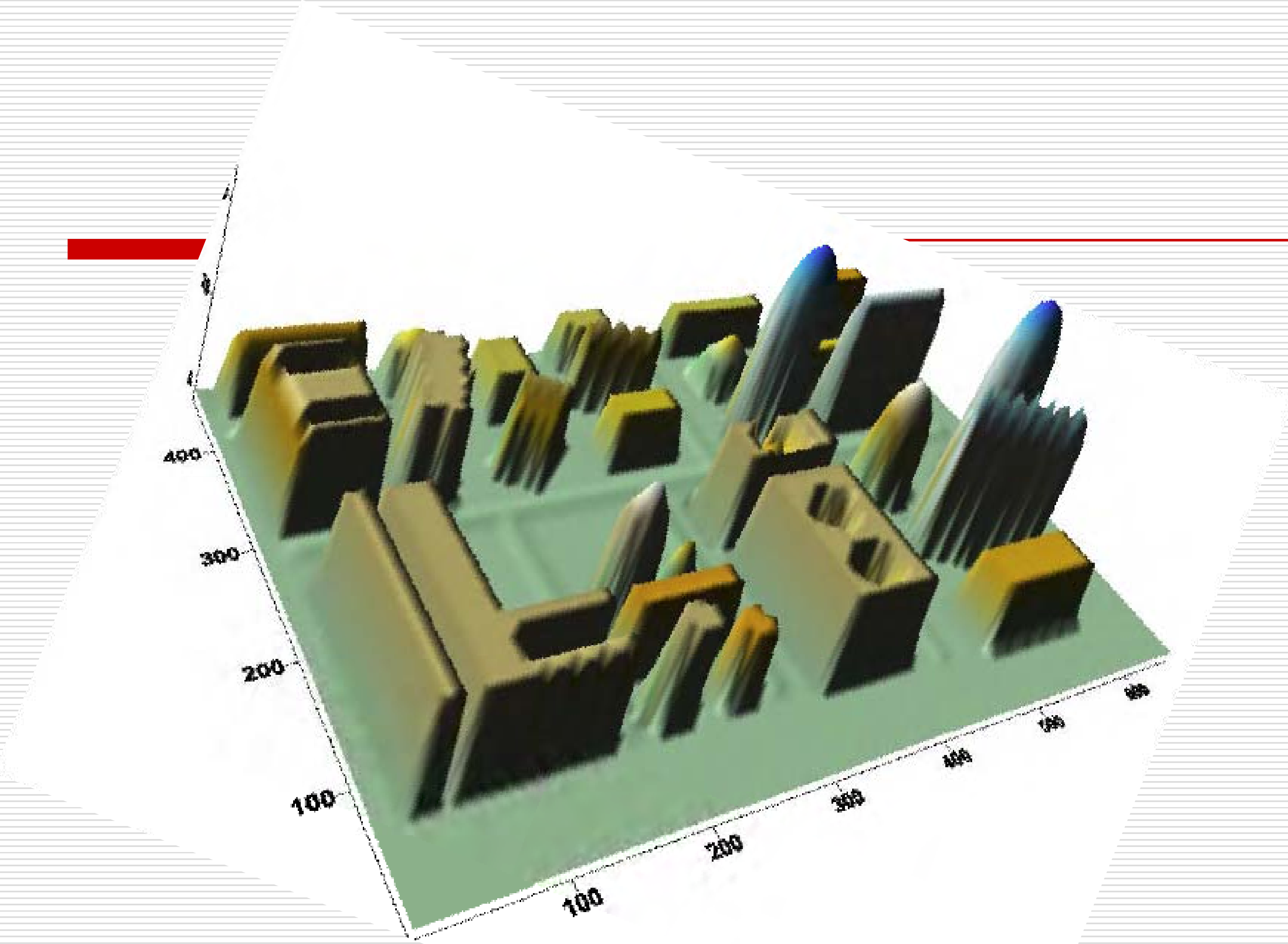
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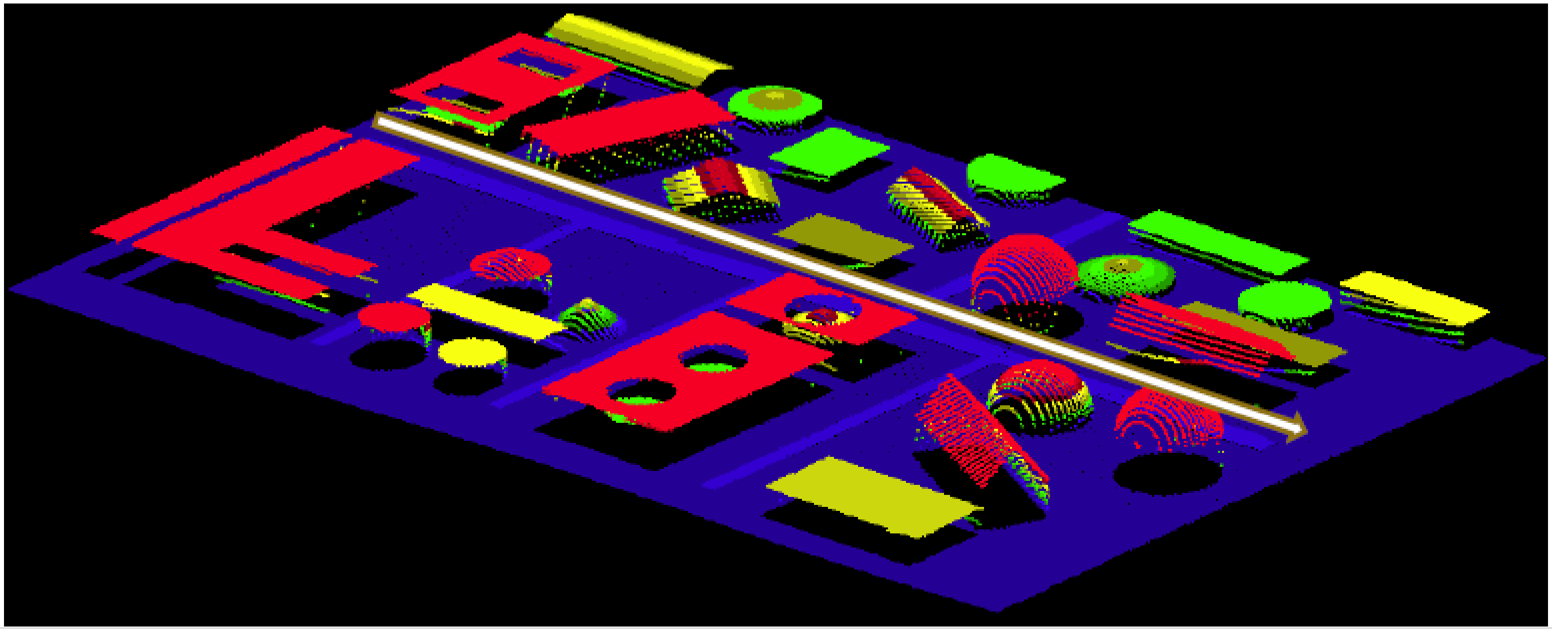
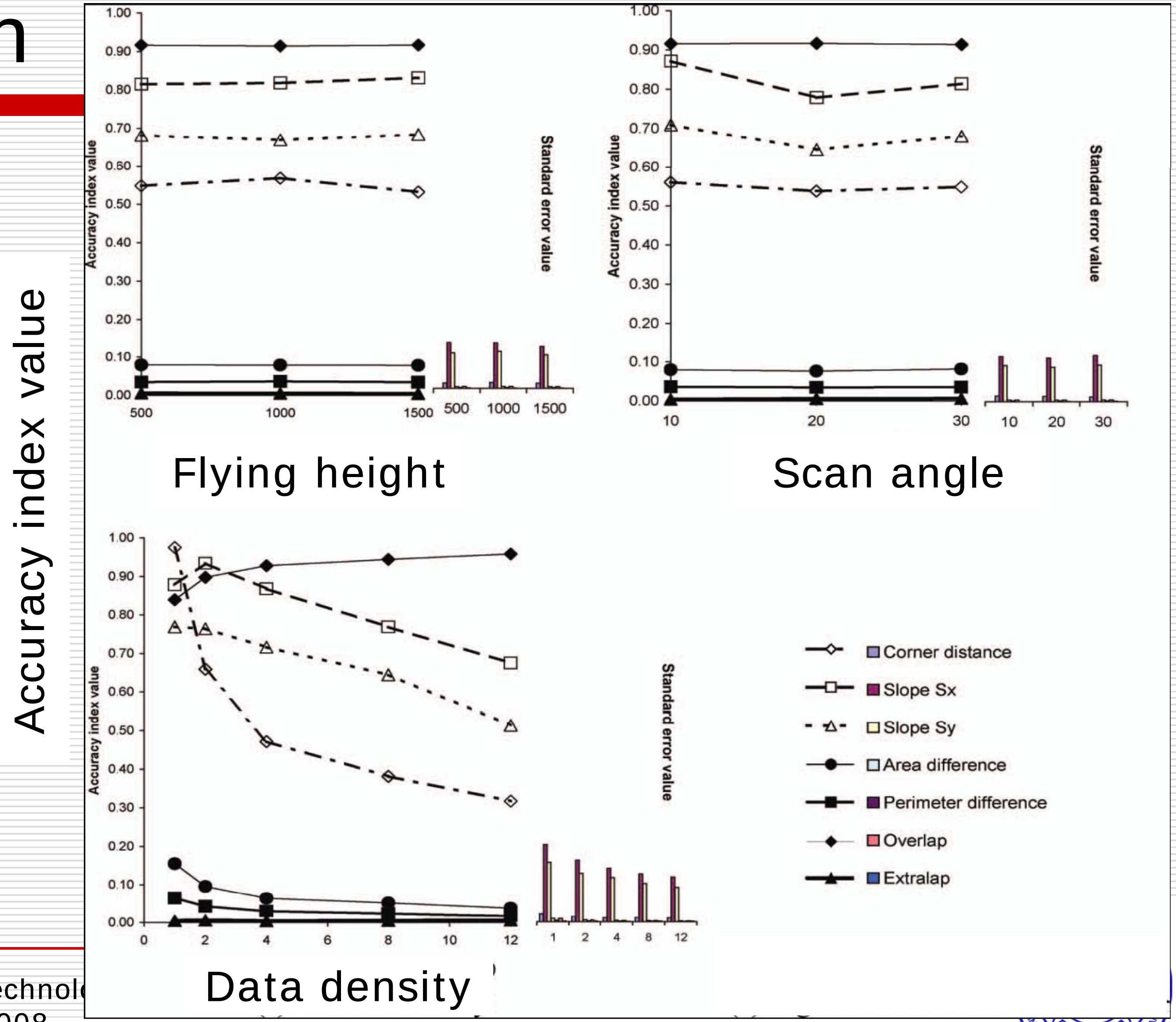


Effect of data type on building extraction



Other planer approaches...

- Segmentation using surface normals
- RANSAC (Random Concensus Sampling) method
- Others...
- Terrascan uses holes in ground class to locate possible building points

References

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