

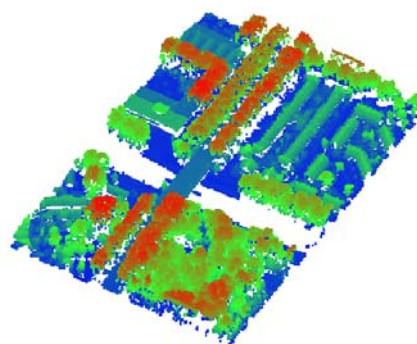
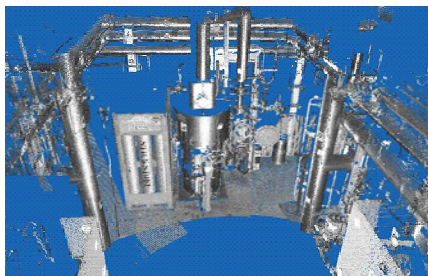
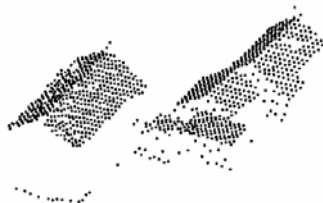
Segmentation of point clouds

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Extraction of information from point clouds



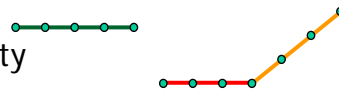
Segmentation algorithms

- Extraction of smooth surfaces
 - Scan line segmentation
 - Surface growing
 - Surface merging
 - Voxel space analysis
- Extraction of parameterised surfaces
 - Planes
 - Cylinders
 - Spheres

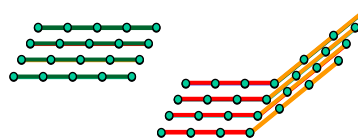


Scan line segmentation

- Independent segmentation of each scan line based on
 - Proximity
 - Curve fit / height continuity
 - Normal vector direction

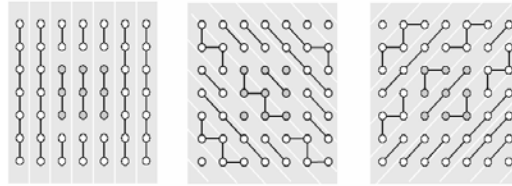


- Merging of scan line segments across neighbouring scan lines

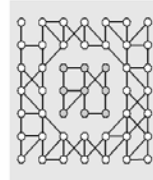


Using multiple scan line segmentations

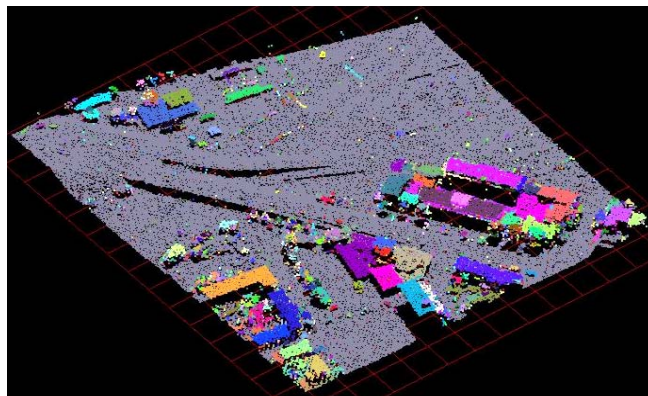
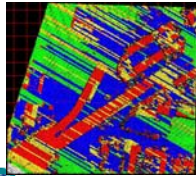
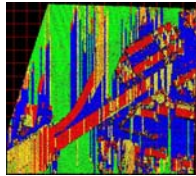
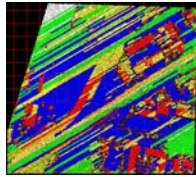
- Independent segmentation for multiple scan line orientations



- Join segments with common nodes

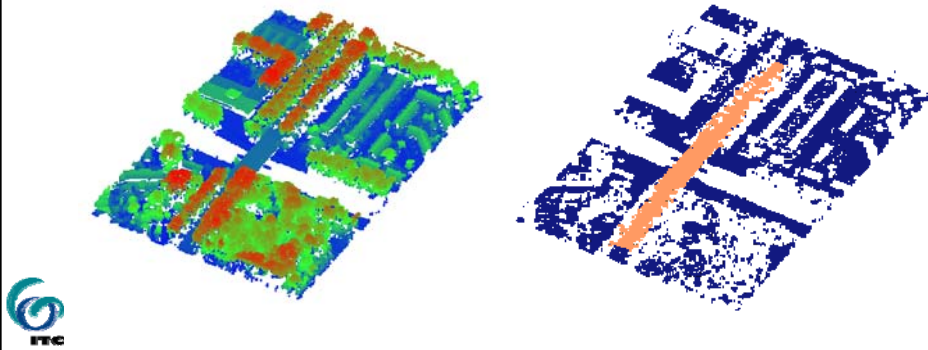


Using multiple scan line segmentations (II)



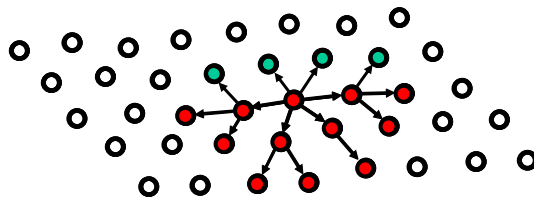
Example scan line segmentation

- Extraction of large smooth surface
- Decomposition into terrain and bridge



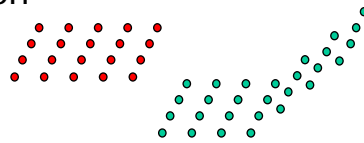
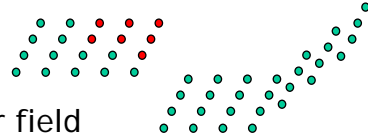
Surface growing

- Select arbitrary point
- Select a few neighbouring points
- If plane fitting results in low residuals use these points as seed surface
- Try to expand this planar surface with further neighbouring points



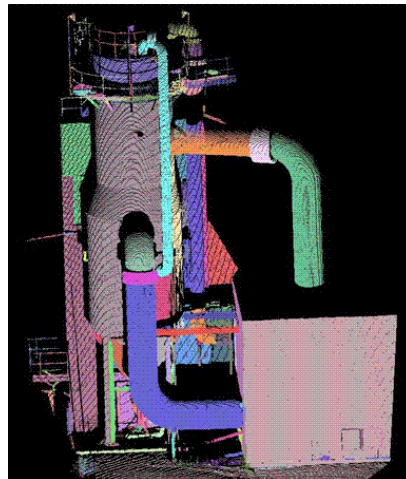
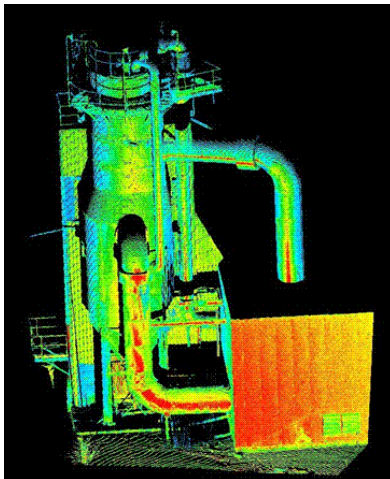
Surface growing (II)

- Determination of seeds - locally smooth patches based on
 - Local surface fitting
 - Local smooth normal vector field
 - Detected planes
- Growing of surfaces based on
 - Proximity (TIN, kNN)
 - Surface fit / height continuity
 - Normal vector direction



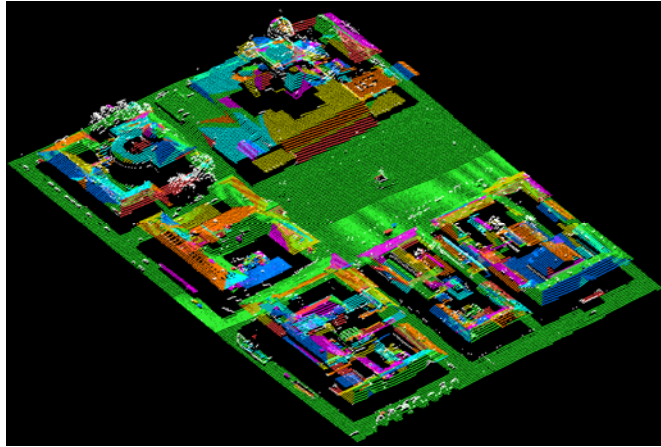
Example surface growing

- Segmentation of an industrial installation



Example surface growing (II)

- Smooth surfaces in the EuroSDR test data on building extraction



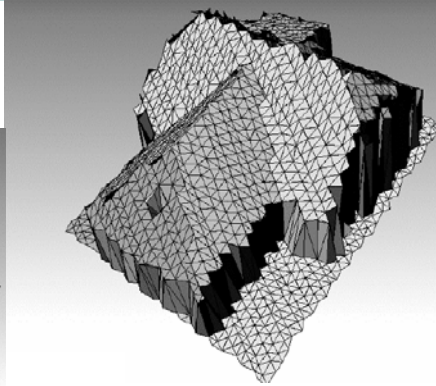
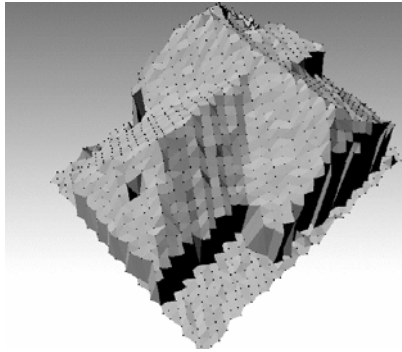
Surface merging

- Split point cloud into triangles (Delaunay triangulation)
- Iterative merging of surfaces based on
 - Adjacency
 - Surface to surface distance



Example surface merging

- Roof surfaces



- Problems with multi-layered surfaces



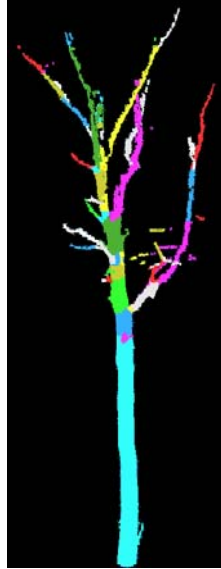
Voxel space analysis

- Rasterise data into voxels
- Connected component analysis
- 3D image processing
 - Mathematical morphology
 - Skeletonising



Example voxel space analysis

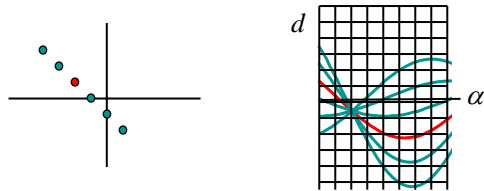
- Tree segmentation



Extraction of parameterised surfaces

Hough transform

Detection of straight lines in 2D space $X \cos \alpha + Y \sin \alpha = d$



Generalised Hough transforms for

- Planes
- Cylinders
- Circles



Detection of planes

Duality between points and planes in 3D space

- Plane in object space - point in Hough space

$$Z = s_x X + s_y Y + d$$

- Point in object space - plane in Hough space

$$Z = s_x X + s_y Y + d$$

Two cases:

1. *Without normal vectors:*

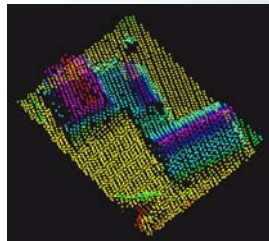
Point X, Y, Z corresponds to plane in Hough space

2. *With normal vectors:*

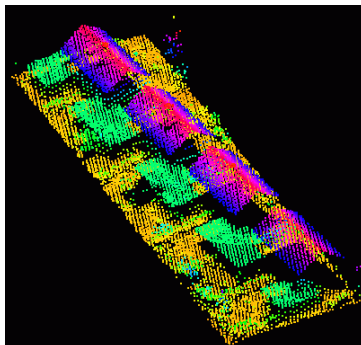
Point X, Y, Z with normal vector defines a plane in object space. This plane corresponds to a point in Hough space.



Example plane detection

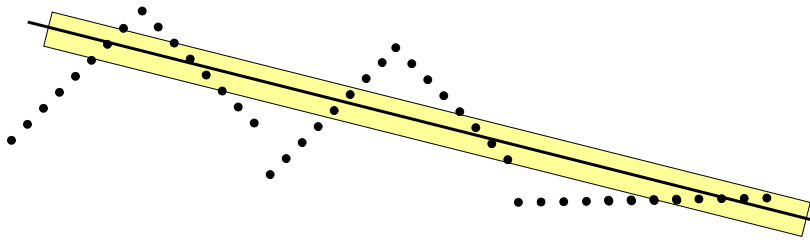


Roof surfaces



Detection of planes (II)

Problems with a global 3D Hough transform



Detection of cylinders

Cylinder described by five parameters

Two step Hough transform

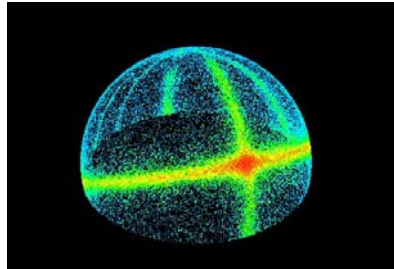
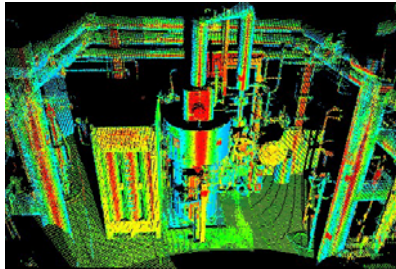
- Detection of orientation (2 parameters)
- Detection of position and radius (3 parameters)



Detection of cylinders (II)

Step 1: Detection of orientation

- Projection of normal vectors onto Gaussian sphere
- Detection of great circles on Gaussian sphere



Detection of cylinders (III)

Step 2: Detection of cylinder position and radius

- Projection of points onto plane perpendicular to cylinder axis
- Detection of circle in 2D space, Hough space X_c, Y_c, r

Two cases:

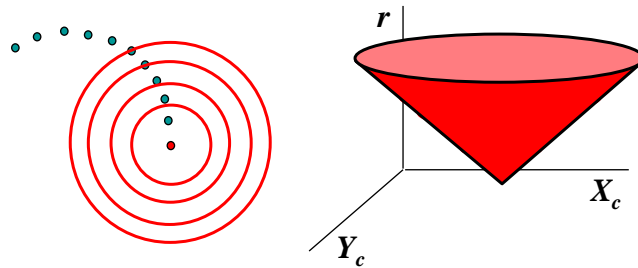
1. *Without normal vectors*
2. *With normal vectors*



Detection of cylinders (IV)

1. *Without normal vectors:*

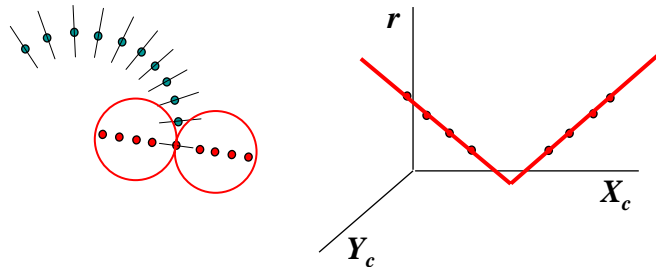
Point X, Y corresponds to cone in parameter space



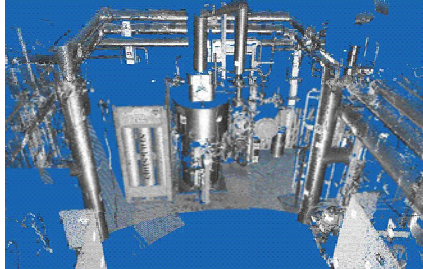
Detection of cylinders (IV)

2. *With normal vectors:*

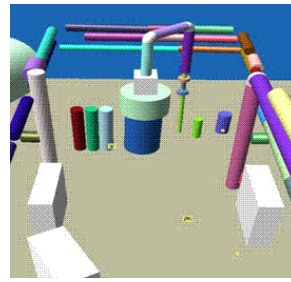
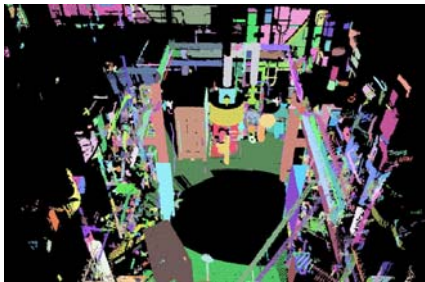
Point X, Y corresponds to two lines in parameter space



Example cylinder detection



- Segmentation into smooth connected components
- Cylinder detection for each component



Detection of spheres

Four dimensional parameter space X_c, Y_c, Z_c, r

Two cases:

1. *Without normal vectors:*
Point X, Y, Z corresponds to sphere for each r
2. *With normal vectors:*
Point X, Y, Z corresponds to two lines in 4D space



Summary

- A variety of algorithms is available for segmentation of point clouds.
- Smooth surfaces and parameterised surfaces can often be extracted reliably.
- The choice for the best method depends on the data quality and the application.

