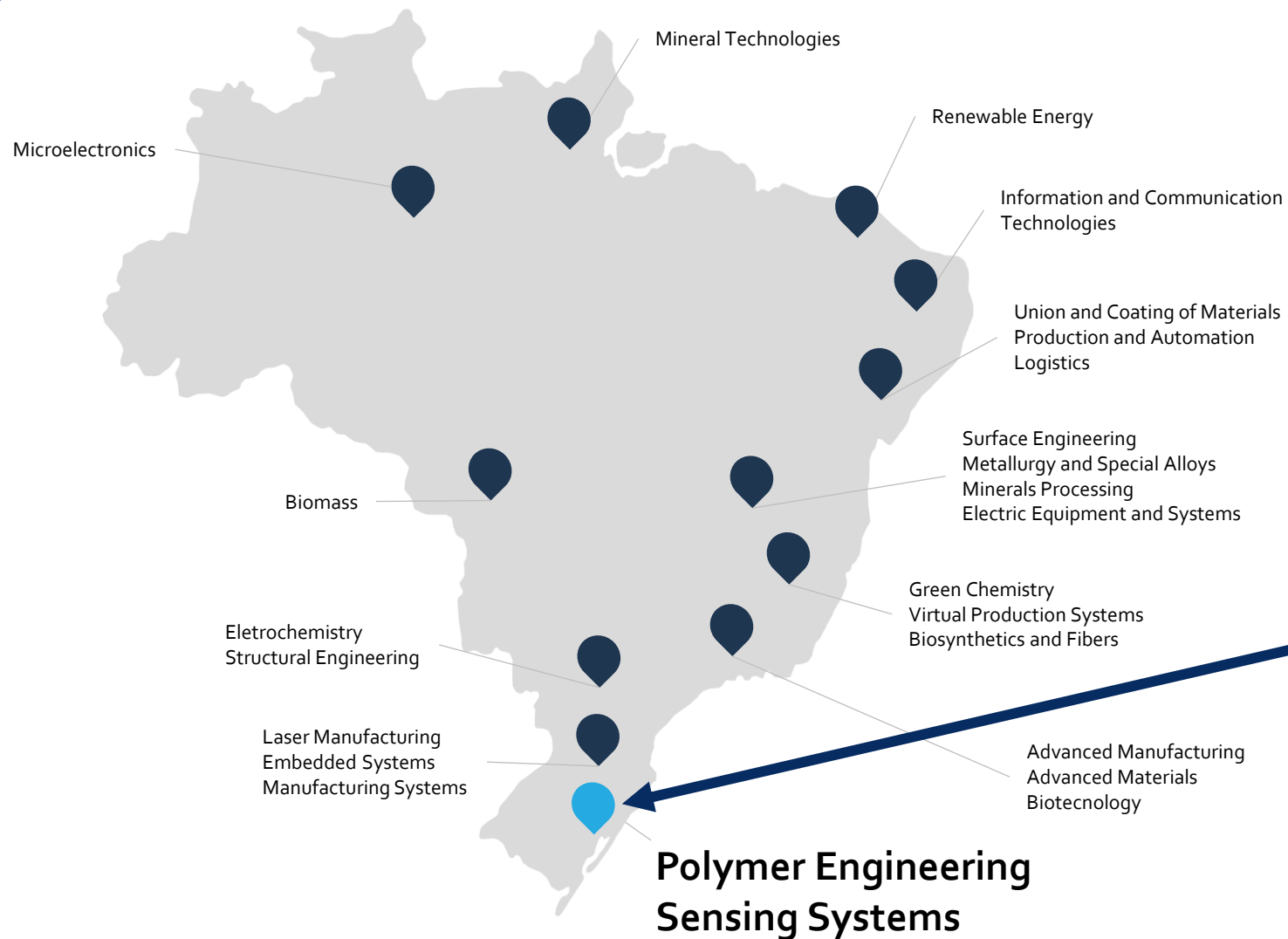


Analyzing the Impact of Laser Scanner Parameters on AI Model Performance for Recognizing Objects

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Largest Private Research and Development Network in Brazil



Serviço Nacional de Aprendizagem Industrial

PELO FUTURO DO TRABALHO





More than 50,000 Services and Projects

Between 2018 and 2023



85 Running Projects

(2024)

with 65 companies



8 International Projects

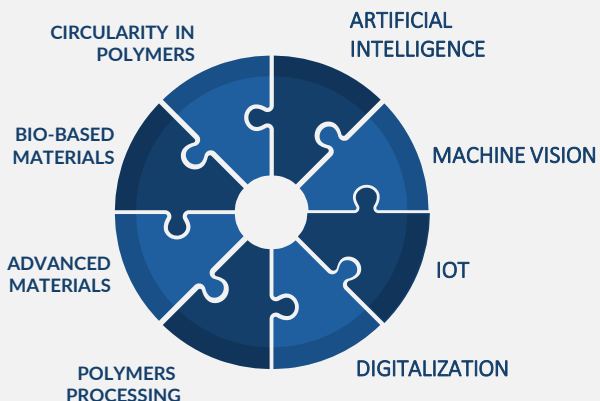
Institutes in Brazil, EU and USA



More than 500 Employees at SENAI-RS

51 PhD e 60 M.Sc.

Technological Development Areas



Funding



Industrial Partners

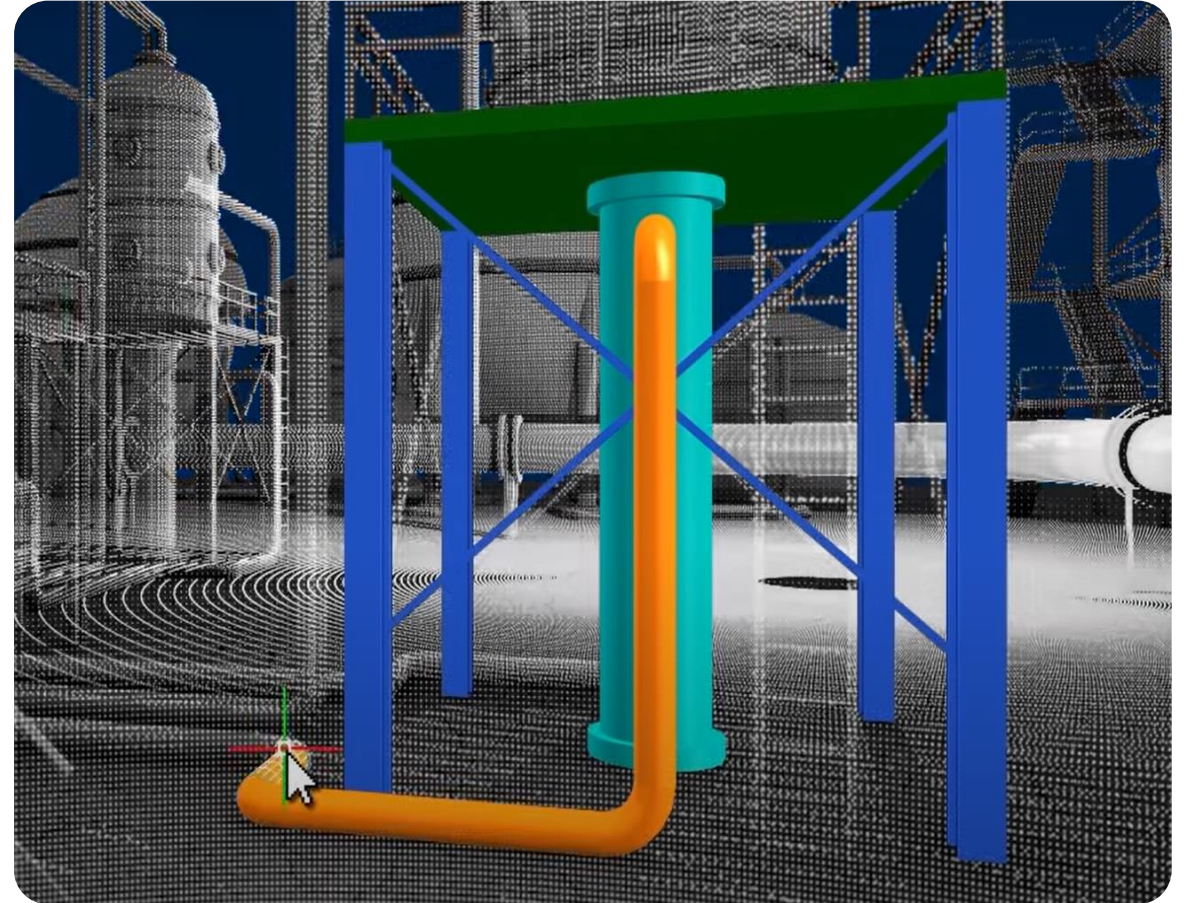


Researchers' Alma Mater



3D Object Recognition in Point Clouds

- Digital Twin 3D representations are usually crafted from point clouds.
- Scan-to-BIM process remains
 - manual,
 - labor-intensive,
 - prone to errors,
 - and incurs significant costs due to the need for specialized labor.
- Recent approaches have been taking advantage of Deep Learning algorithms for automatic segmentation of point clouds.



Source: AVEVA LFM

Goal

A comprehensive Design of Experiment (DoE) to systematically analyze the effects of laser scanner parameters on AI model performance, while assessing the cost-benefit of setting the best possible scanning parameters.



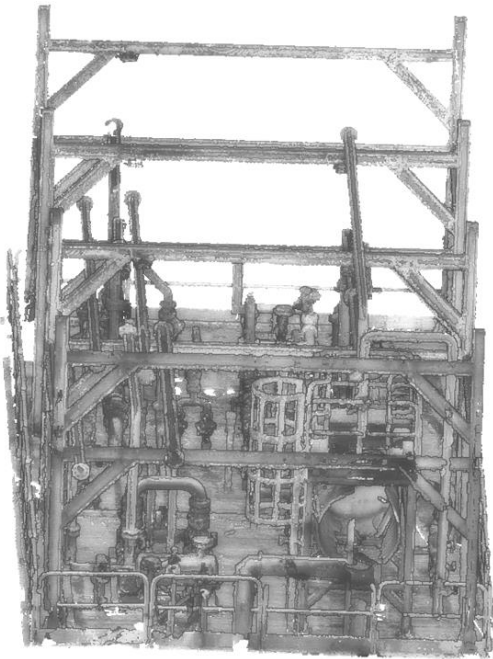
3D METROLOGY
CONFERENCE

Loughborough, UK
September 24 – 26

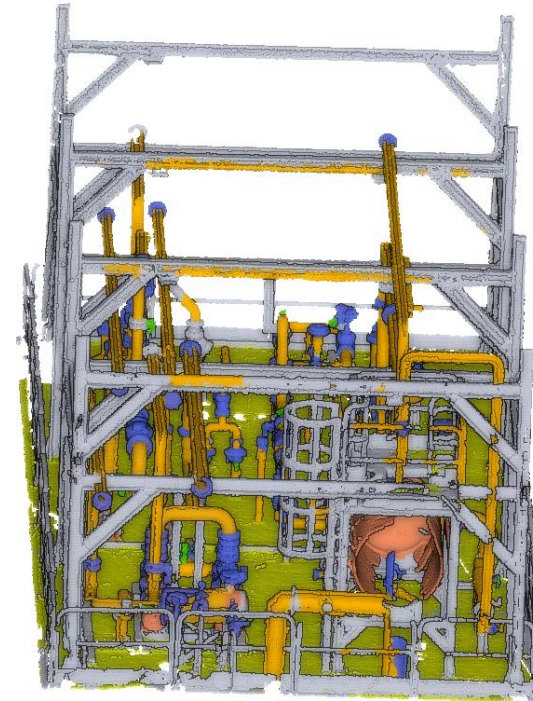
SENAI / Tecnologia
e Inovação

AI performance: 3D instance segmentation in Point Clouds

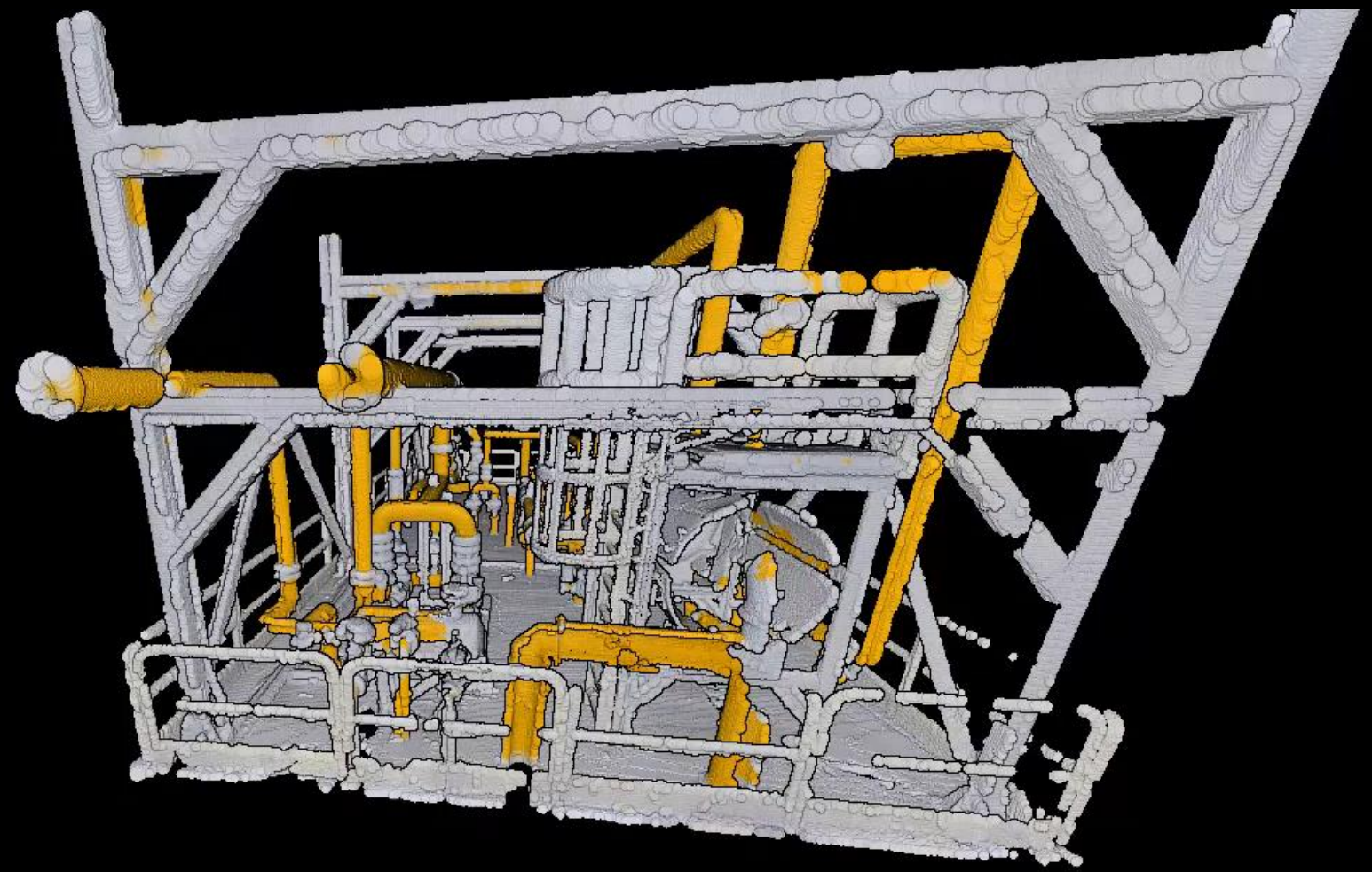
3D Point Cloud acquired in the Oil & Gas domain



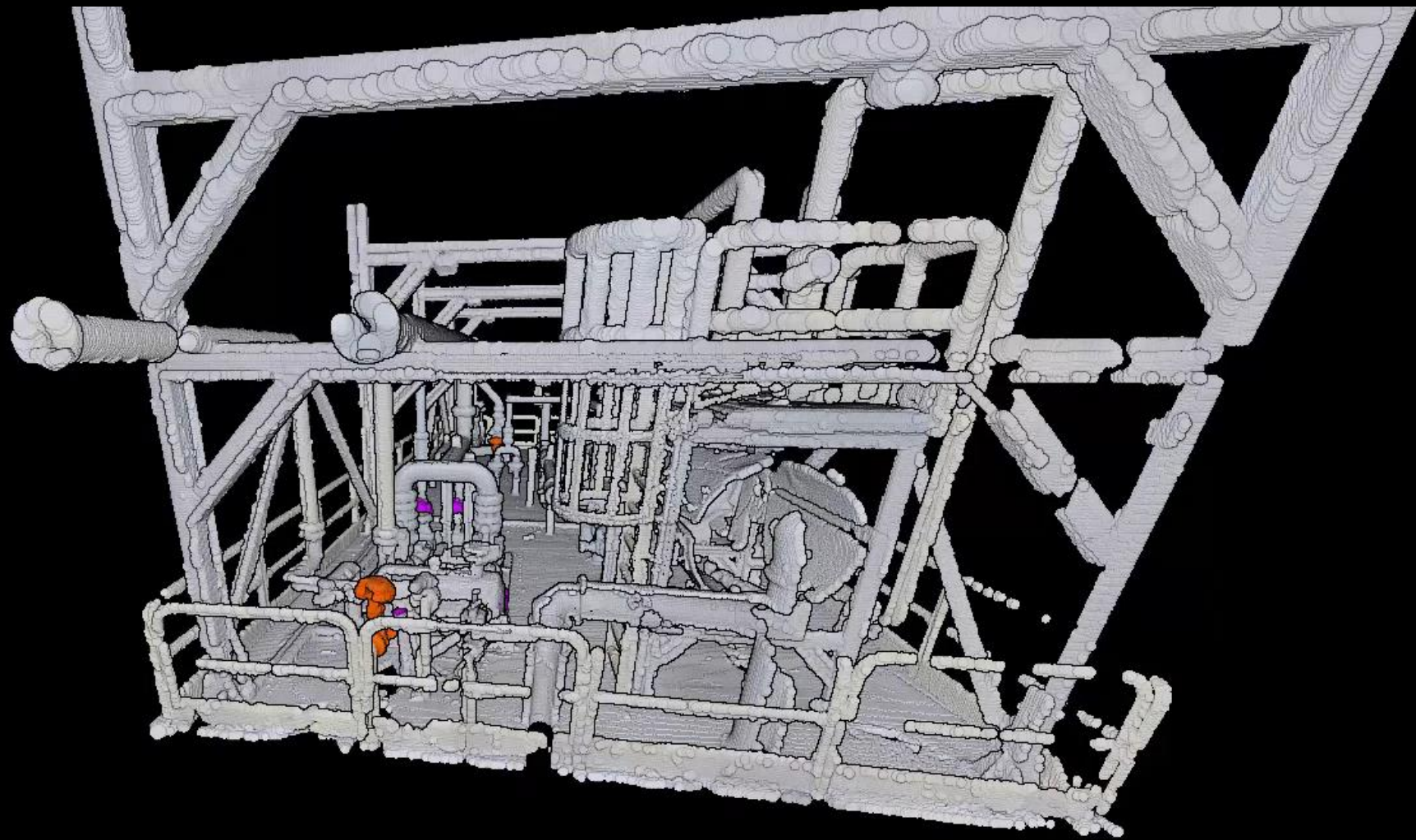
AI-based 3D Point Cloud Components Recognition



- Planar surface
- Pipe-like geometry
- Large equipments
- Structural
- Small sized components and measurement
- Medium size components



Pipes



Control valves | Motors

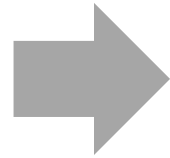
DoE: factors and response variables

Factors:

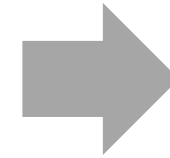
*Scanning
parameters*

X

- Resolution
- Scan quality
- Scanner positions



DoE
 $f(x)$




Response variables:

*AI model performance
metrics*

Y

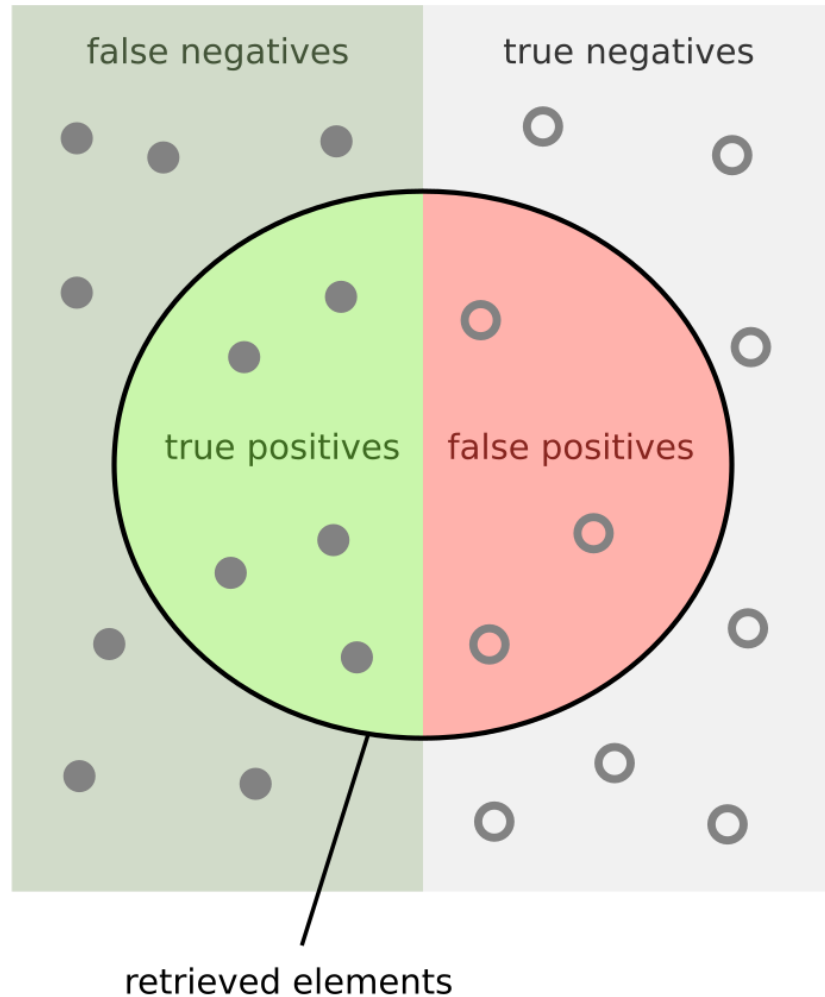
- mIoU
- F-Score
- Recall
- Precision
- Total Time

Mean - Intersection over Union

$$\text{IoU} = \frac{\text{Area of Overlap}}{\text{Area of Union}}$$




Precision and Recall



		Predicted	
		0	1
Actual	0	TN	FP
	1	FN	TP

$$Precision = \frac{TP}{TP + FP}$$

$$Recall = \frac{TP}{TP + FN}$$

$$F\text{-score} = \frac{2 \times Precision \times Recall}{Precision + Recall}$$

DoE: factors levels and response variables weights

Factors	Levels	Values
Resolution	3	1/2, 1/8 & 1/16
Scan quality	2	3X & 4X
Number of scanning positions	5	1,2,3,5 & 9

Response variables	Goal	Weight
mIoU	Maximize	1
F-Score	Maximize	1
Recall	Maximize	1
Precision	Maximize	1
Time (h)	Minimize	1

Check how individual factors or their interaction...



Influence to the response variables and how we can optimize them.

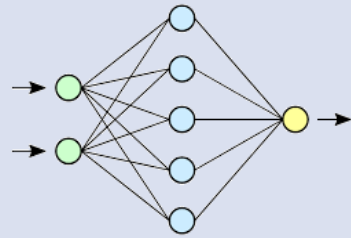
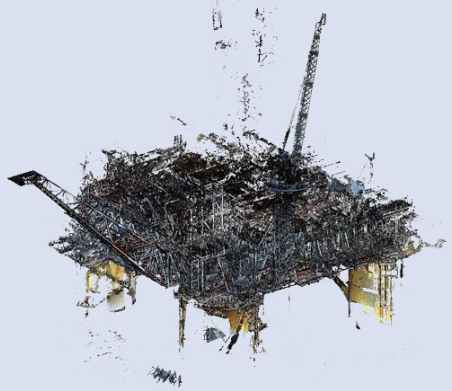


The experiment

Oil & Gas Platform



Training dataset



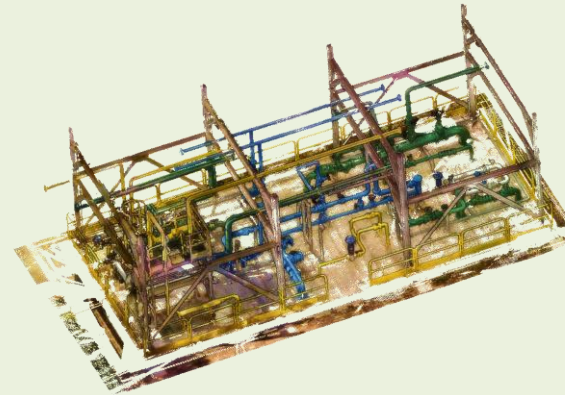
**Fixed Scanning
Parameters Values**
(limited conclusions)

**AI Model
Training**
SoftGroup for 3D Instance
Segmentation on Point Clouds

Oil & Gas Mockup



Test dataset



**Multiple Scanning
Parameters Values**
(DoE Factors Levels)

Best combination of
testing scanning
parameter values

DoE output

Oil & Gas Mockup

- Goal
 - Scanning parameters to ensure object recognition in 3D point clouds
- Specification
 - 1:1 scale
 - 5m x 7,5m x 15m (H x W x L)
 - ~25 tons

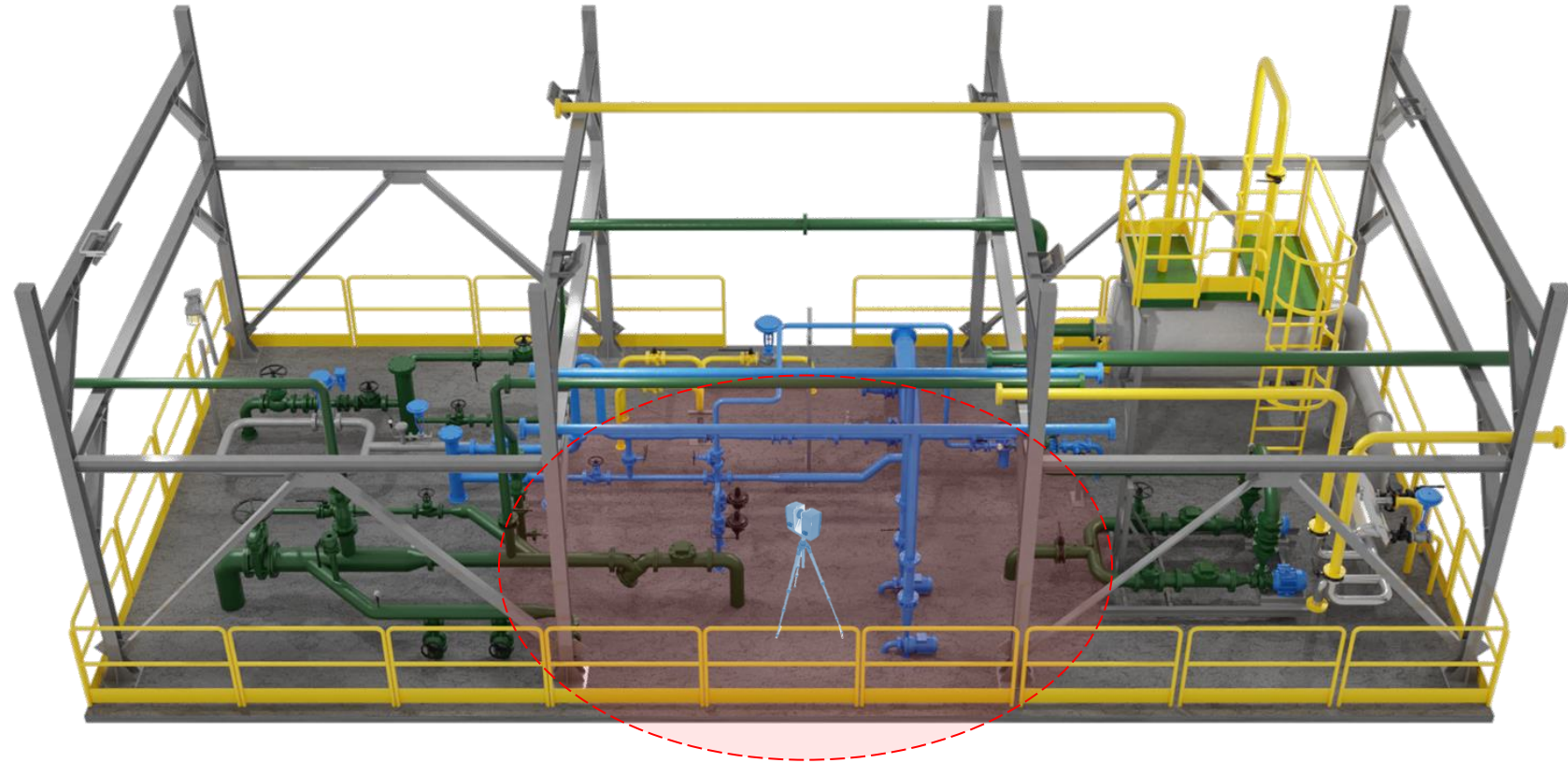


The experiment: *execution conditions*

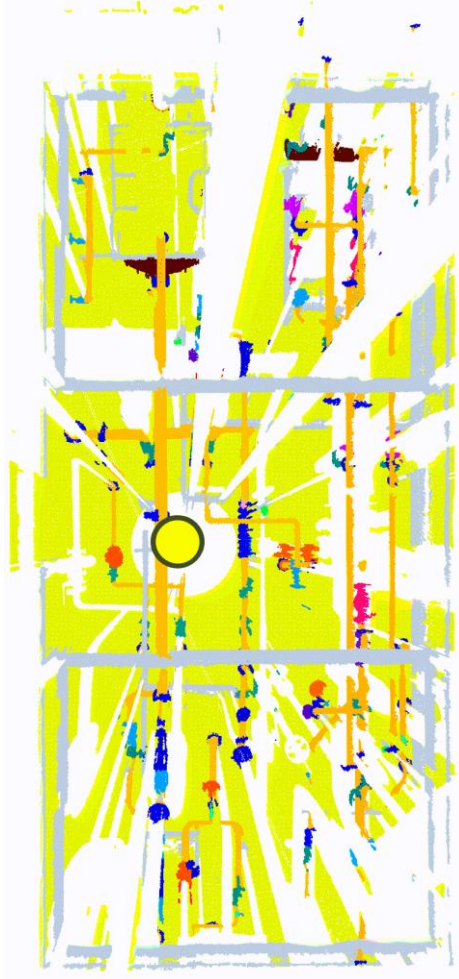
Volume : 562 m³
7,5m x 15m x 5m



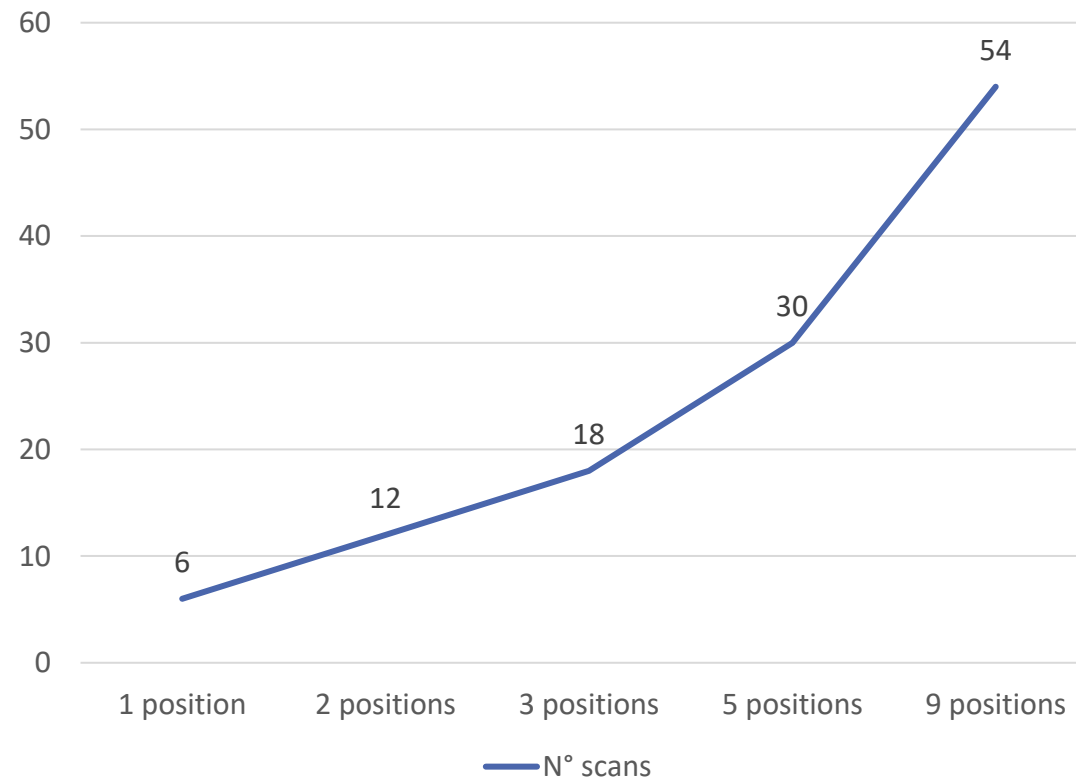
Laser Scanner, Faro Focus S 150



Data acquisition: *N* scanning points



#N scans per number of positions



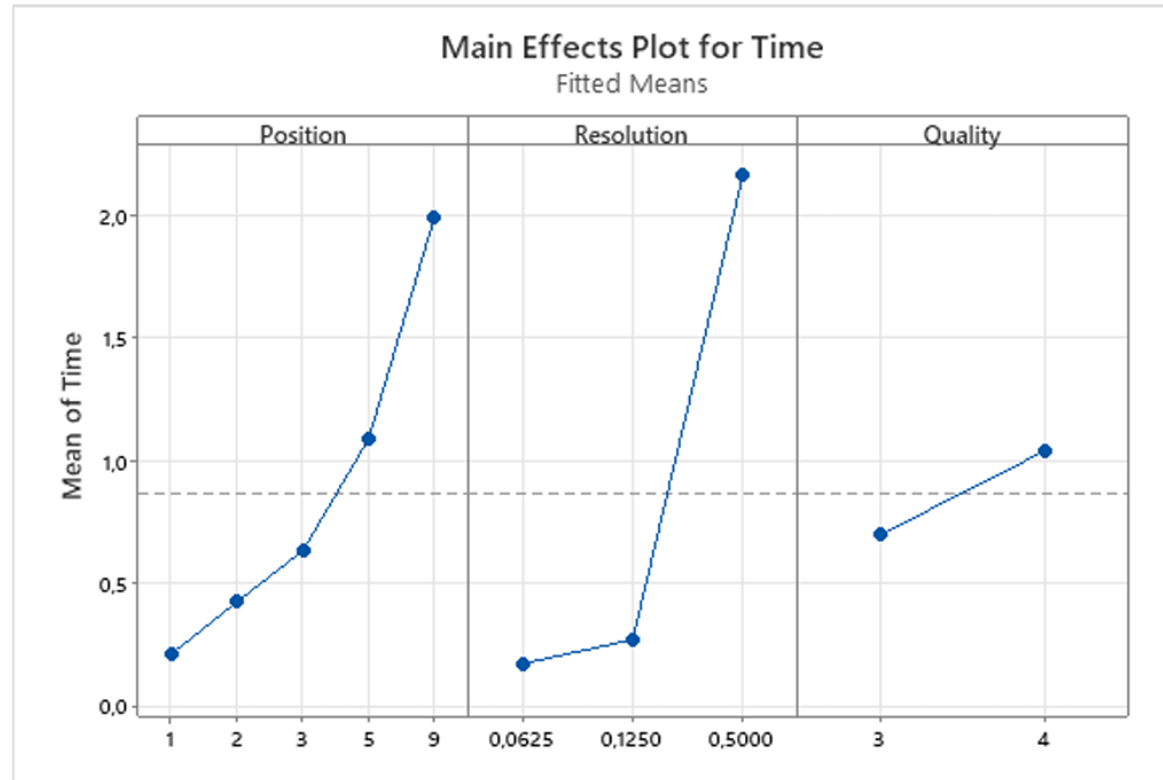
$$\#Scans = positions * resolution * quality$$

- Resolution: 3 levels
- Quality: 2 levels
- 6 clouds

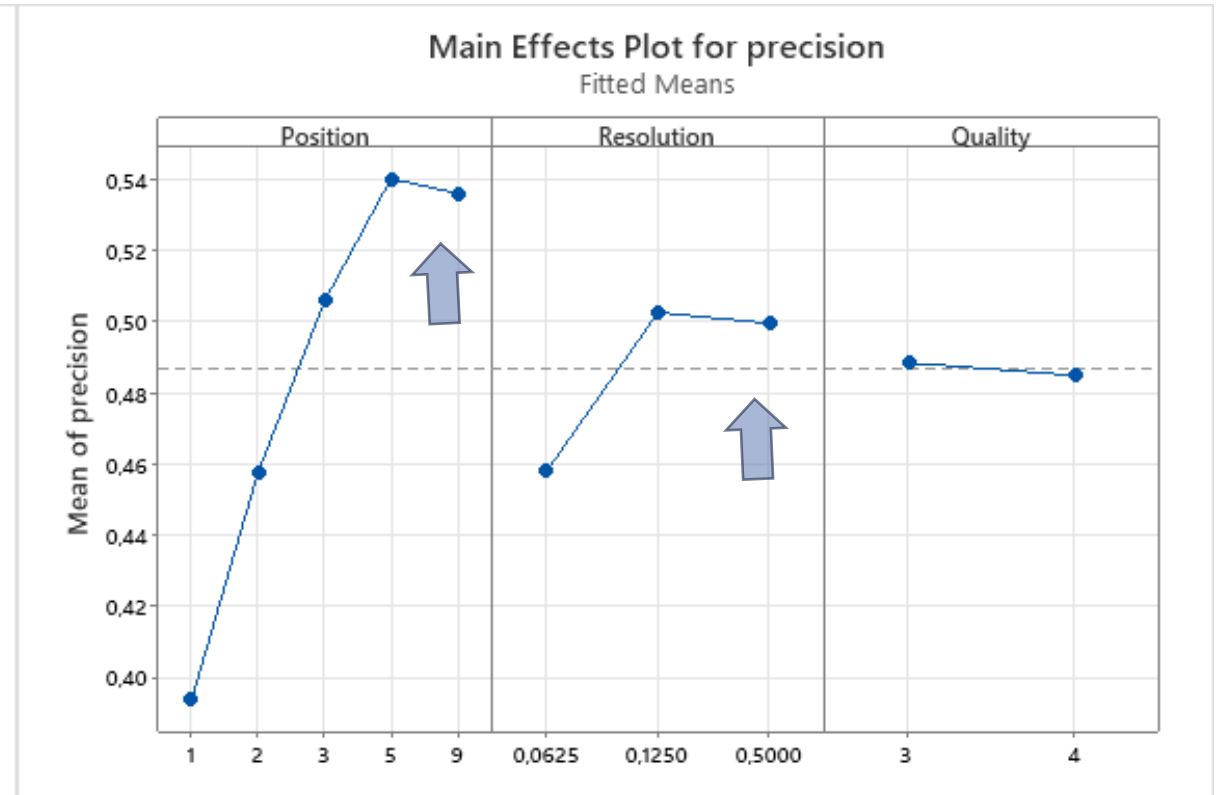


Results

Factor effects for different metrics



Factor effects for different metrics



Response optimization: *all response variables*

Parameters

Response	Goal	Lower	Target	Upper	Weight
mIoU	Maximum	0,2111	0,6695		1
F-score	Maximum	0,2353	0,5625		1
Recall	Maximum	0,2117	0,5346		1
Precision	Maximum	0,2631	0,5934		1
Time (h)	Minimum		0,05	6,22	1

Higher resolution and quality bring diminishing returns - it is possible to optimize for time

Solution

Position	Resolution	Quality	mIoU Fit	F-score Fit	Recall Fit	Precision Fit	Time Fit	Composite Desirability
9	1/8	3	0,648	0,5245	0,5042	0,5460	0,3596	0,909

Response Optimization: *focus on point segmentation*

Parameters

Response	Goal	Lower	Target	Upper	Weight
mIoU	Maximum	0,2111	0,6695		1
Time (h)	Minimum		0,05	6,22	1

Solution

Position	Resolution	Quality	mIoU Fit	Time Fit	Composite Desirability
9	1/8	3	0,648	0,3596	0,909

If optimizing for segmentation mIoU: high number of positions increased performance (larger covered area)

Response Optimization: *focus on object detection*

Parameters

Response	Goal	Lower	Target	Upper	Weight
Recall	Maximum	0,2117	0,5346		1
Precision	Maximum	0,2631	0,5934		1
Time (h)	Minimum		0,05	6,22	1

Solution

Position	Resolution	Quality	Recall Fit	Precision Fit	Time Fit	Composite Desirability
5	1/8	3	0,5119	0,5560	0,2746	0,9262

If optimizing for instance detection: more scanning positions did not increase performance

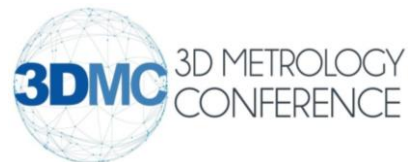
Concluding remarks

- Critical analysis or limitations
 - Fixed scanning parameters values for model training
- Higher resolution and quality bring negligible benefits to AI performance
- As expected, the higher the number of scanning positions, the better the AI model performance (mIoU)
- More scanning positions do not increase performance per instance

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Loughborough, UK | September 24 – 26

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