The Smart Point Cloud framework to detect pipelines using raw point cloud generated from panoramic images

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MSc Thesis Geomatics

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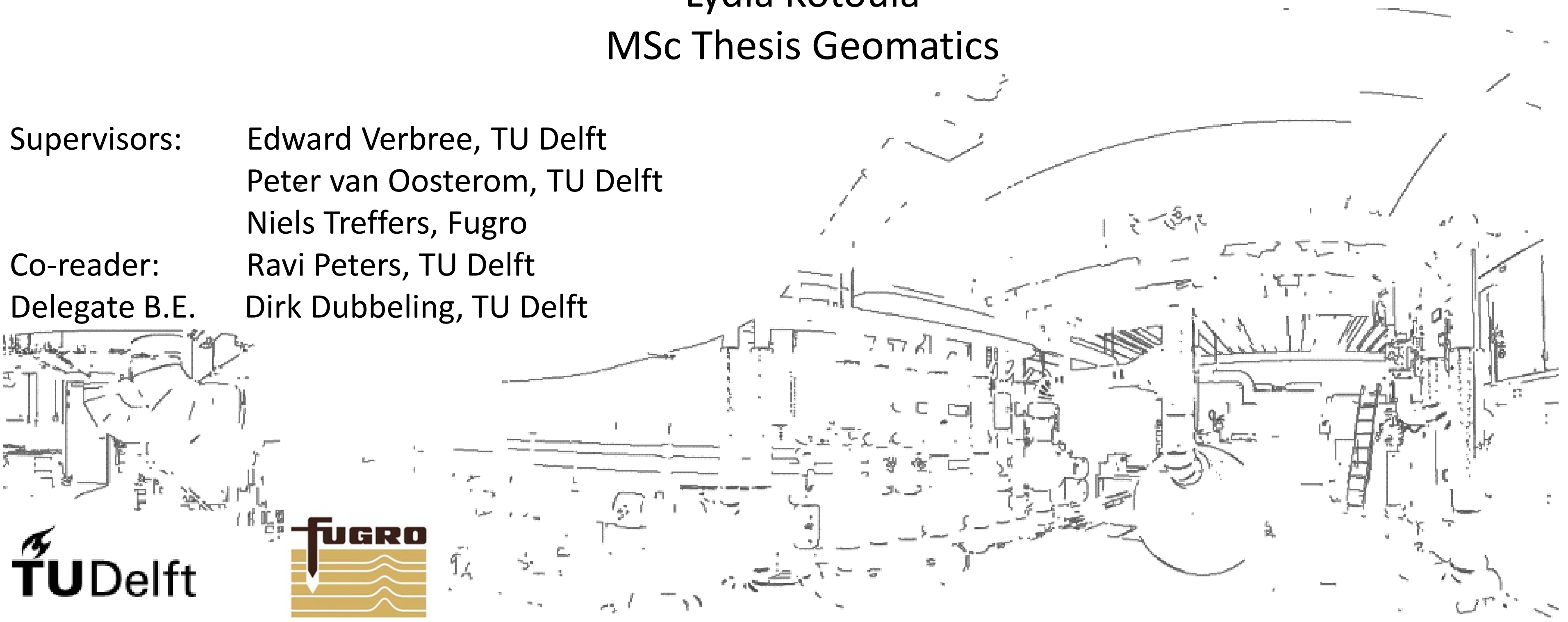

Outline

1. Motivation & Challenges
2. Background & Research objectives
3. Research Prototype
4. Implementation & Results
5. Conclusions & Future work

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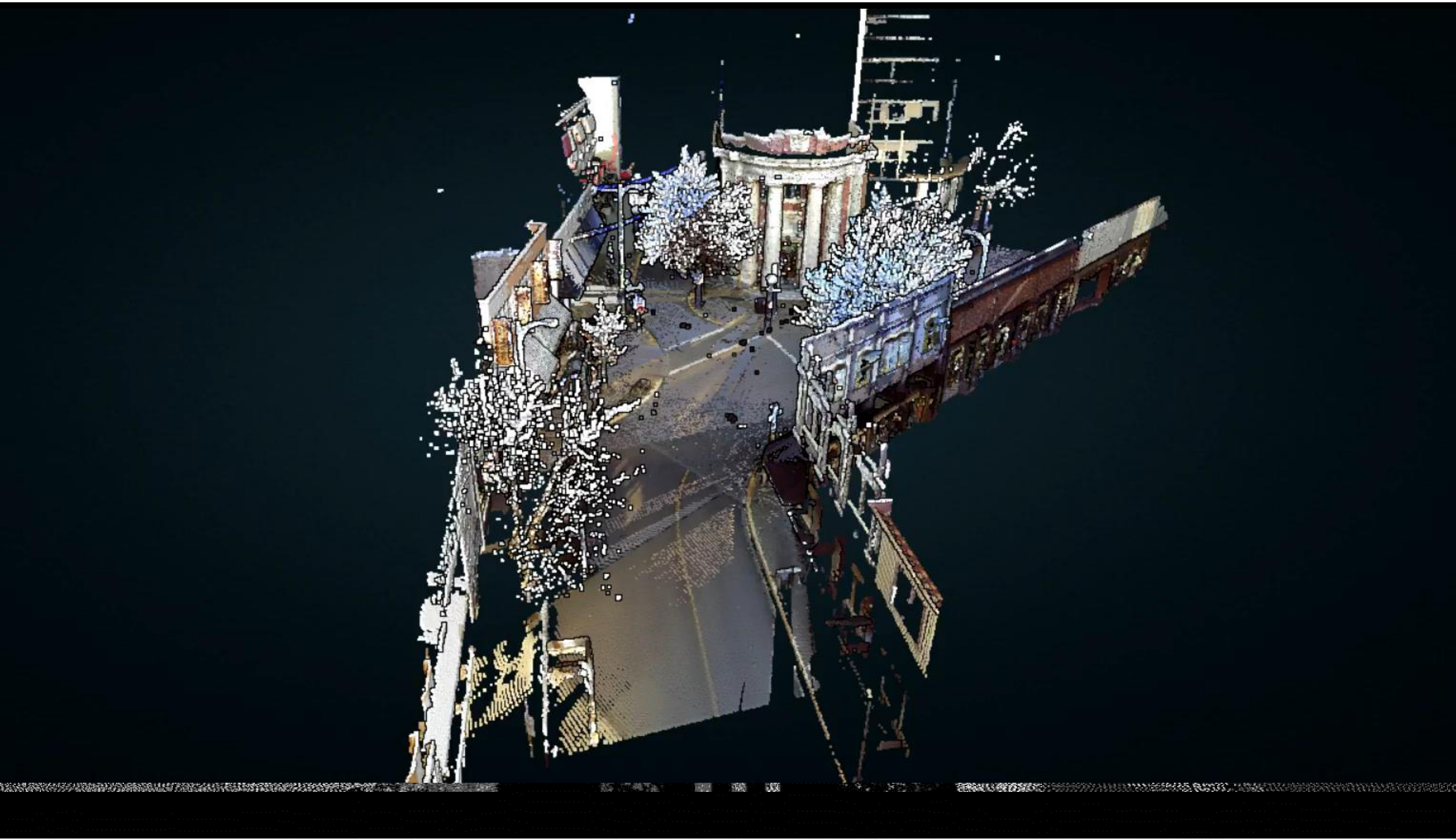
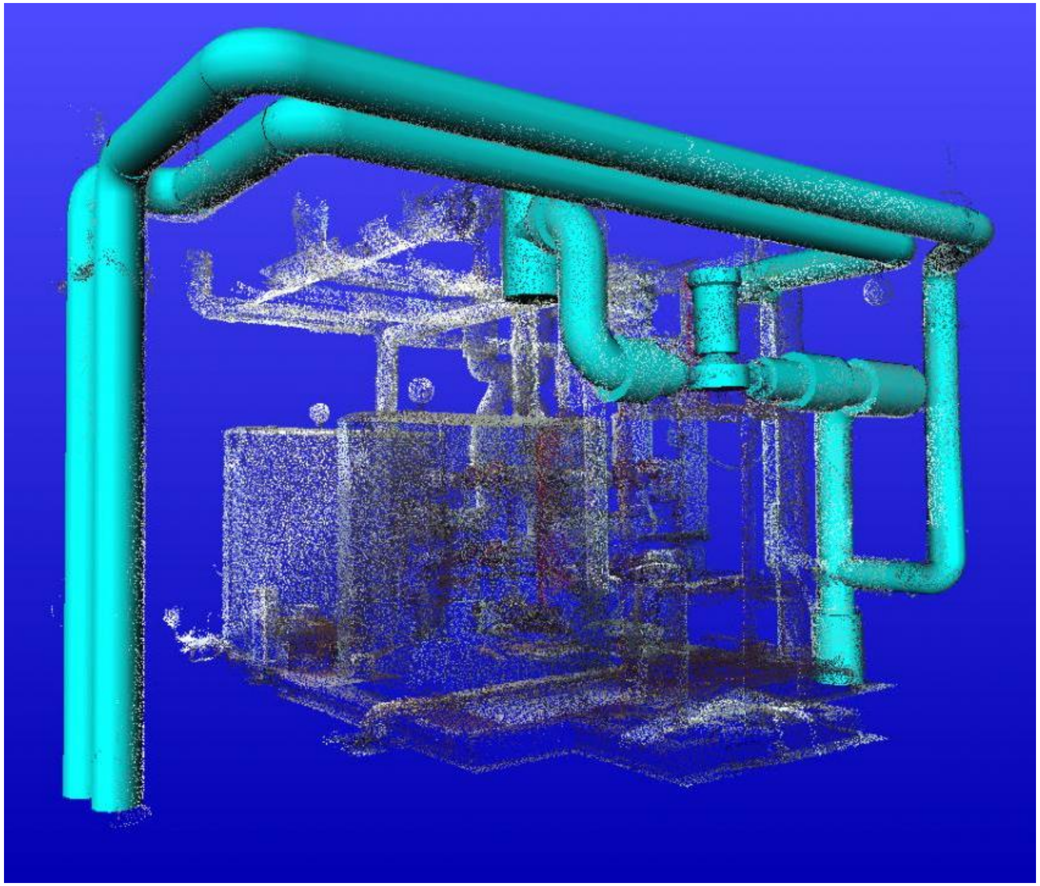
Motivation



Motivation - Eliminate the Modelling Step

- Time consuming
- Interpolation
- Lose important information
- Loss of accuracy



Point Cloud as an Authentic Source

- Decision making process
- More value than derived products
- Visual interaction

However…

- Interprete point clouds need special knowledge and analytical skills
- Attach domain information through visual and semantic variables

Point Cloud Challenges

- Object recognition
- Visualisation & Dissemination
- Data Fusion
- Assign semantics-Object Identification

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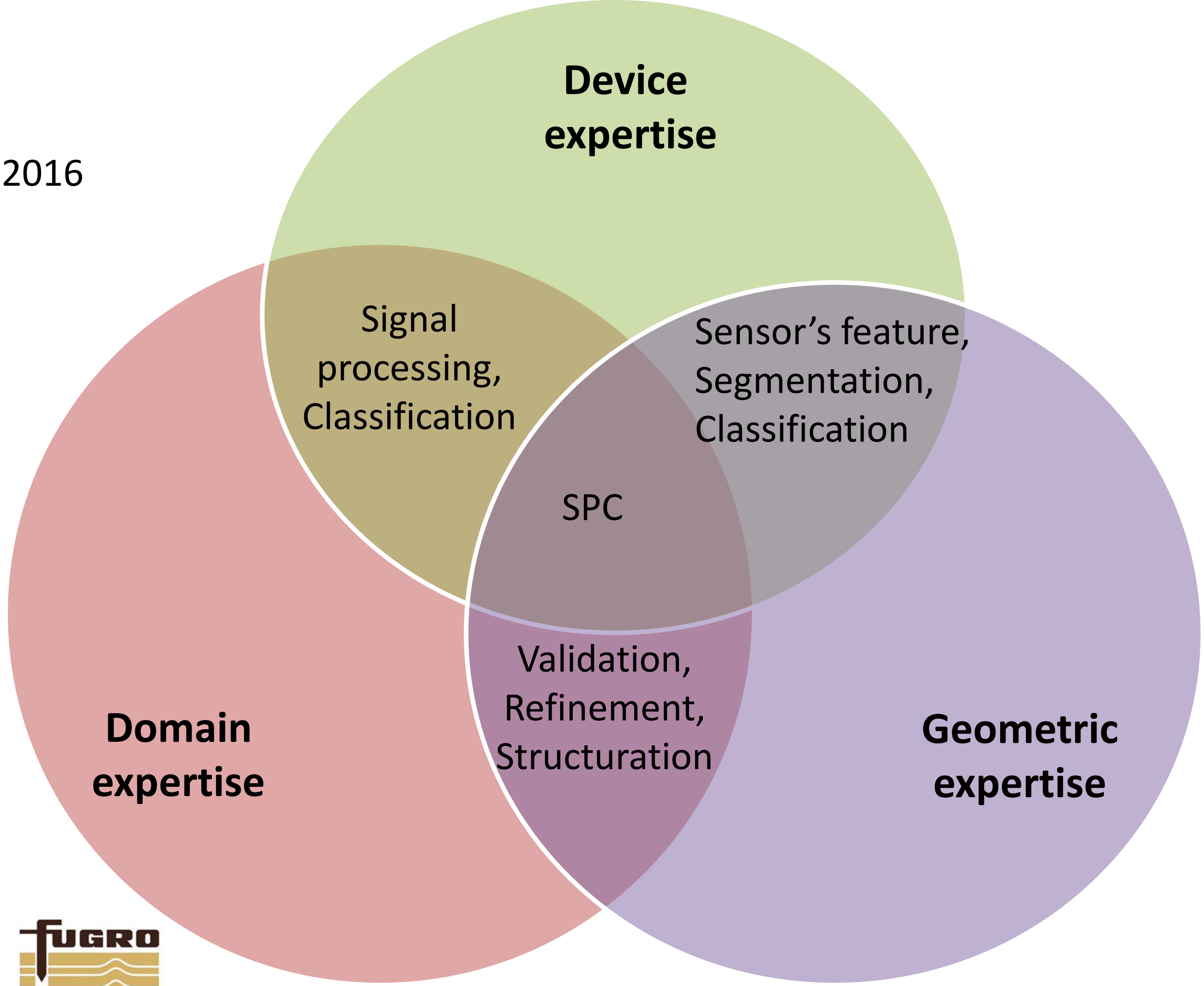
Smart Point Cloud (SPC) Framework

Poux et al., 2016



Device expertise

Domain expertise

Geometric expertise

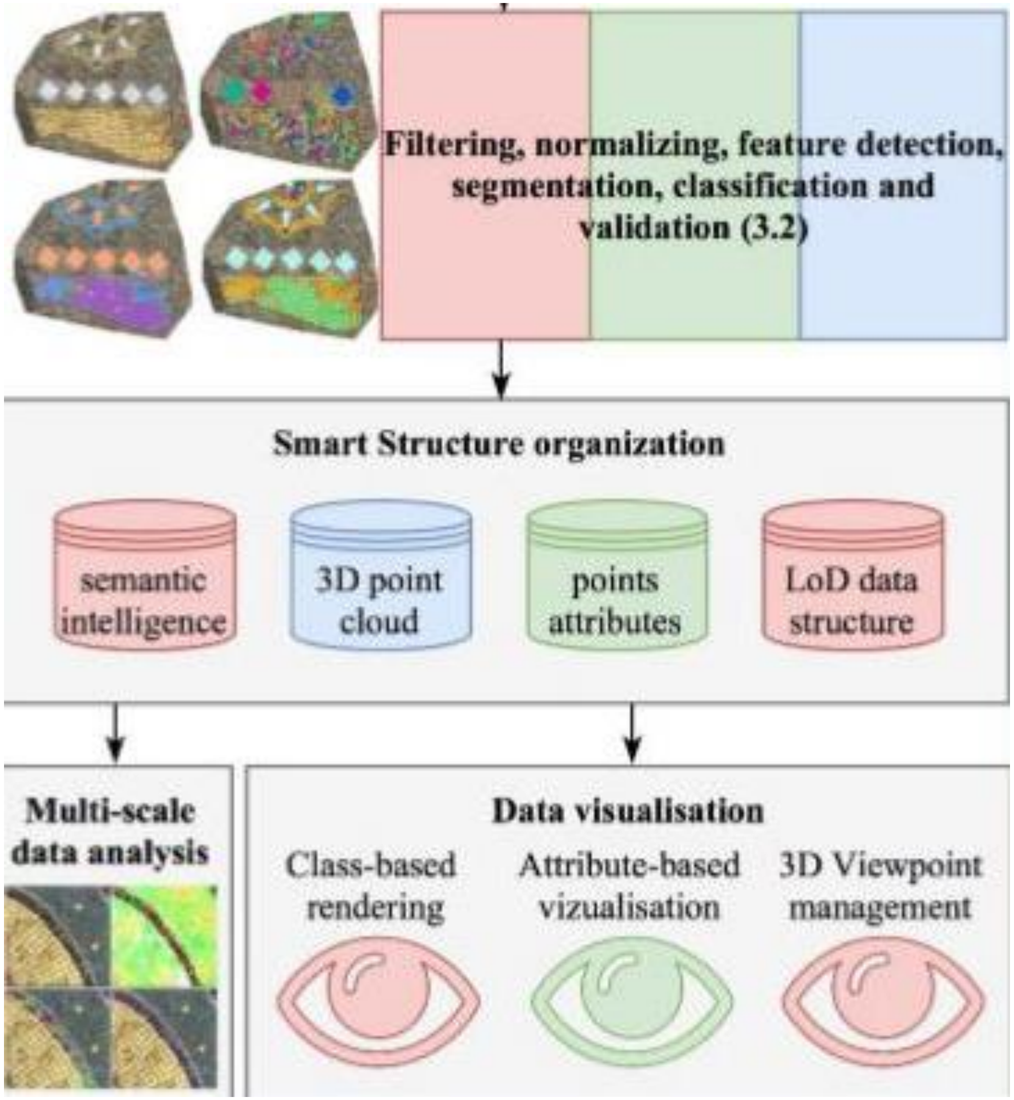
Signal processing, Classification

Sensor's feature, Segmentation, Classification

Validation, Refinement, Structuration

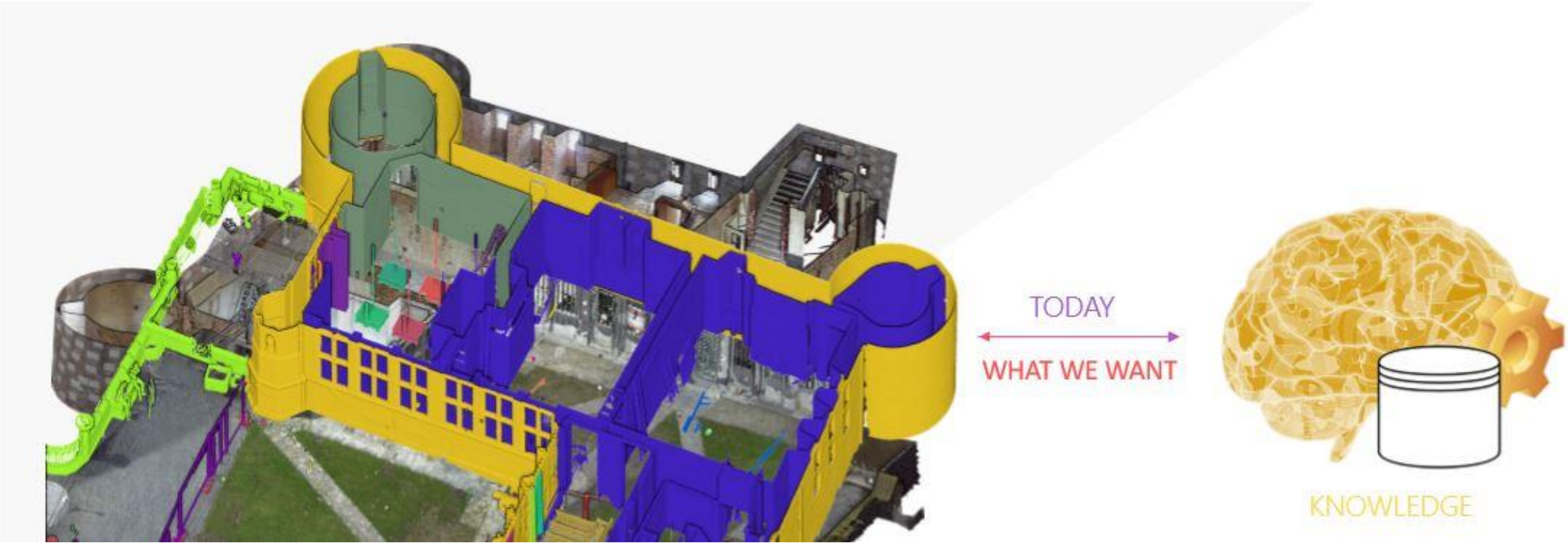
SPC

Related Work-SPC Framework


Filtering, normalizing, feature detection, segmentation, classification and validation (3.2)
Smart Structure organization
semantic intelligence
3D point cloud
points attributes
LoD data structure
Multi-scale data analysis
Data visualisation
Class-based rendering
Attribute-based vizualisation
3D Viewpoint management

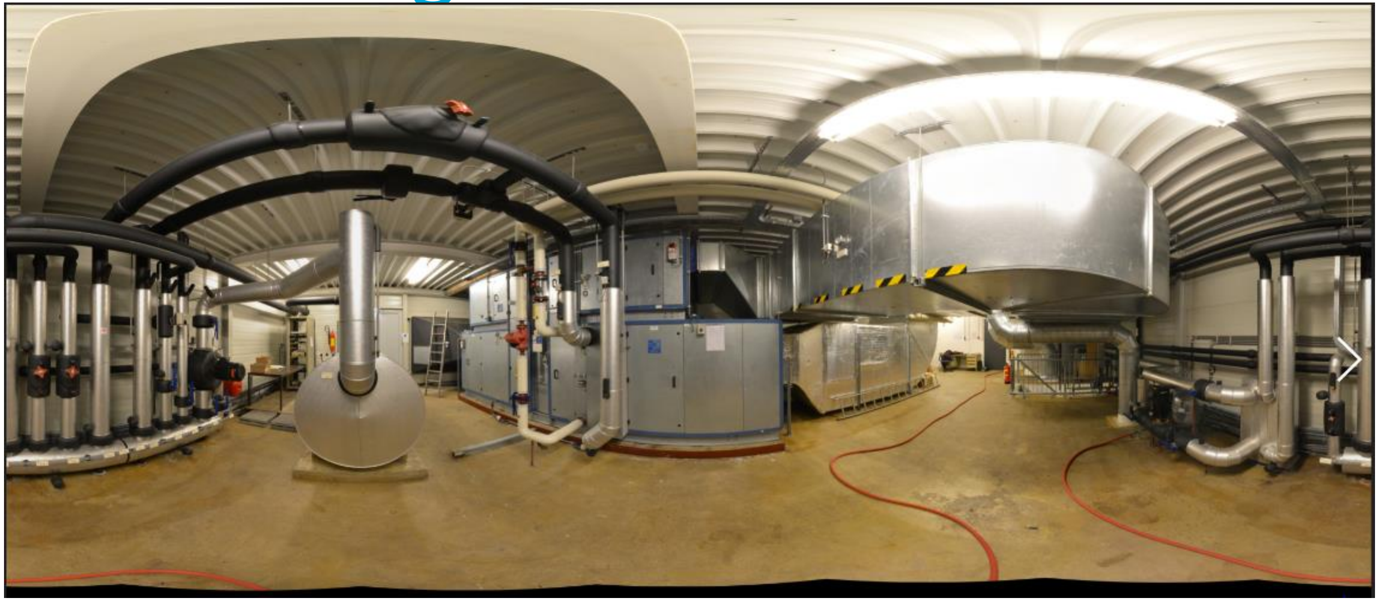
Poux et al., 2017c

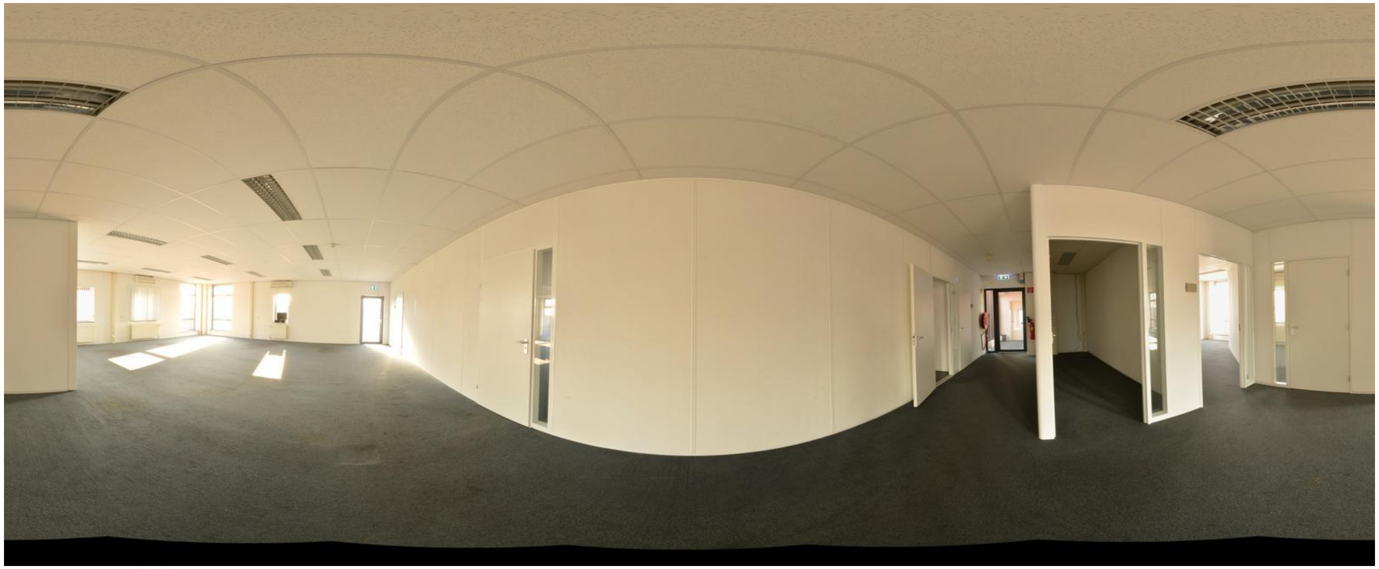
SPC Framework-Objective



Poux et al., 2017b

Panoramic Images



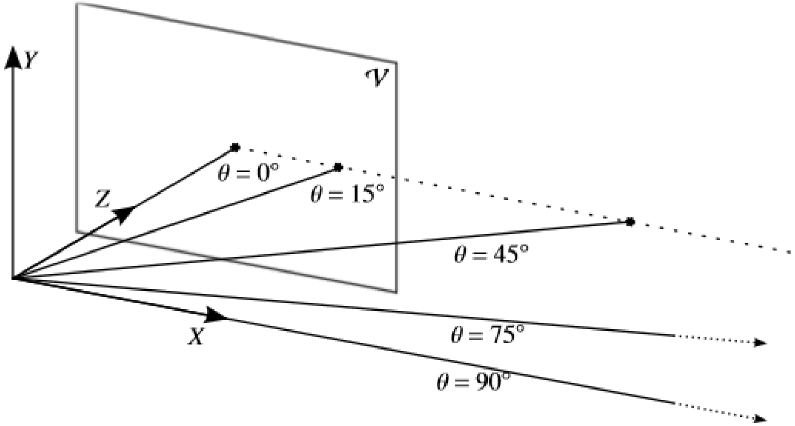


TUDelft FUGRO

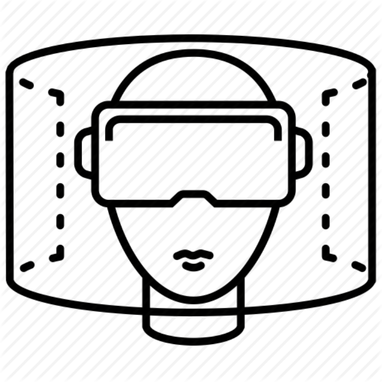
Importance of Panoramas

Replace pair of images

360 field of view



VR/AR with panoramas



Better object detection

Research Question

What is the Smart Point Cloud way to provide a framework for object detection (pipelines), using panoramic images for point cloud creation?

Sub-questions

- What are the **differences** between point clouds that are created using **terrestrial** (close range) **photogrammetry** and **laser scanners**?
- To what extent do the **number** of panoramic images **affect** the generated point cloud in terms of **density** and **accuracy**?
- What is the optimal way for **object detection**, using feature detection and segmentation **techniques on images**, as applicable to **point clouds**?
- What is the best way to **combine domain-geometric-device** knowledge?

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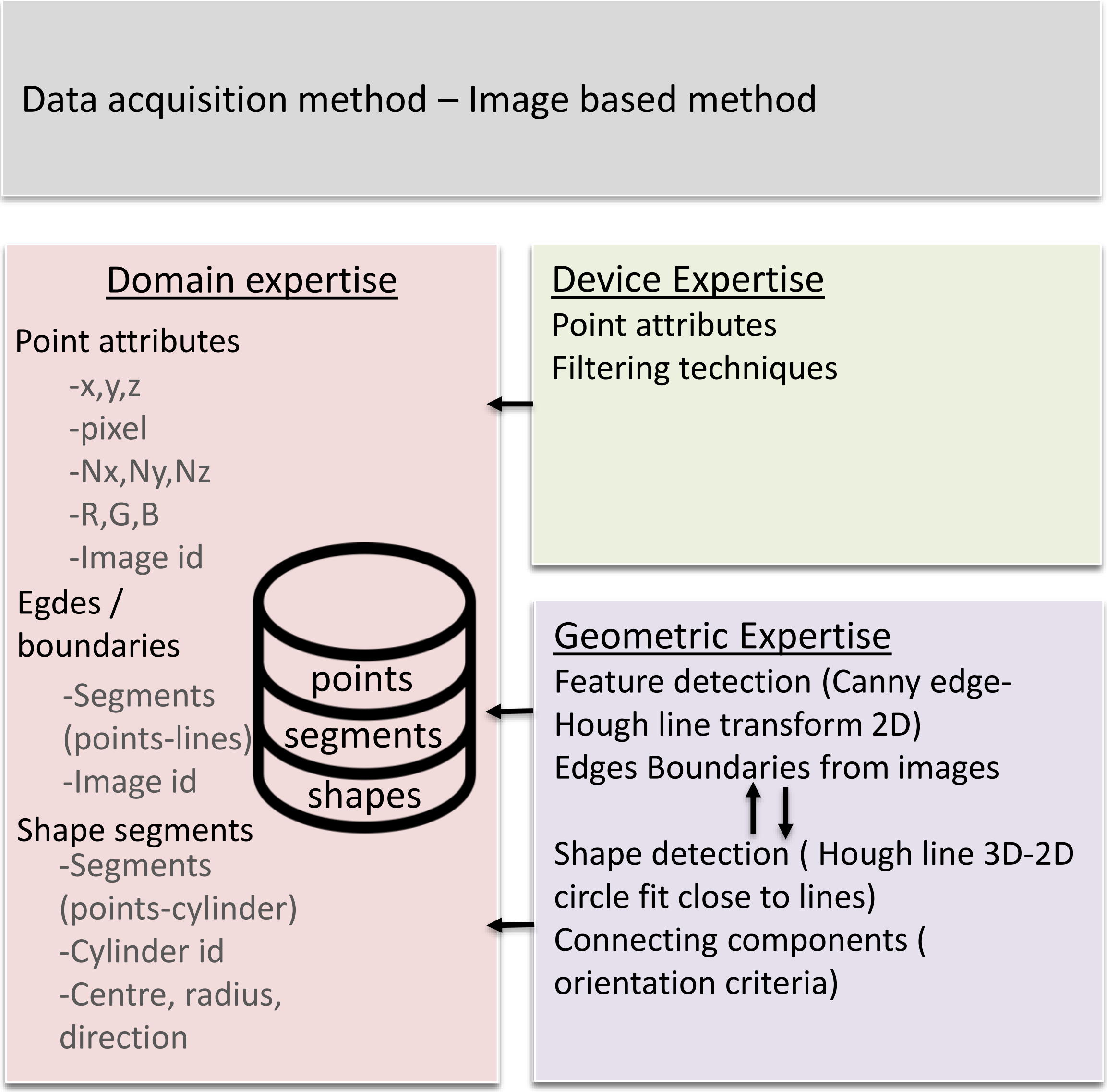
SPC Framework



Data acquisition method – Image based method

Domain expertise

Point attributes

-x,y,z

-pixel

-Nx,Ny,Nz

-R,G,B

-Image id

Egdes / boundaries

-Segments (points-lines)

-Image id

Shape segments

-Segments (points-cylinder)

-Cylinder id

-Centre, radius, direction

Device Expertise

Point attributes

Filtering techniques

Geometric Expertise

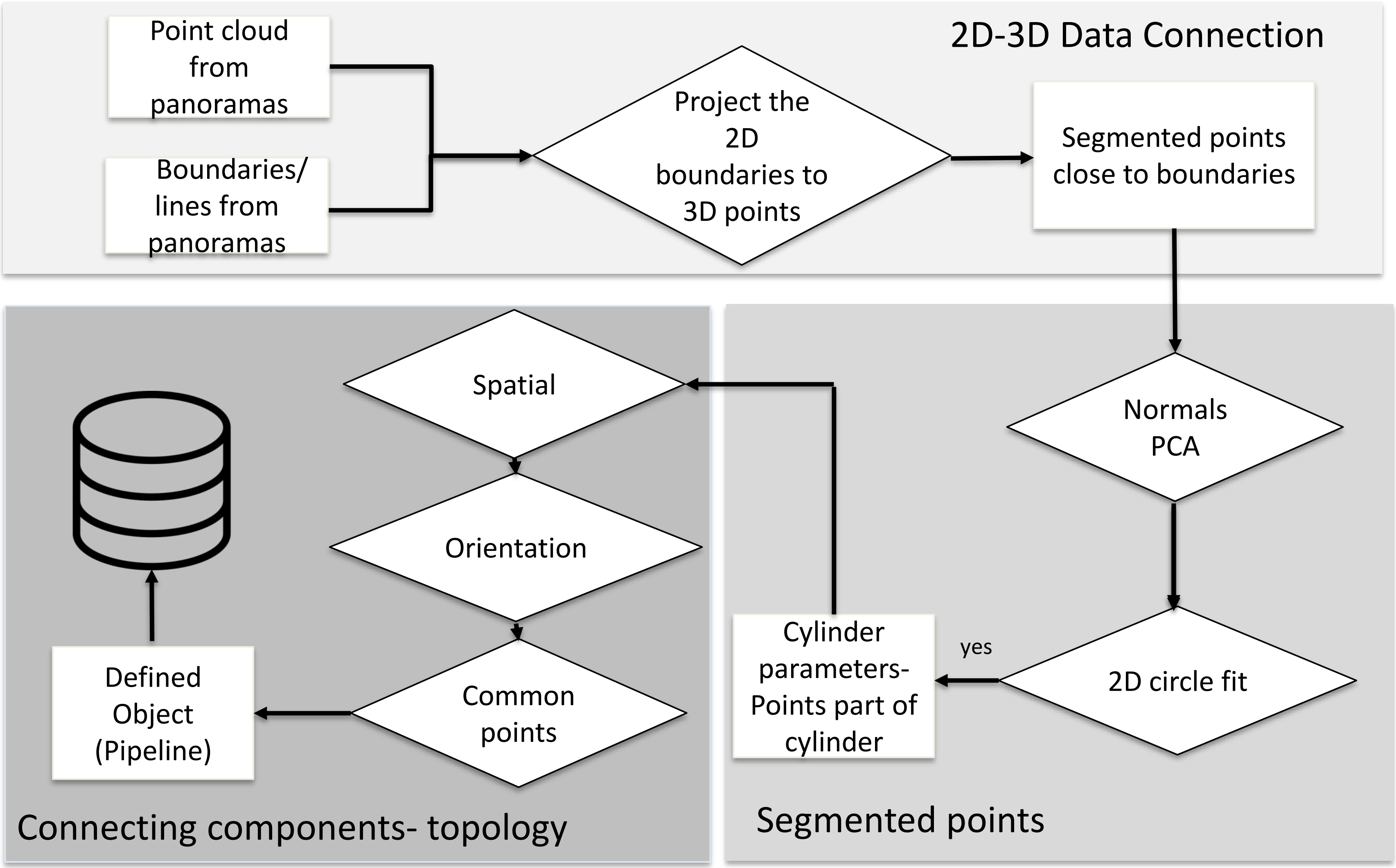
Feature detection (Canny edge-Hough line transform 2D)

Edges Boundaries from images

Shape detection (Hough line 3D-2D circle fit close to lines)

Connecting components (orientation criteria)

Geometric Expertise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Common points
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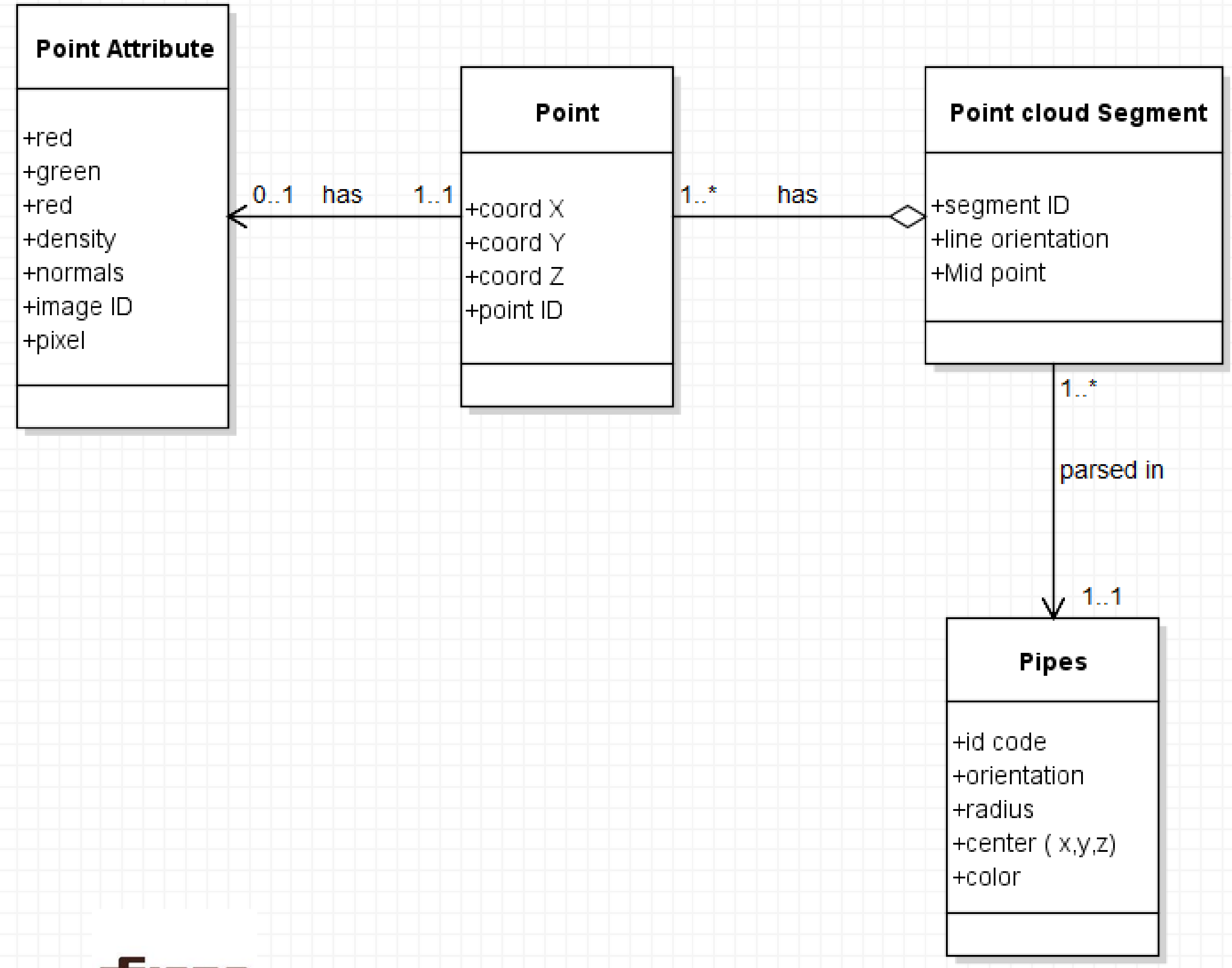
Connecting components- topology

SPC UML Class Diagram



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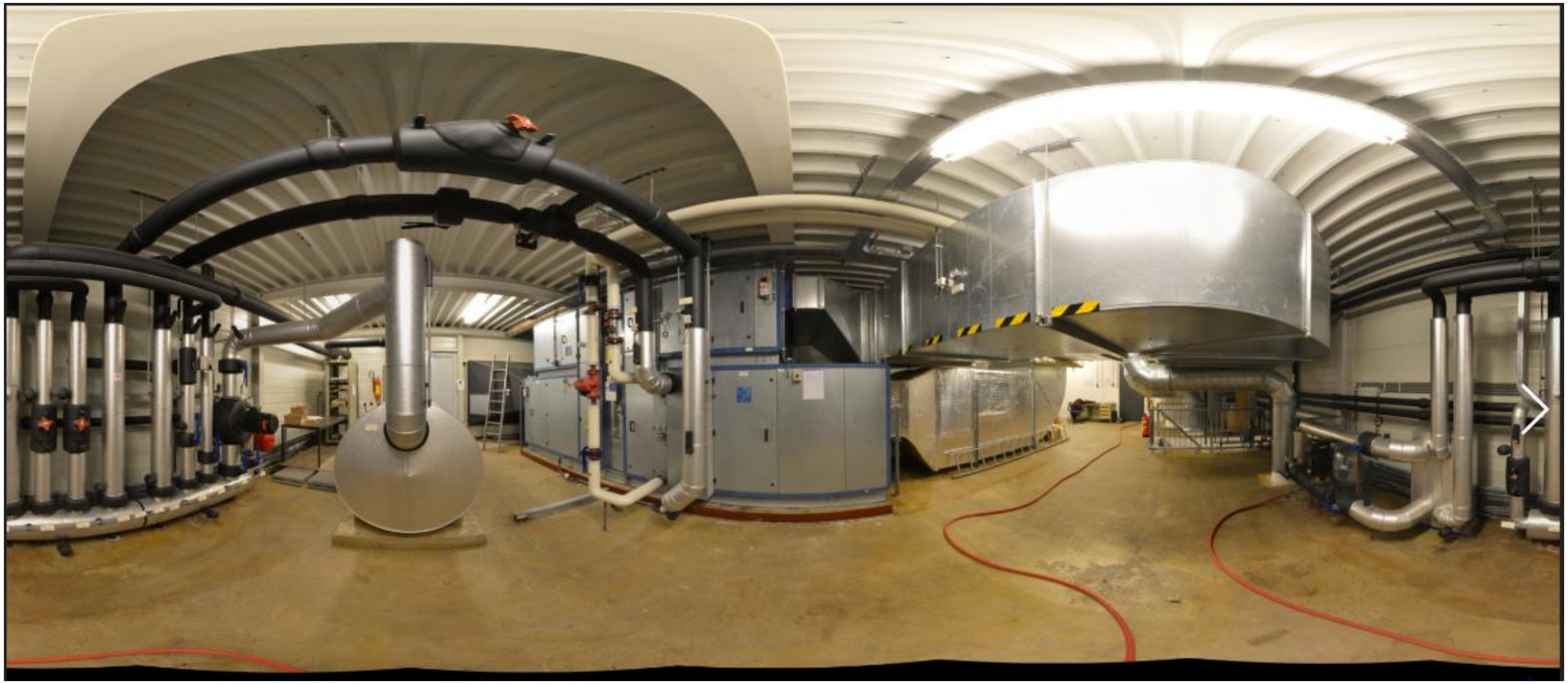
Projection

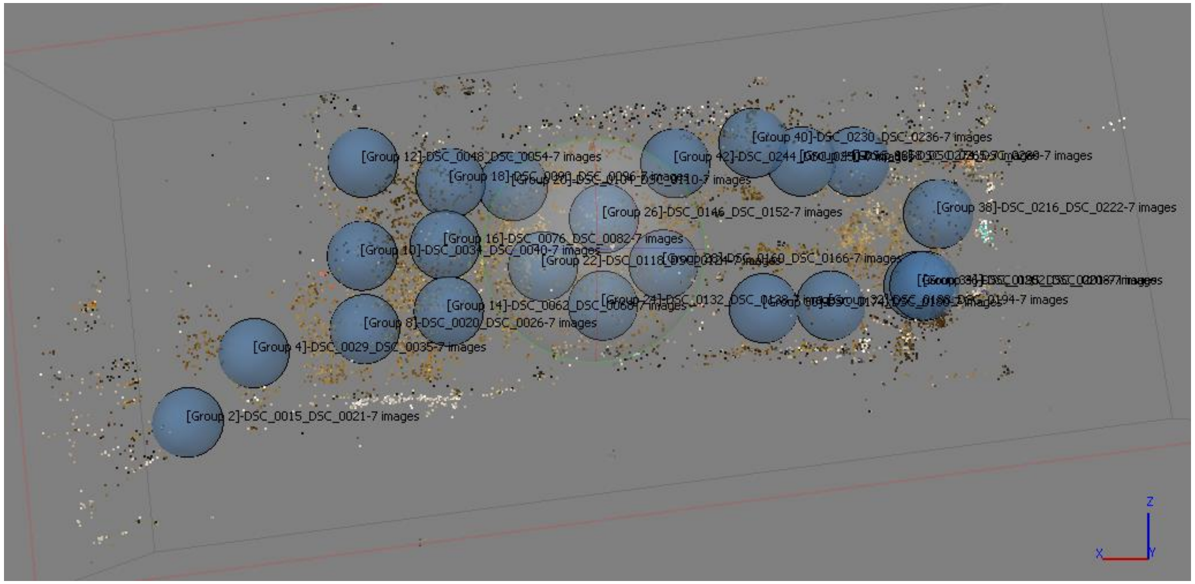
Software

Compare with laser scanner

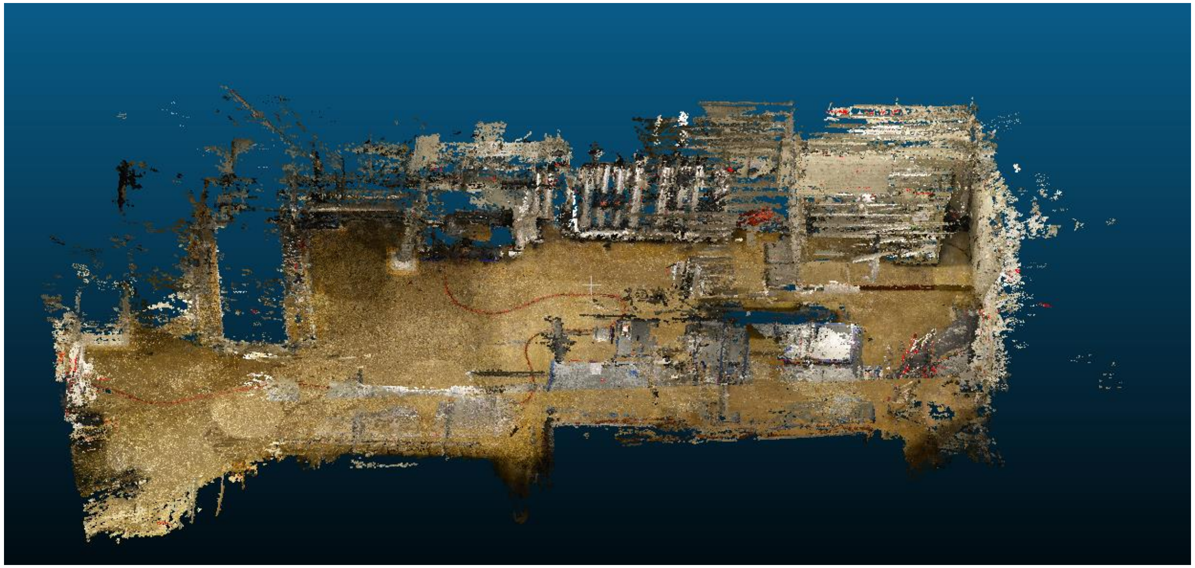
Testing the number of images

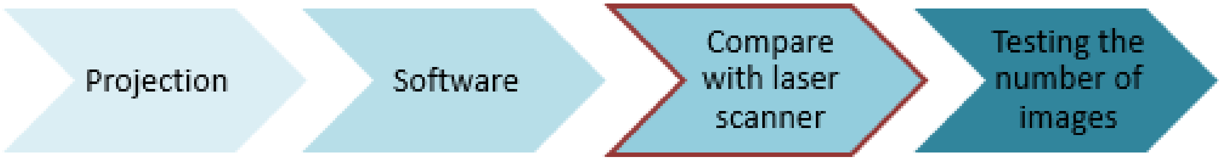


1. Alignment


[Group 40]-DSC_0230_DSC_0236-7 images
[Group 12]-DSC_0048_DSC_0054-7 images
[Group 42]-DSC_0244
[Group 18]-DSC_0090_DSC_0096-7 images
[Group 20]-DSC_0104_DSC_0110-7 images
[Group 26]-DSC_0146_DSC_0152-7 images
[Group 38]-DSC_0216_DSC_0222-7 images
[Group 16]-DSC_0076_DSC_0082-7 images
[Group 10]-DSC_0034_DSC_0040-7 images
[Group 22]-DSC_0118
DSC_0160_DSC_0166-7 images
[Group 14]-DSC_0062_DSC
[Group 8]-DSC_0020_DSC_0026-7 images
[Group 4]-DSC_0029_DSC_0035-7 images
[Group 2]-DSC_0015_DSC_0021-7 images
Z
X
Y

2. Dense point cloud





Projection

Software

Compare with laser scanner

Testing the number of images

Photogrammetry	Laser scanner
Passive sensors → image based	Active sensors → range based
Low cost	Expensive
Portable	Difficulties
Quick in the field	Time consuming
Small areas	Big areas
Color value	No color value
Noisy	Less noisy

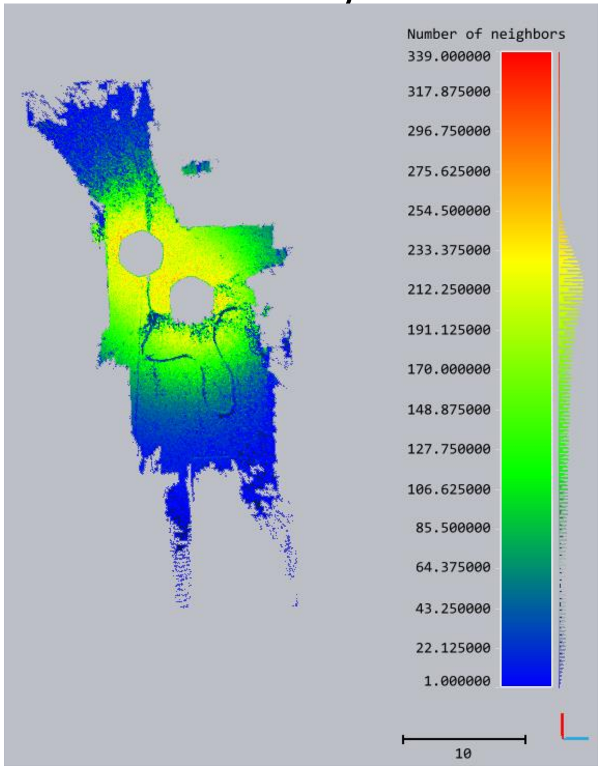
Projection

Software

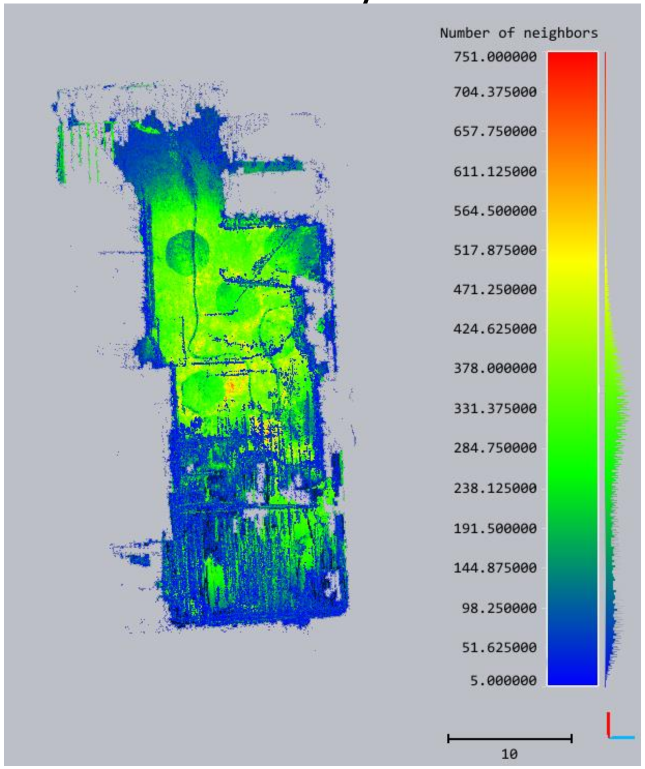
Compare with laser scanner

Testing the number of images

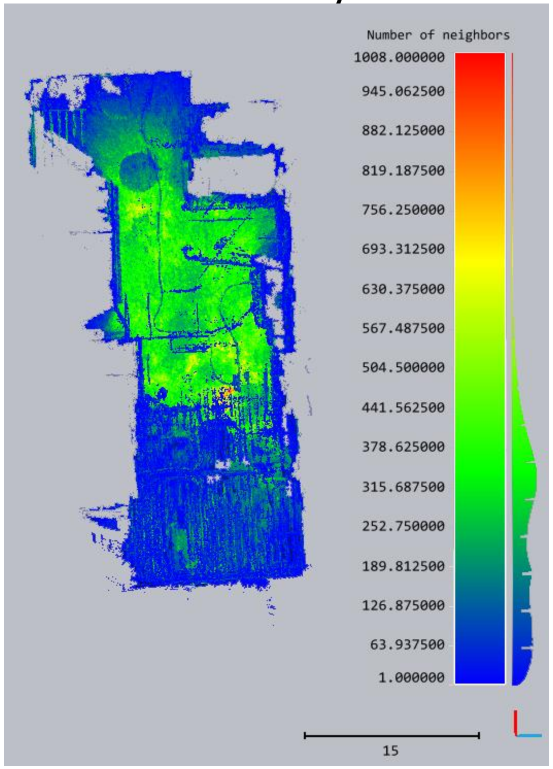
5 panoramas/339 max density



10 panoramas/751 max density

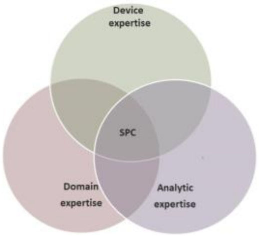


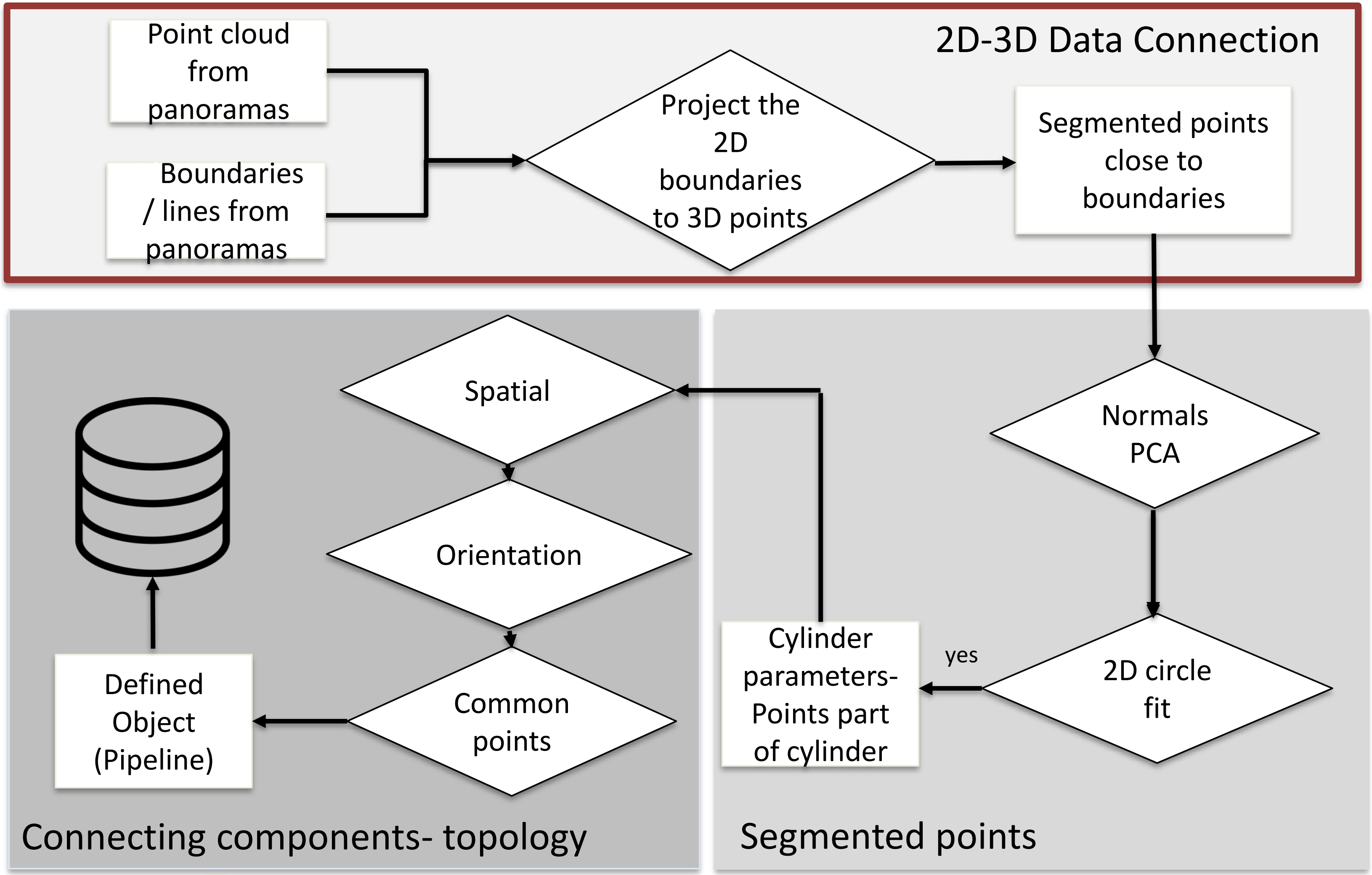
23 panoramas/1008 max density



6 133 607 points	25 619 925 points	40 011 520 points

SPC Geometric Expertise





2D-3D Data Connection

Point cloud from panoramas

Boundaries / lines from panoramas

Project the 2D boundaries to 3D points

Segmented points close to boundaries

Segmented points

Normals PCA

2D circle fit

yes

Cylinder parameters- Points part of cylinder

Connecting components- topology

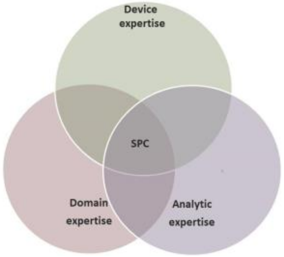
Spatial

Orientation

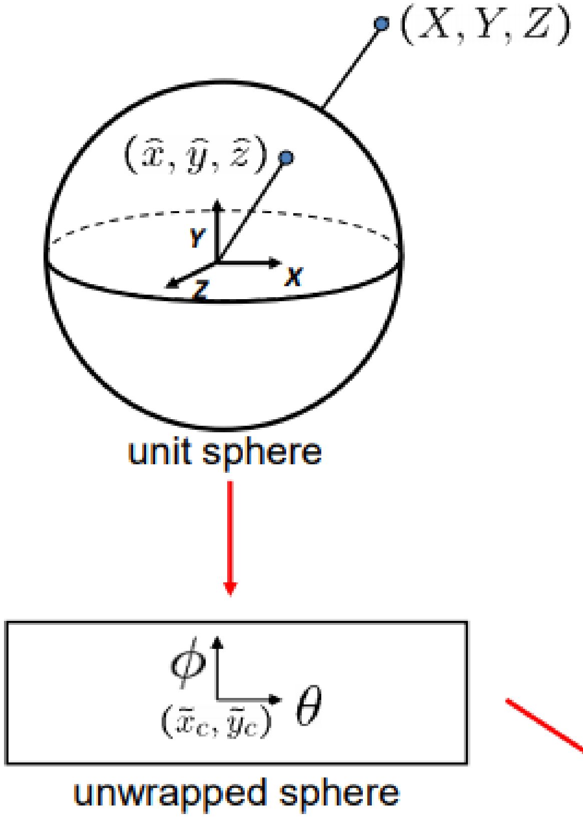
Common points

Defined Object (Pipeline)

Projection 3D Points-Pixels



- 3D coordinates → Spherical → Image coordinates (2D)



- Map 3D point (X,Y,Z) onto sphere

$$(\hat{x},\hat{y},\hat{z}) = \frac{1}{\sqrt{X^2+Y^2+Z^2}}(X,Y,Z)$$

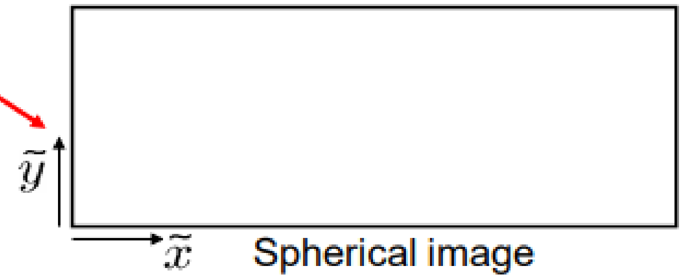
- Convert to spherical coordinates

$$(sin\theta cos\phi, sin\phi, cos\theta cos\phi) = (\hat{x},\hat{y},\hat{z})$$

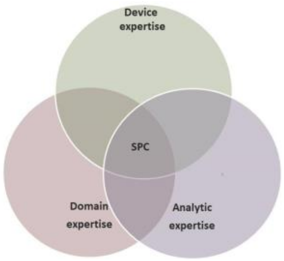
- Convert to spherical image coordinates

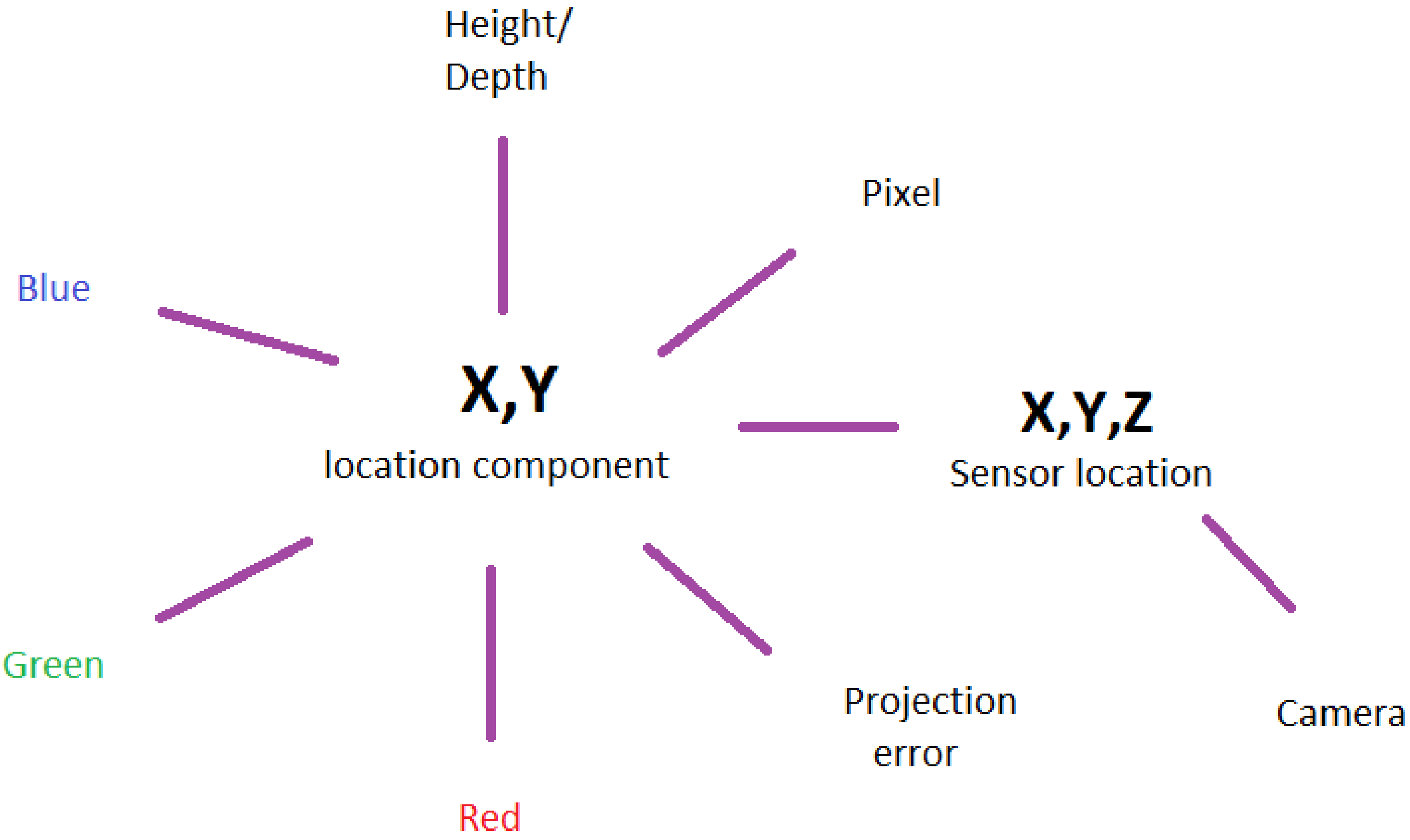
$$(\tilde{x},\tilde{y}) = (s\theta, s\phi) + (\tilde{x}_c,\tilde{y}_c)$$

  - s defines size of the final image
    - » often convenient to set s = camera focal length in pixels



Point attributes





Height/ Depth

Pixel

Blue

X,Y

location component

X,Y,Z

Sensor location

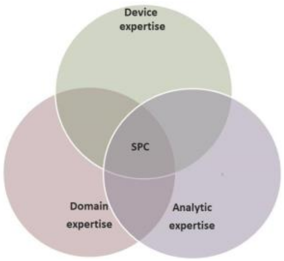
Green

Red

Projection error

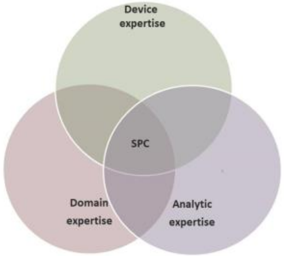
Camera

Image Processing-Canny Detection



1. Filter image with x,y derivatives of Gaussian
2. Find magnitude and orientation of gradient
3. Non-maximum suppression
4. Threshold and linking (hysteresis):
    - Define two thresholds: low and high
    - Use the high threshold to start the edge and the low to continue

Image Processing-Canny Detection



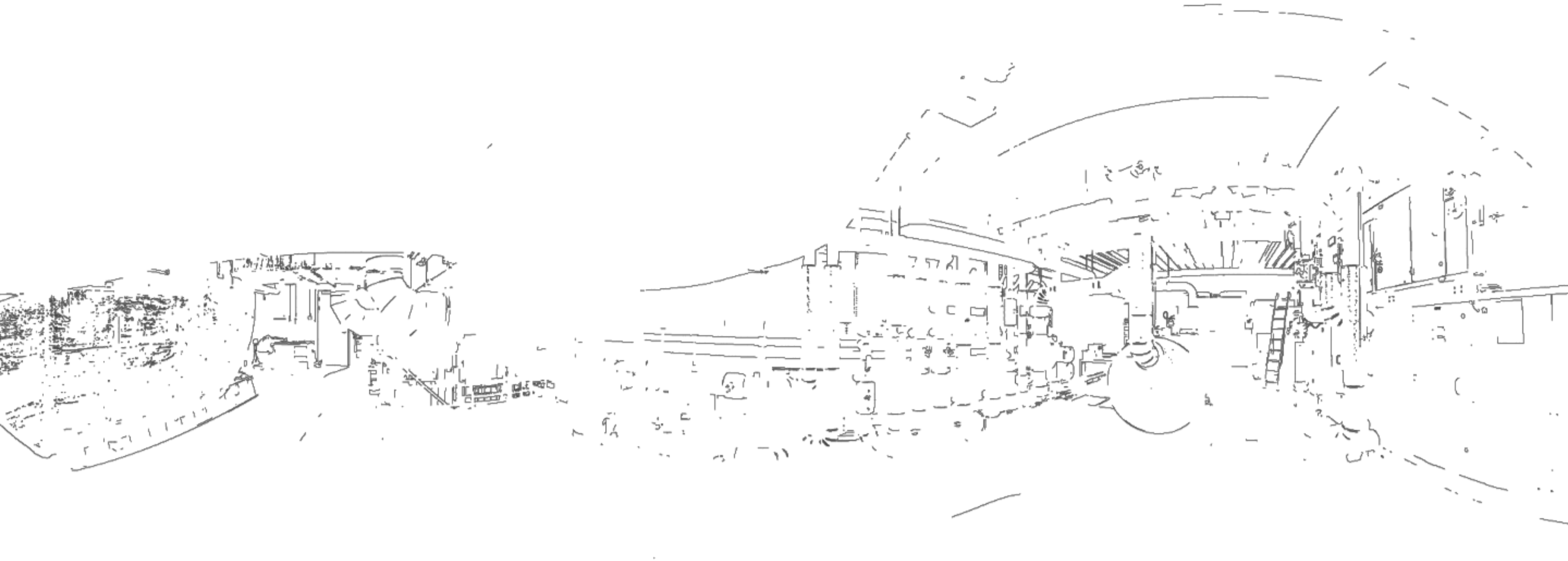
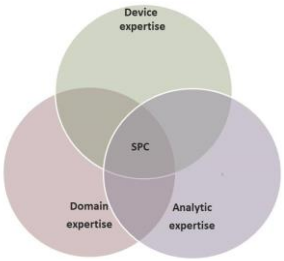


Image Processing –
Hough Line Transform



Voting technique in parameter space

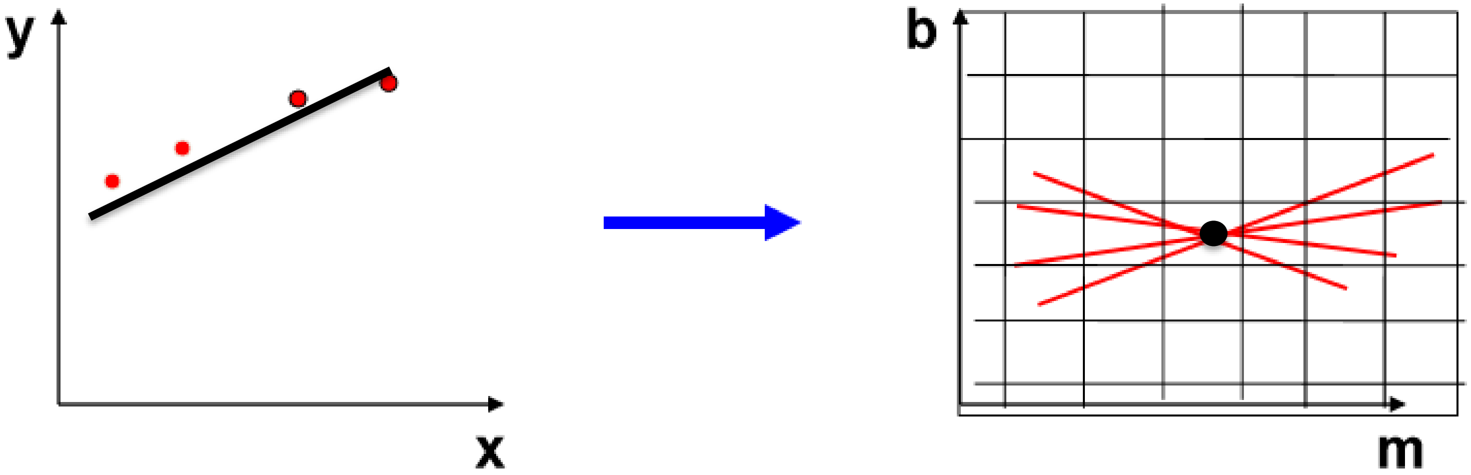
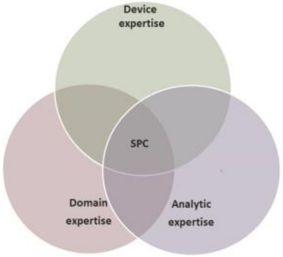
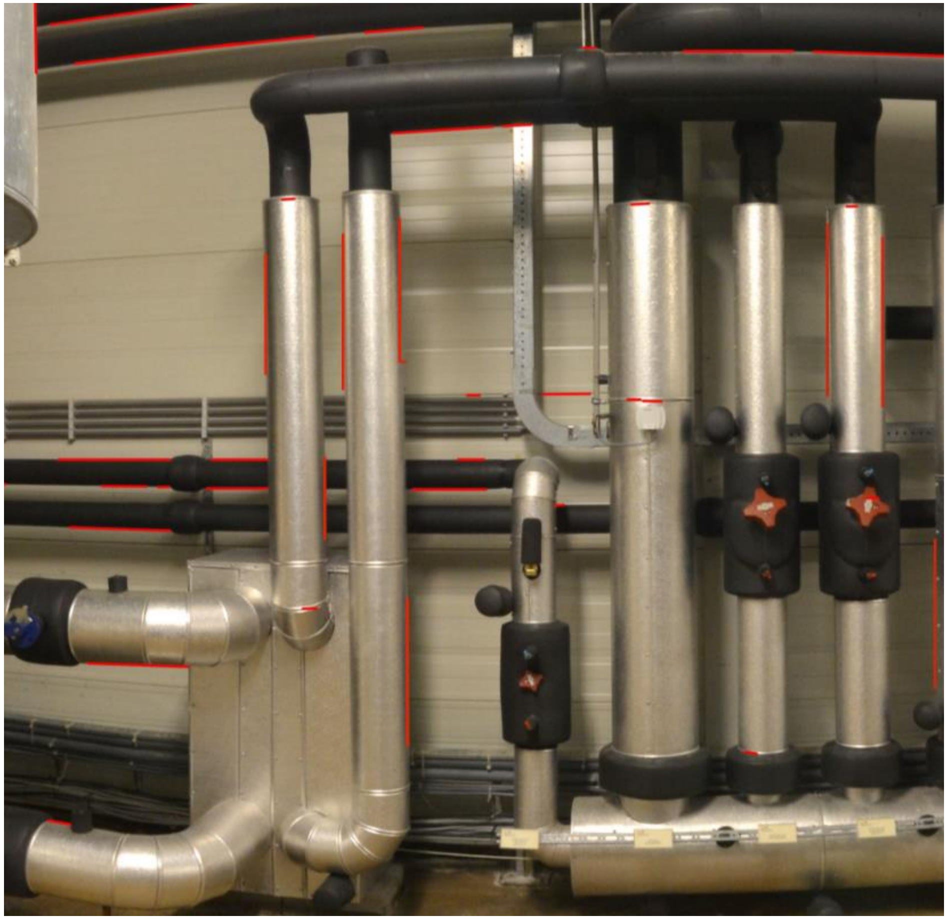


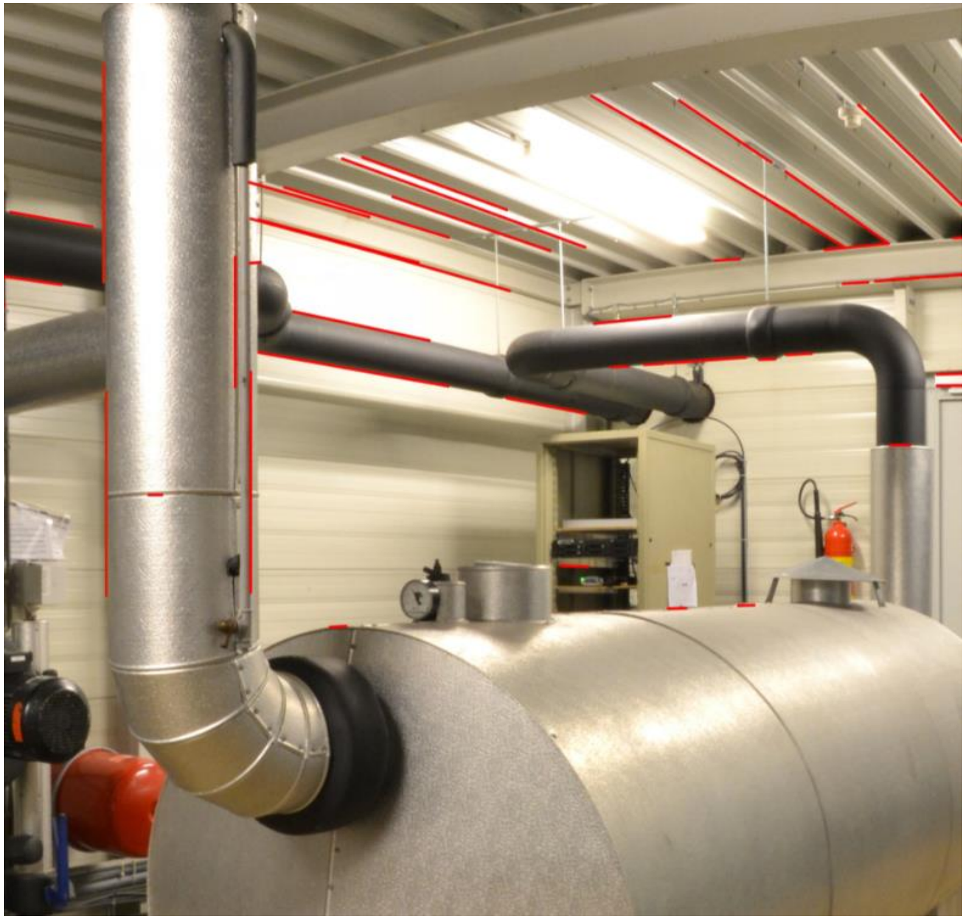
Image space

Hough (parameter) space

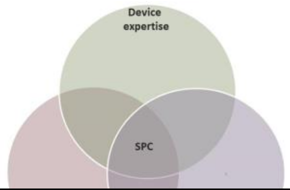
Image Processing – Hough Line Transform

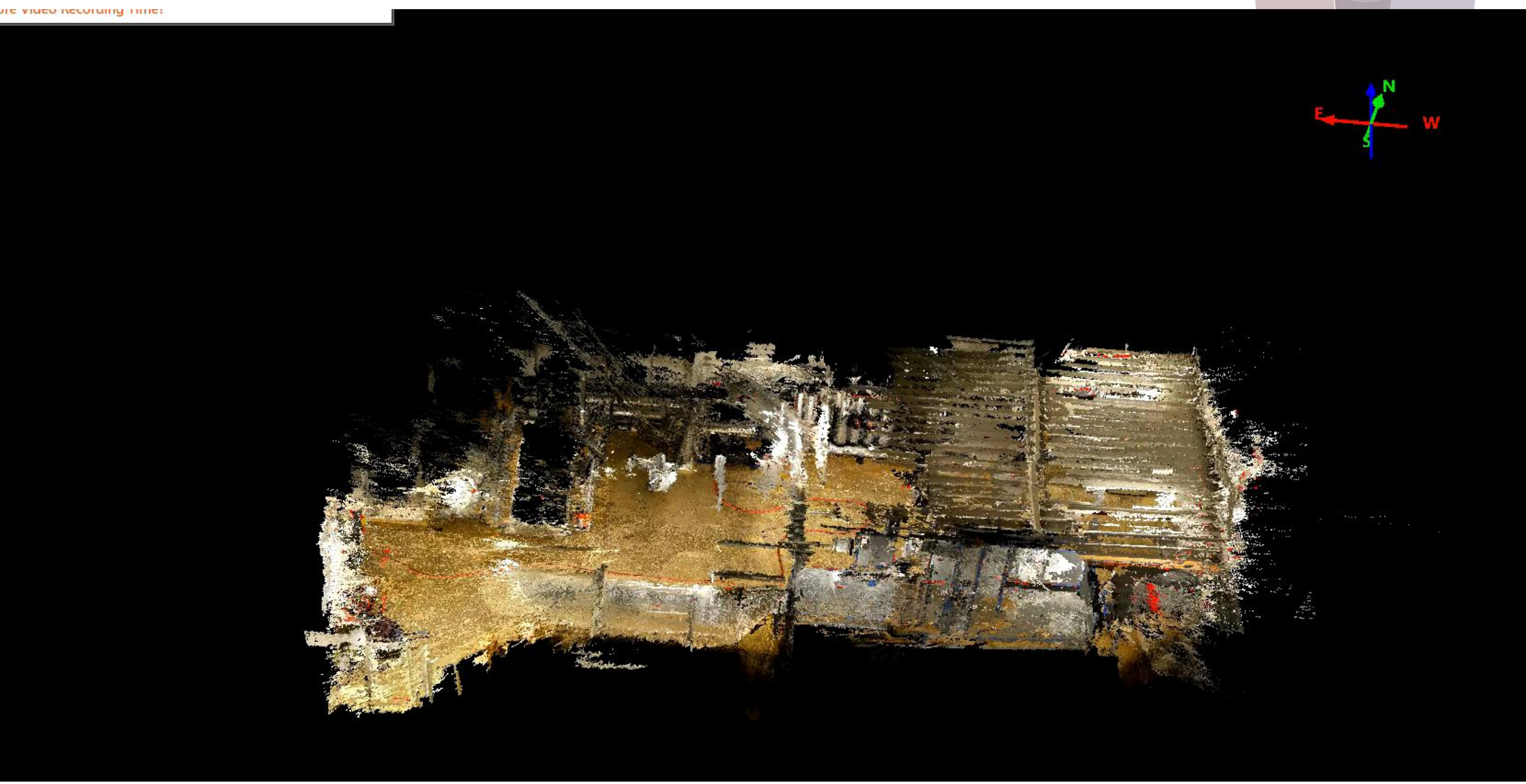






Point Cloud Generation





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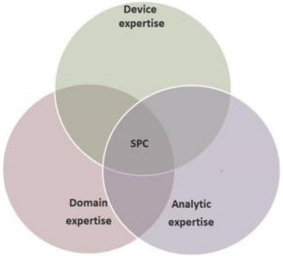
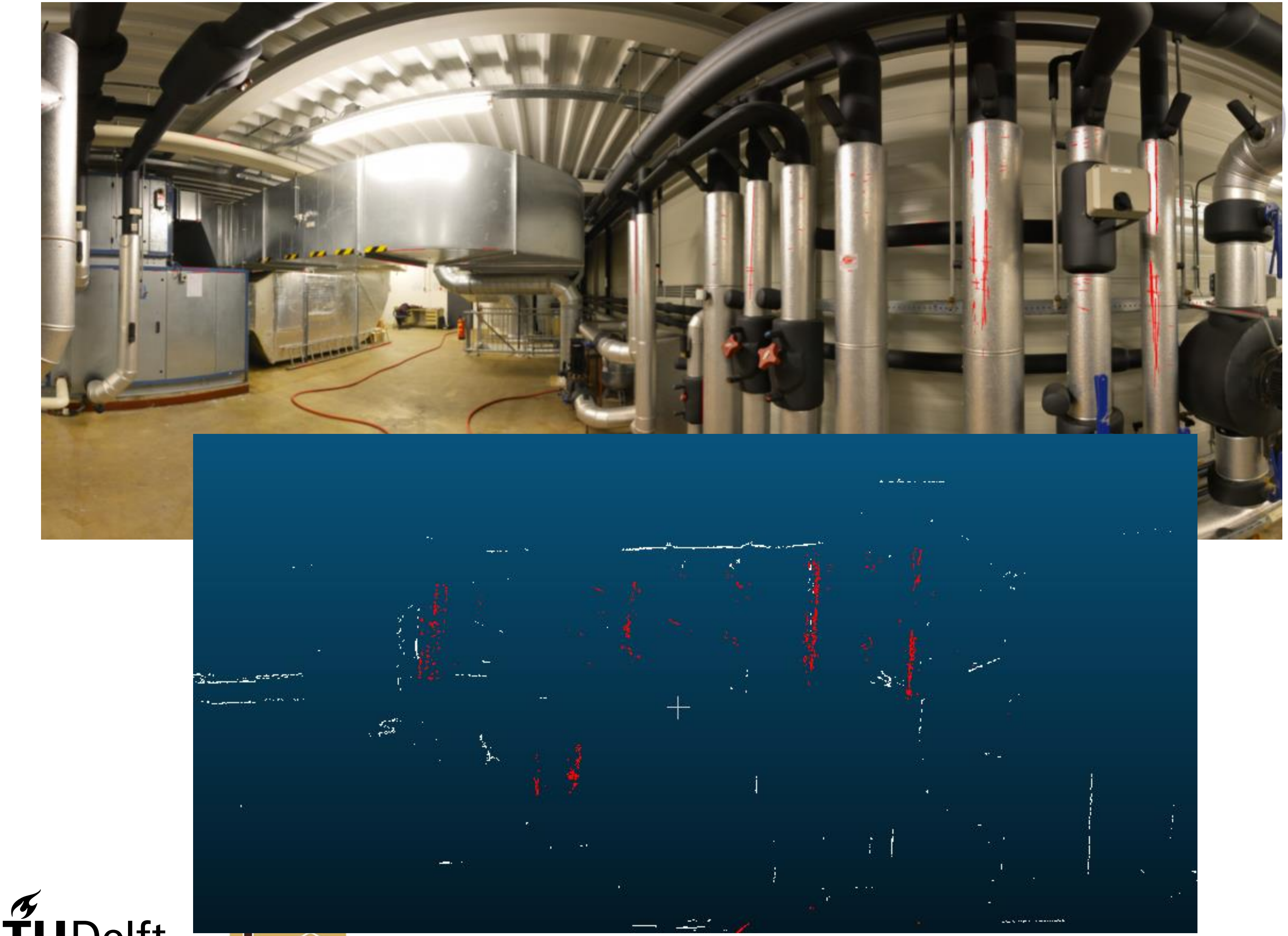
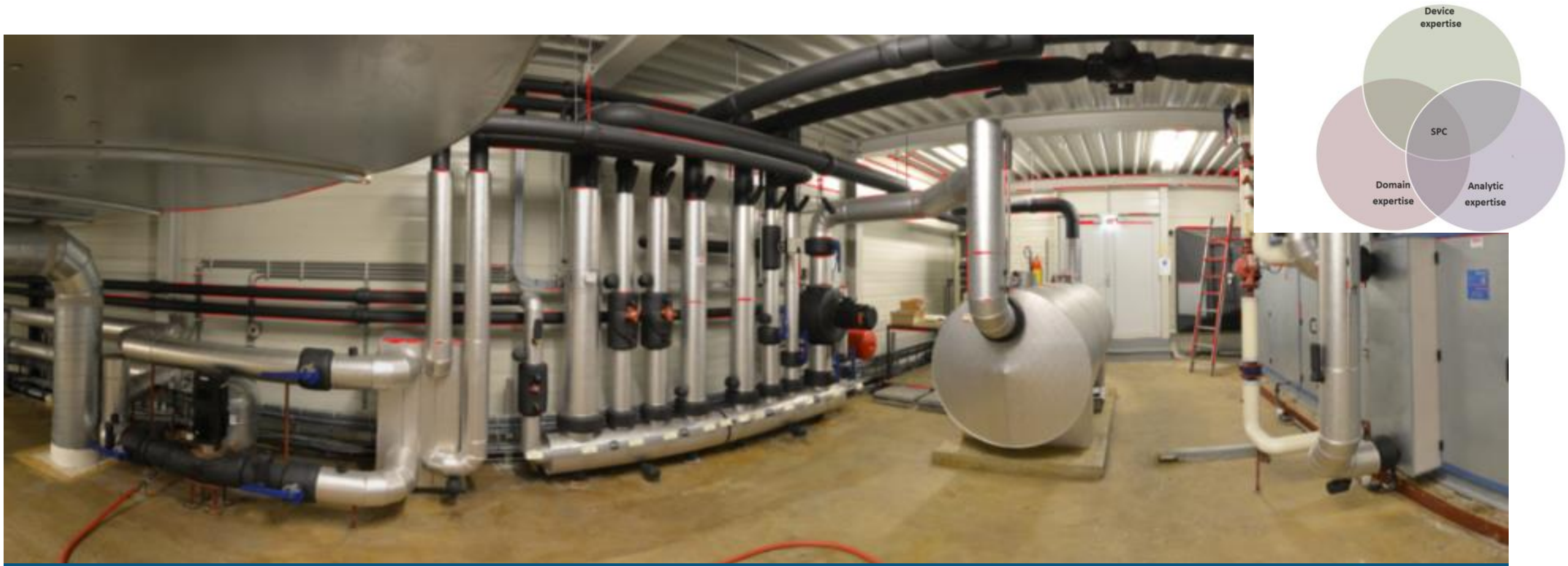
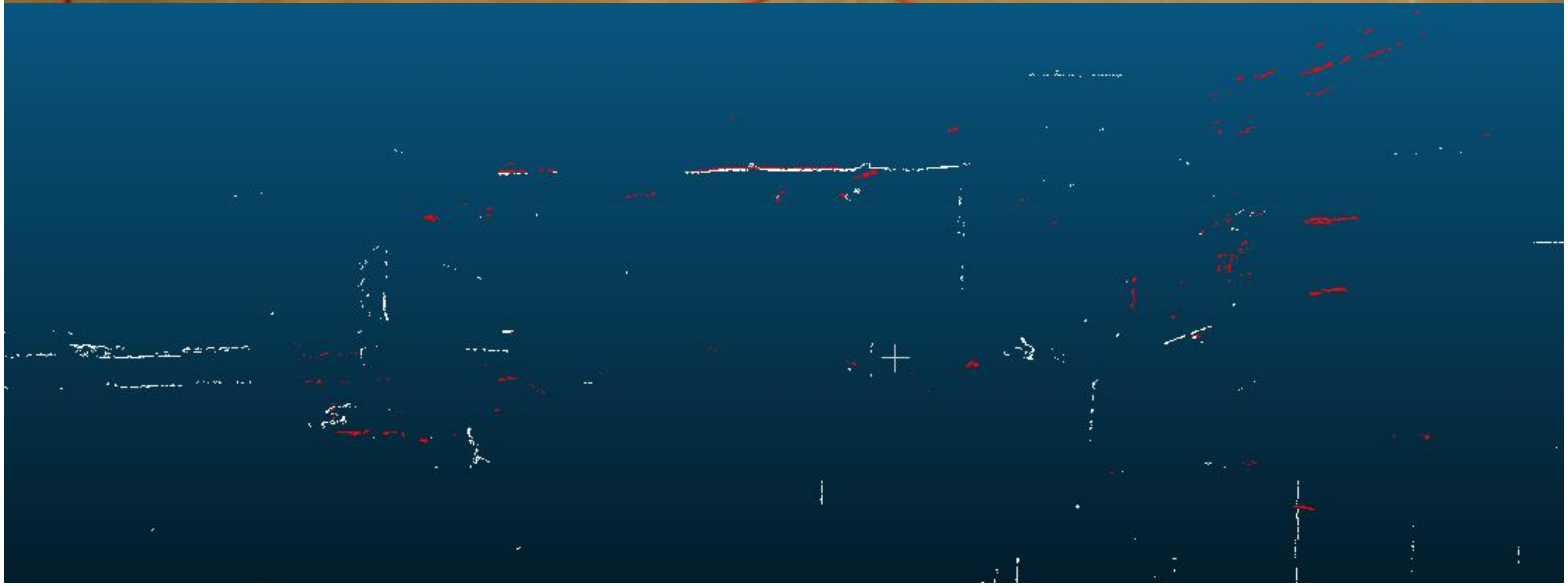
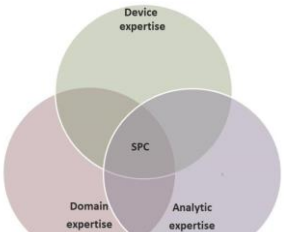


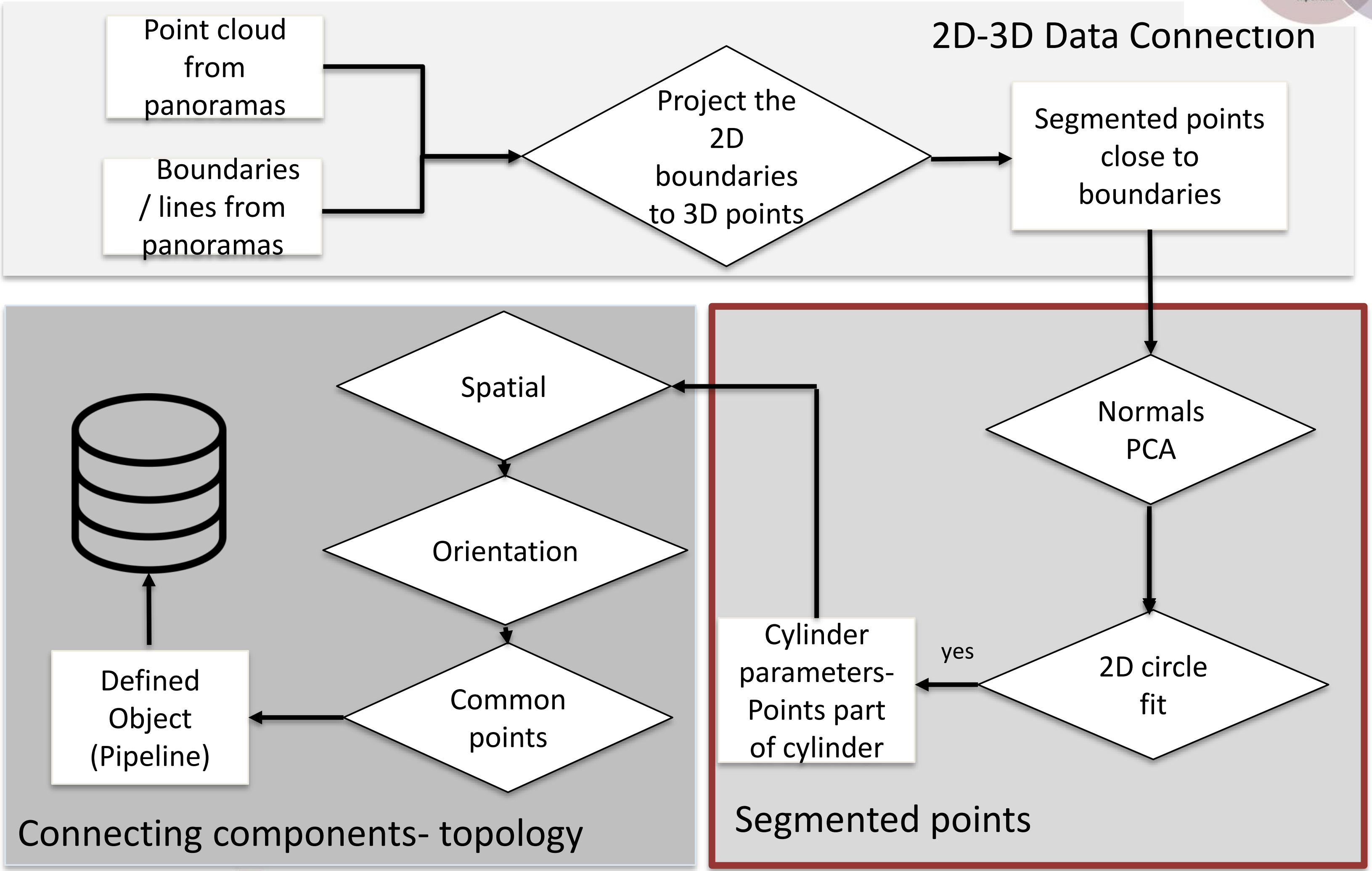



Device expertise
SPC
Domain expertise
Analytic expertise



Geometric Expertise

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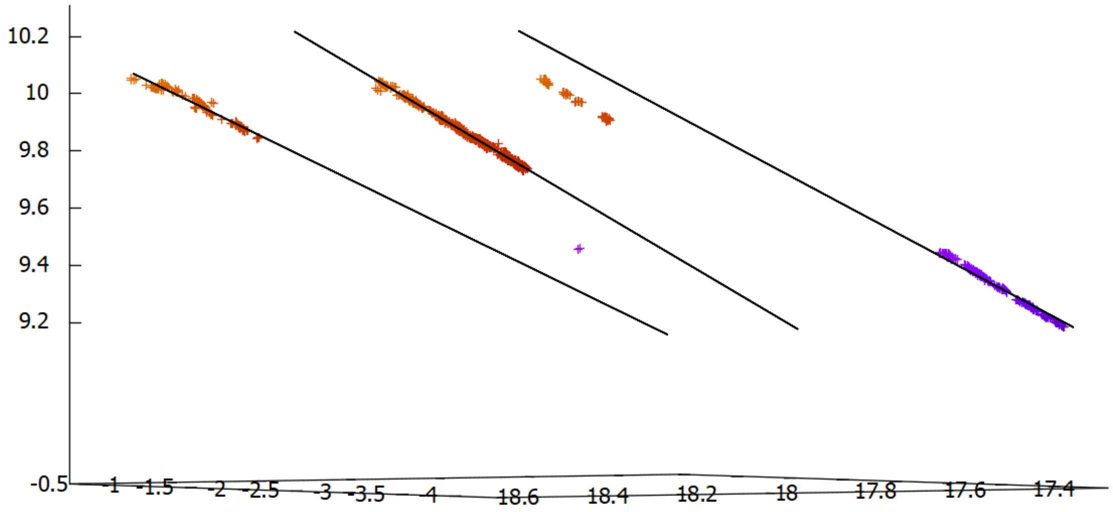
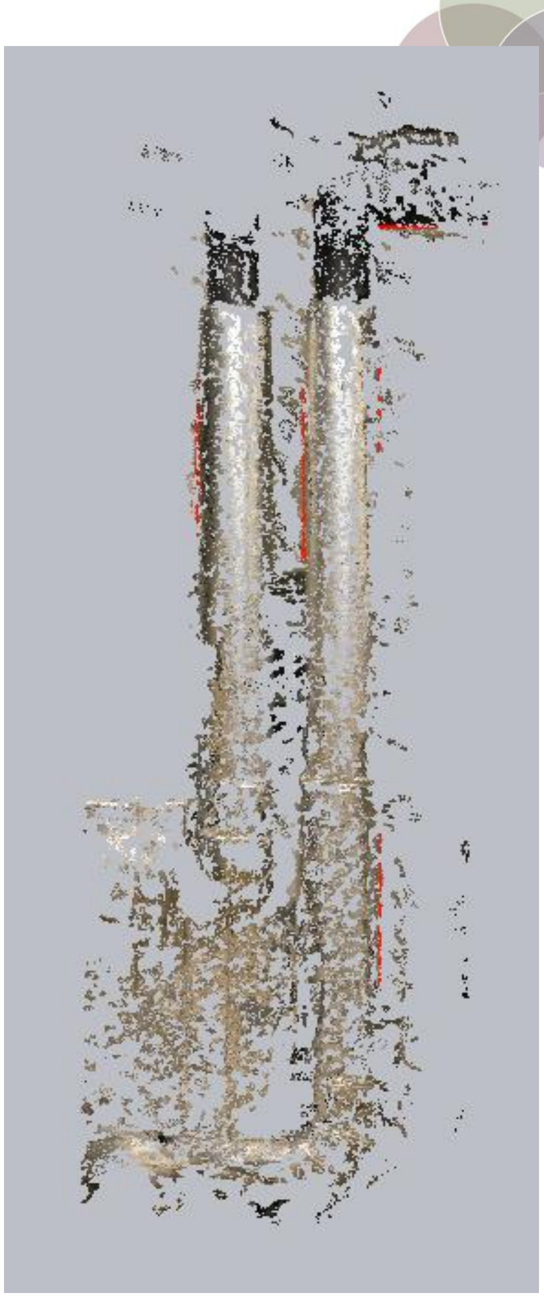
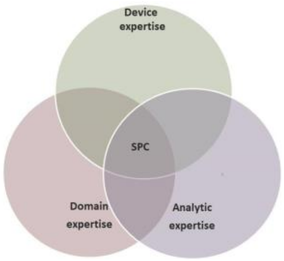
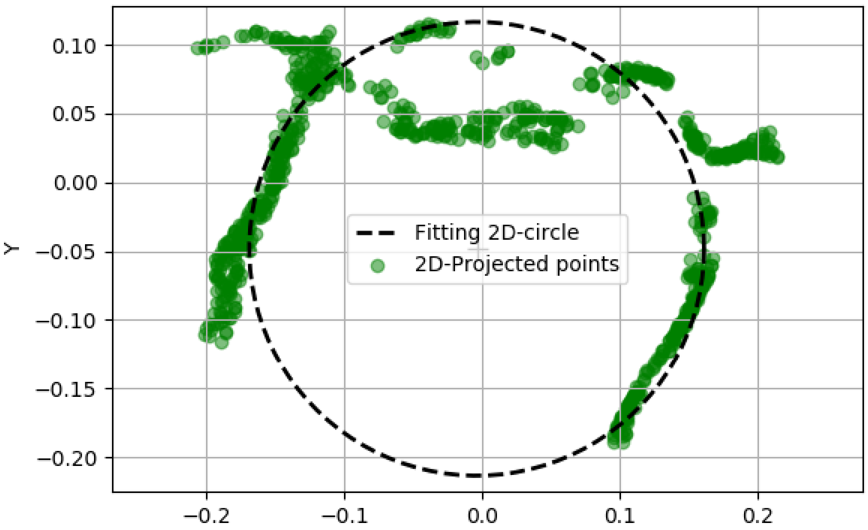
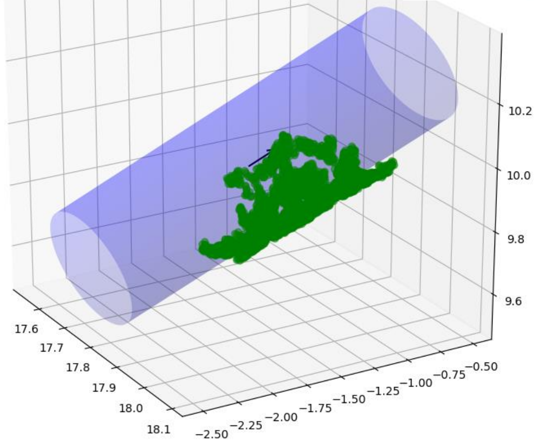


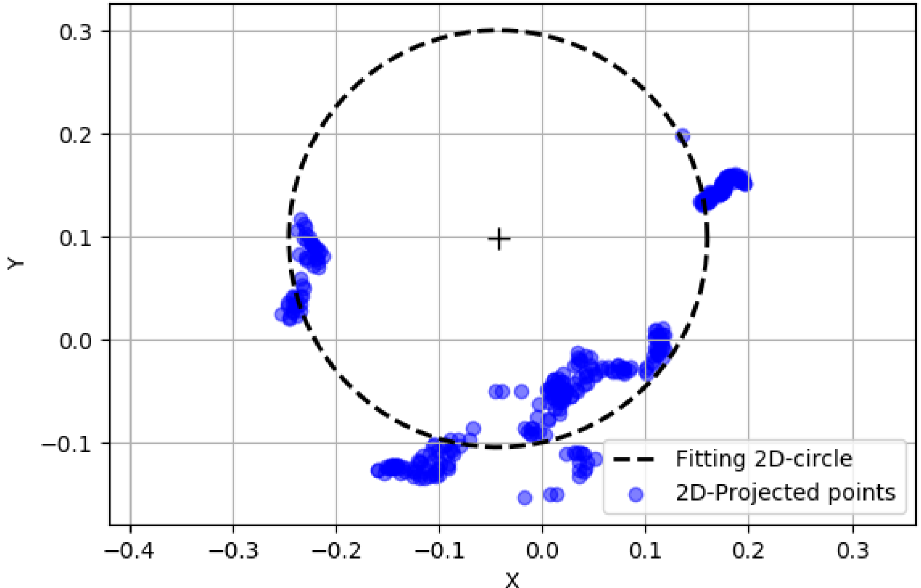


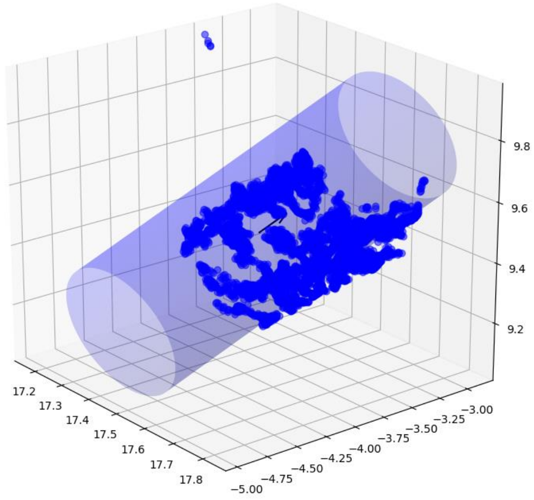


2D Circle Fit









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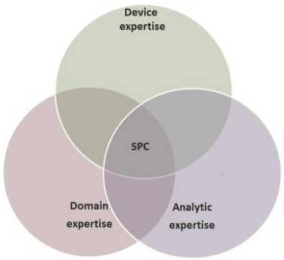
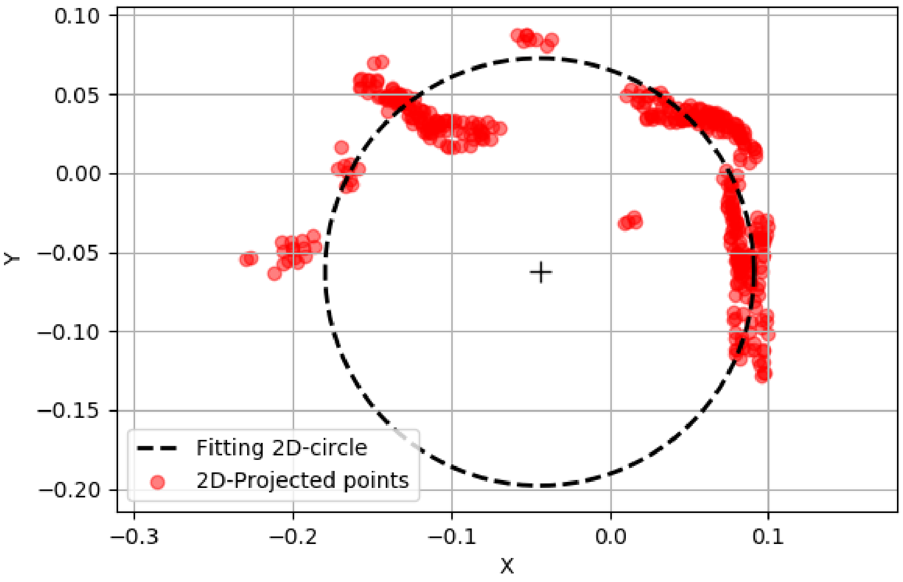
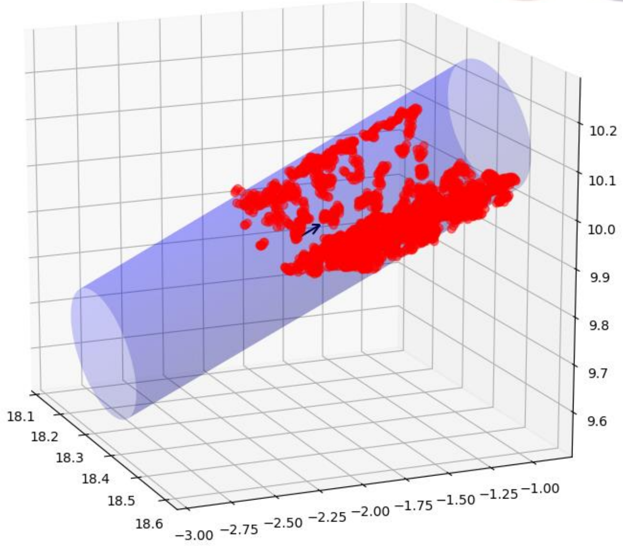
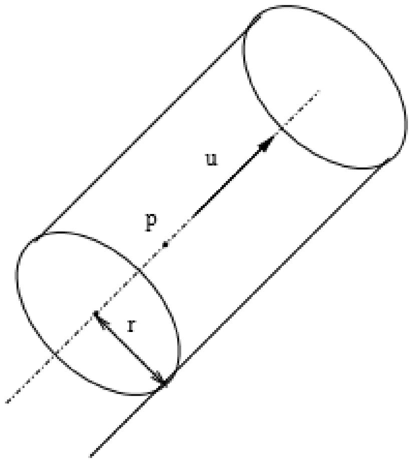
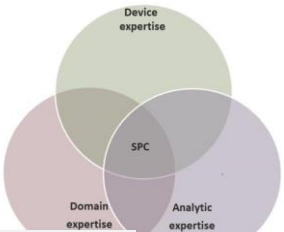


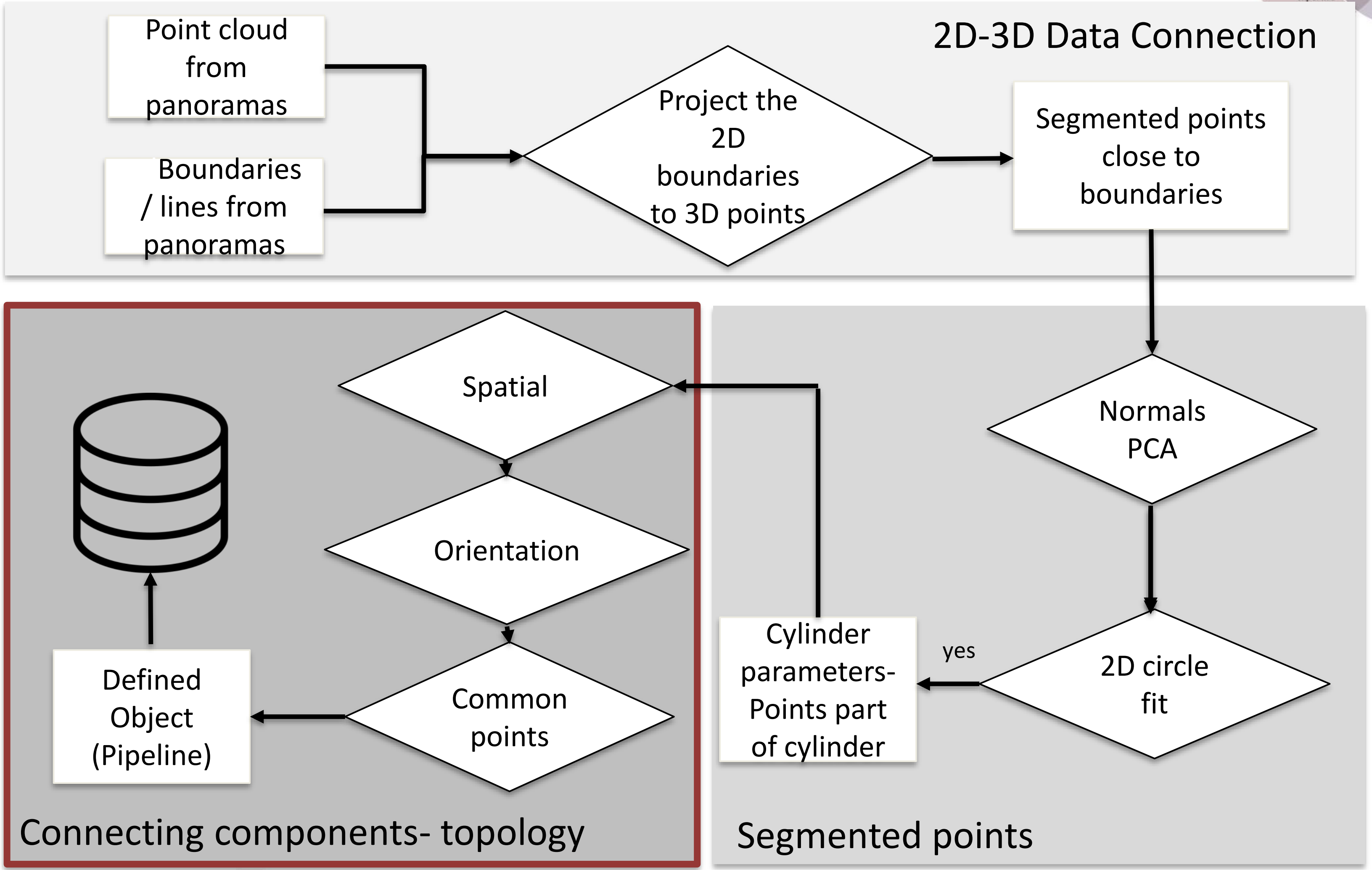






SPC Methodology





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Orientation

Common points

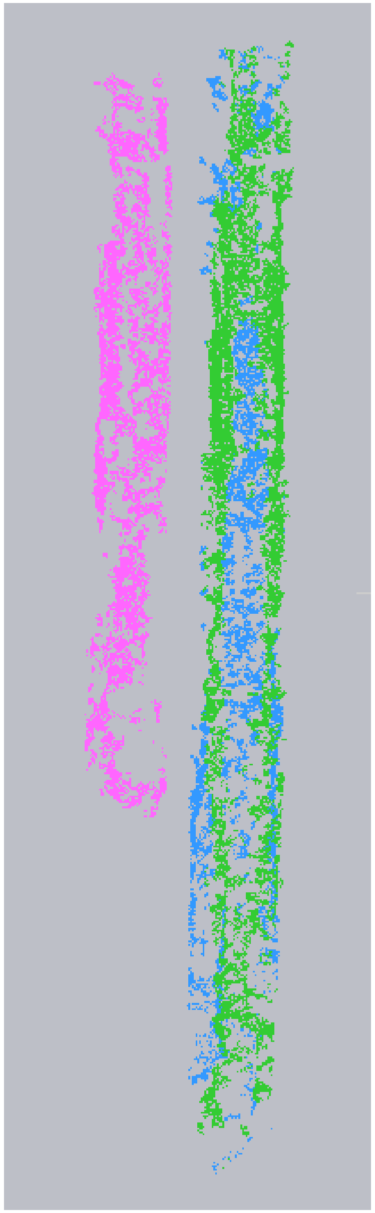
Defined Object (Pipeline)

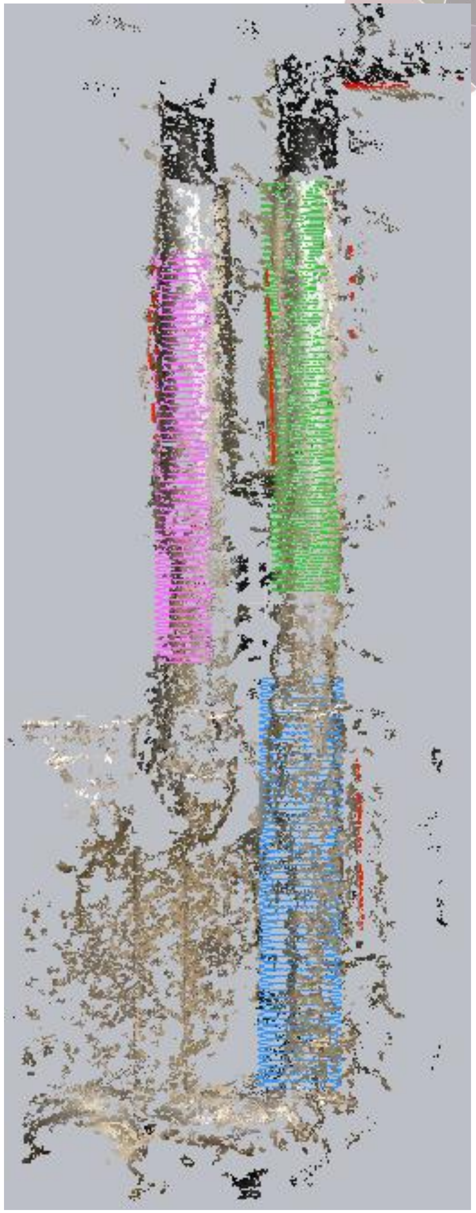
Connecting Components

- ✓ Same orientation
- ✓ Points in common

Combine segments

to one Pipe





Store in Database

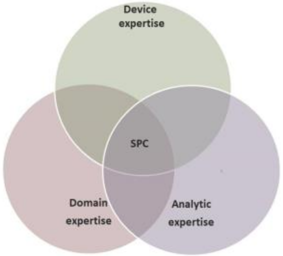
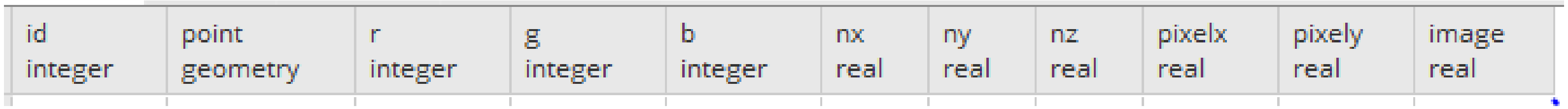
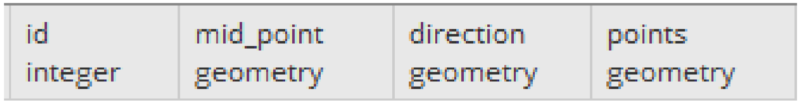


Table: Points



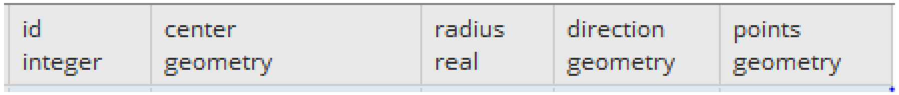
id	point	r	g	b	nx	ny	nz	pixelx	pixely	image
integer	geometry	integer	integer	integer	real	real	real	real	real	real

Table: Segments



id	mid_point	direction	points
integer	geometry	geometry	geometry

Table: Pipes

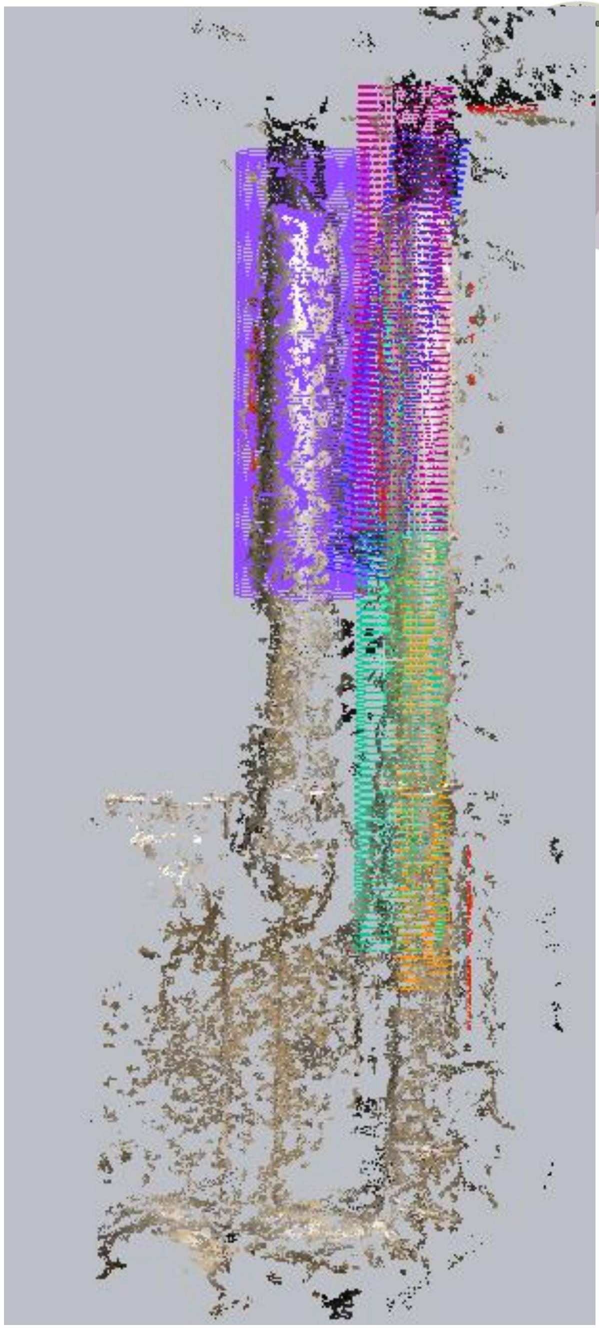


id	center	radius	direction	points
integer	geometry	real	geometry	geometry

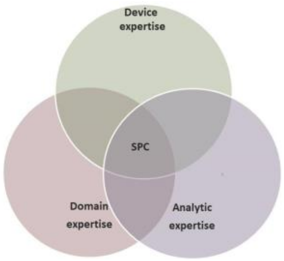
- ✓ Topology –Relationships
- ✓ Save once
- ✓ Analyze data
- ✓ Retrieve data
- ✓ PostGIS extension store geometry

Random Sample Consensus (RANSAC)

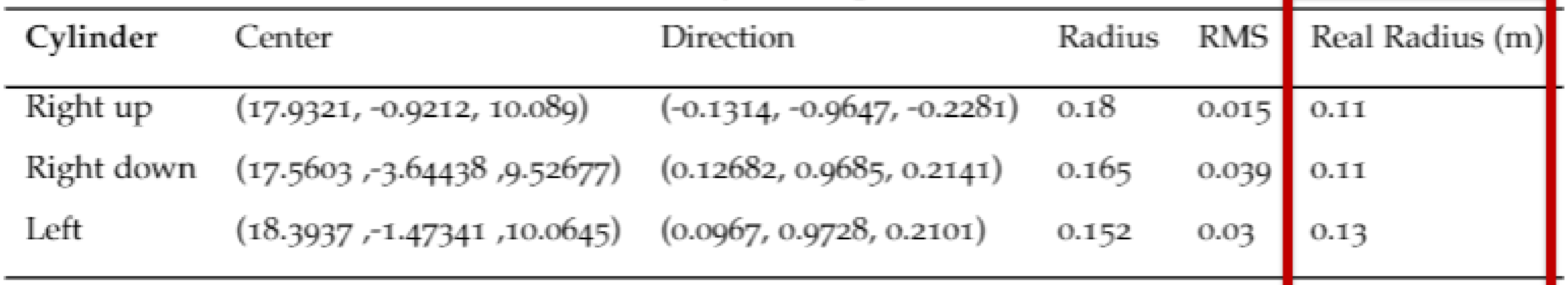
- Feature extraction technique
- Direct to point cloud
- Randomly using the minimum amount of points to estimate the cylinder parameters.
- Must not contain outliers



Compare Results

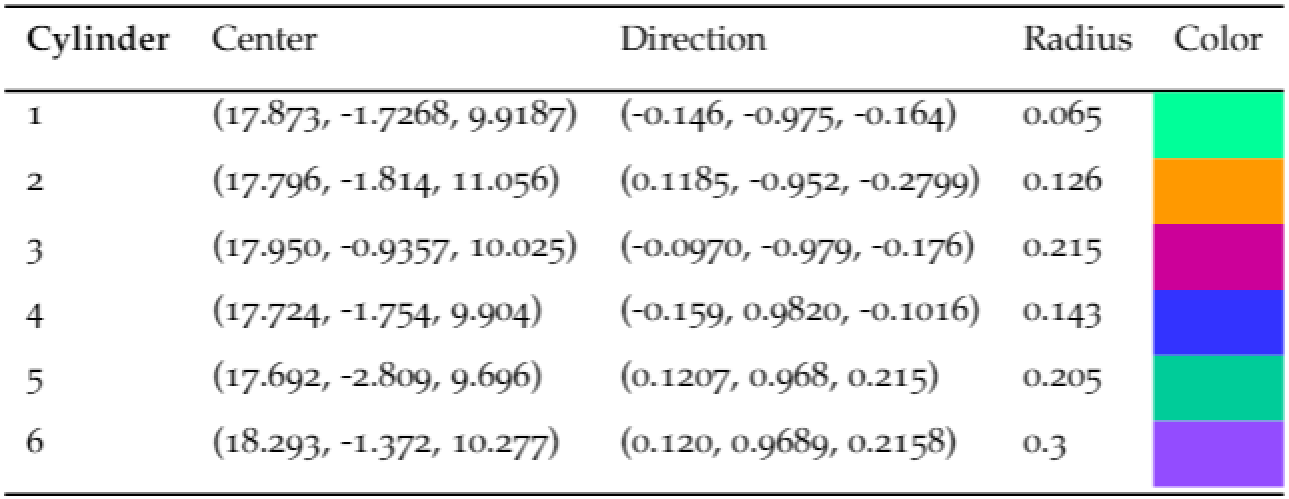


FROM 2D CIRCLE FIT



Cylinder	Center	Direction	Radius	RMS	Real Radius (m)
Right up	(17.9321, -0.9212, 10.089)	(-0.1314, -0.9647, -0.2281)	0.18	0.015	0.11
Right down	(17.5603 ,-3.64438 ,9.52677)	(0.12682, 0.9685, 0.2141)	0.165	0.039	0.11
Left	(18.3937 ,-1.47341 ,10.0645)	(0.0967, 0.9728, 0.2101)	0.152	0.03	0.13

FROM RANSAC



Cylinder	Center	Direction	Radius	Color
1	(17.873, -1.7268, 9.9187)	(-0.146, -0.975, -0.164)	0.065	🟩
2	(17.796, -1.814, 11.056)	(0.1185, -0.952, -0.2799)	0.126	🟧
3	(17.950, -0.9357, 10.025)	(-0.0970, -0.979, -0.176)	0.215	🟪
4	(17.724, -1.754, 9.904)	(-0.159, 0.9820, -0.1016)	0.143	🟦
5	(17.692, -2.809, 9.696)	(0.1207, 0.968, 0.215)	0.205	🟩
6	(18.293, -1.372, 10.277)	(0.120, 0.9689, 0.2158)	0.3	🟪

Outline

1. Motivation & Challenges

2. Background & Research objectives

3. Proposed Prototype

4. Implementation & Results

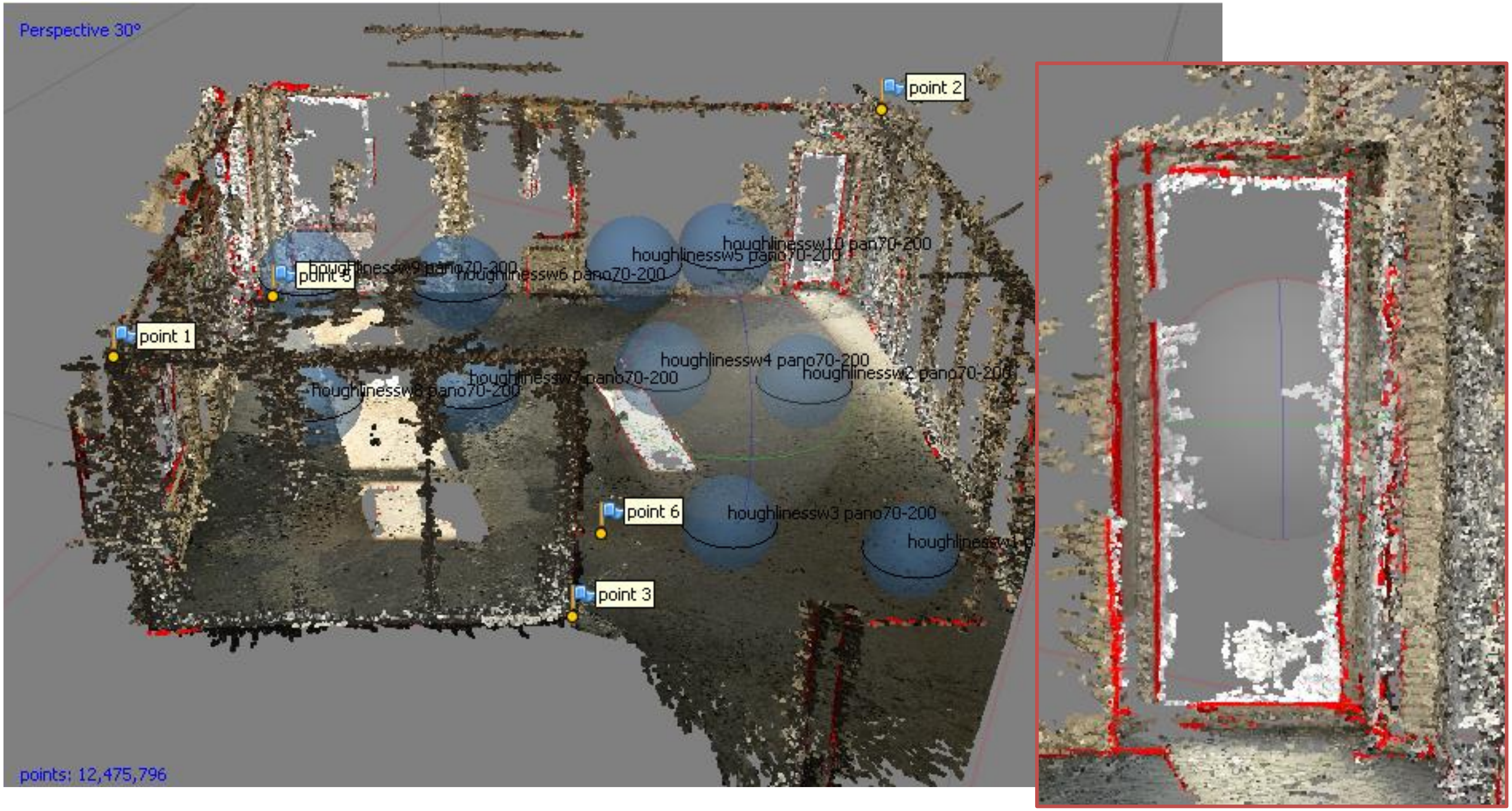
5. Conclusions & Future work

Conclusions

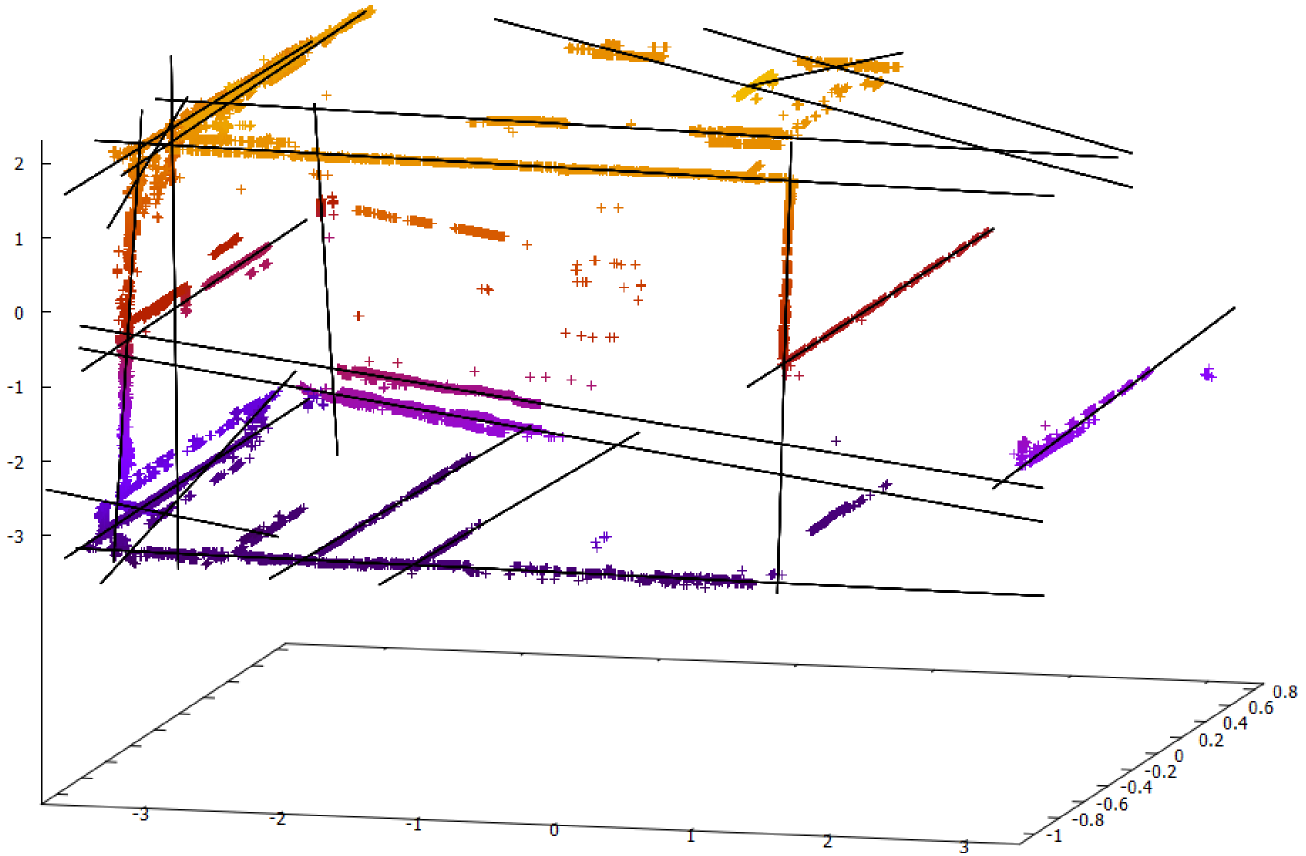
What is the Smart Point Cloud way to provide a framework for object detection (pipelines), using panoramic images for point cloud creation?

- ✓ Connection 2D-3D Boundaries
- ✓ Object identification (pipe)
- ✓ Semantically rich point cloud
- ✓ Working also fine with different data (edge detection e.g. windows, doors)

Test Data – Empty Room



Test Data – Empty Room



Future Work

- Test on a bigger/different (traffic lights, trees) data set
- Input point cloud in VR/AR, interaction with the user
- Improvements in the image processing for better results
- Create points for occluded areas
- Apply RANSAC to segments
- Colour the pixels related to the identified objects

Thank you for your attention!