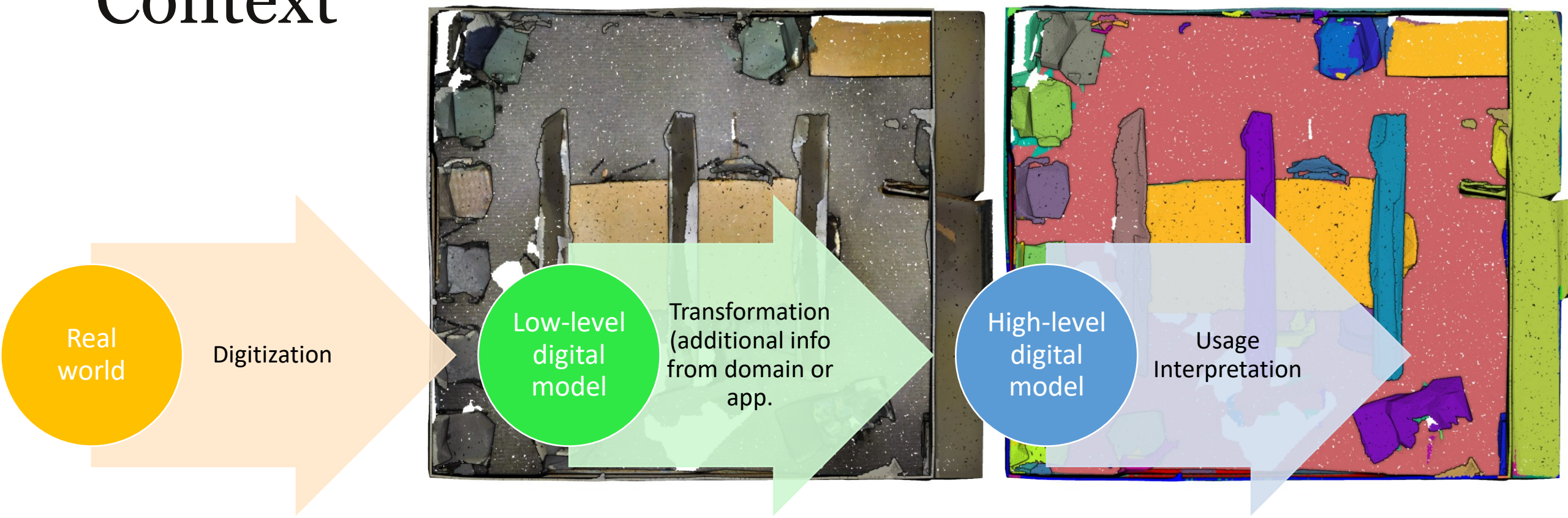
LIÈGE université
Geomatics

Point Clouds, Segments, Semantics and Automation

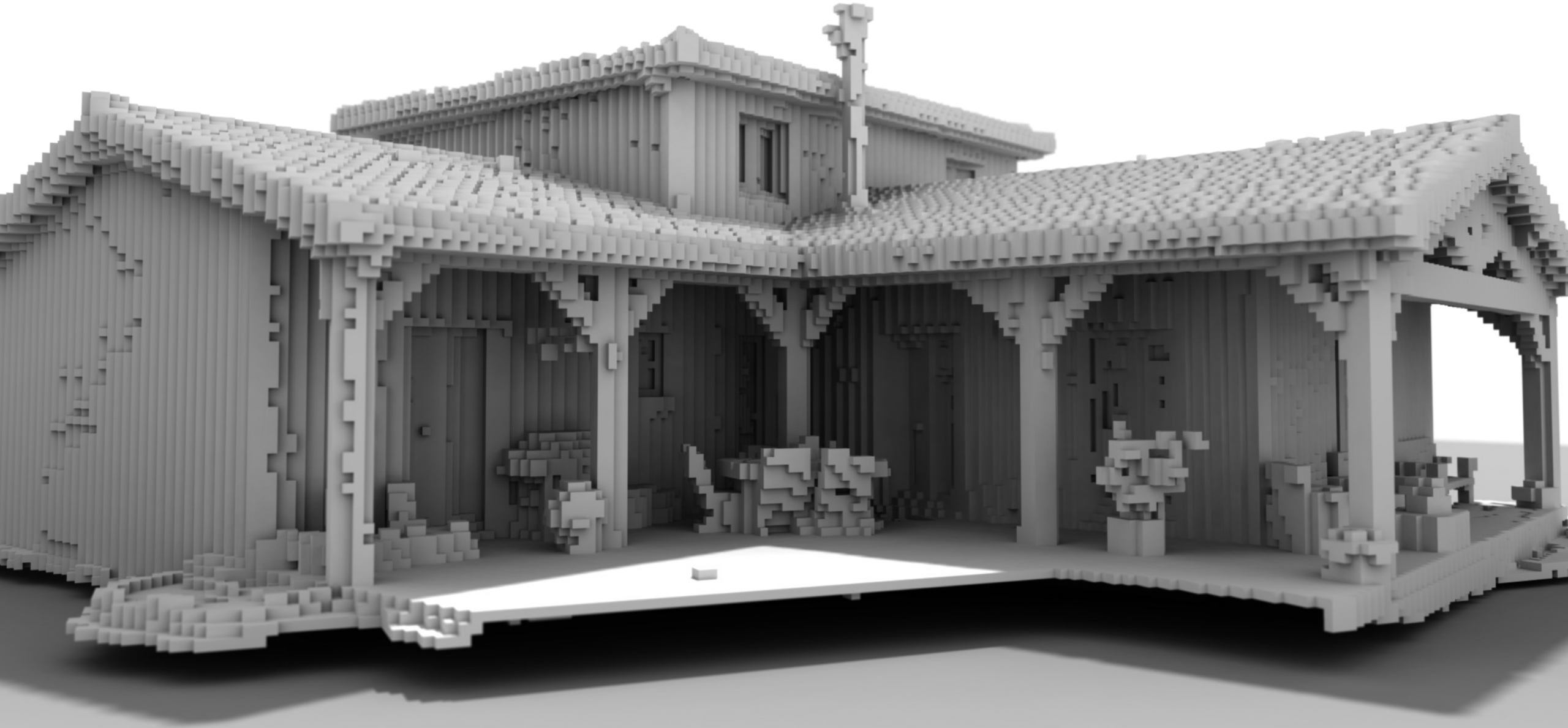
Florent Poux

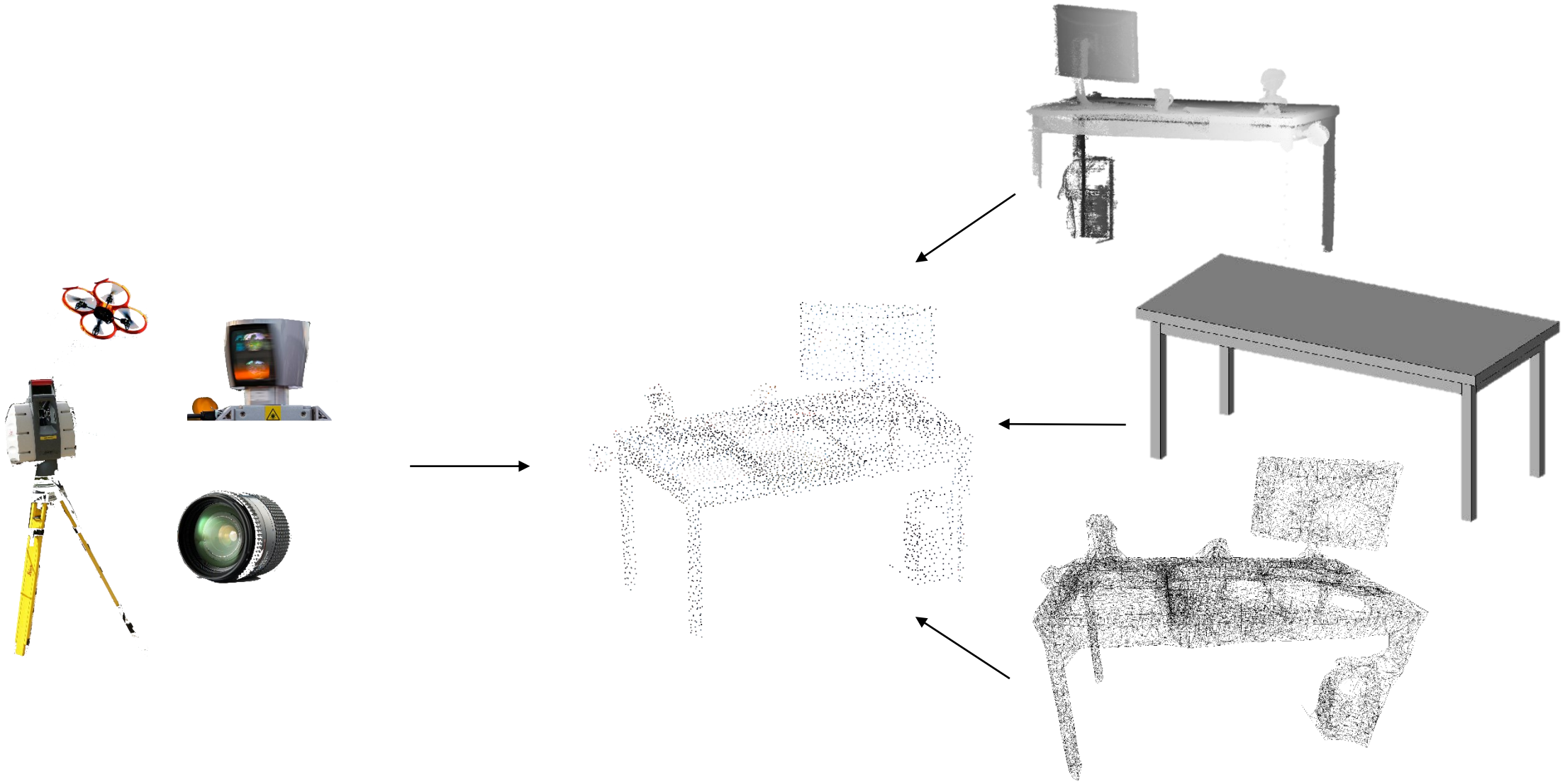
Context


Real world
Digitization
Low-level digital model
Transformation (additional info from domain or app.
High-level digital model
Usage Interpretation

3D Point Cloud Specificities

Representation & Structuration





Automation

Video Source : Emescent

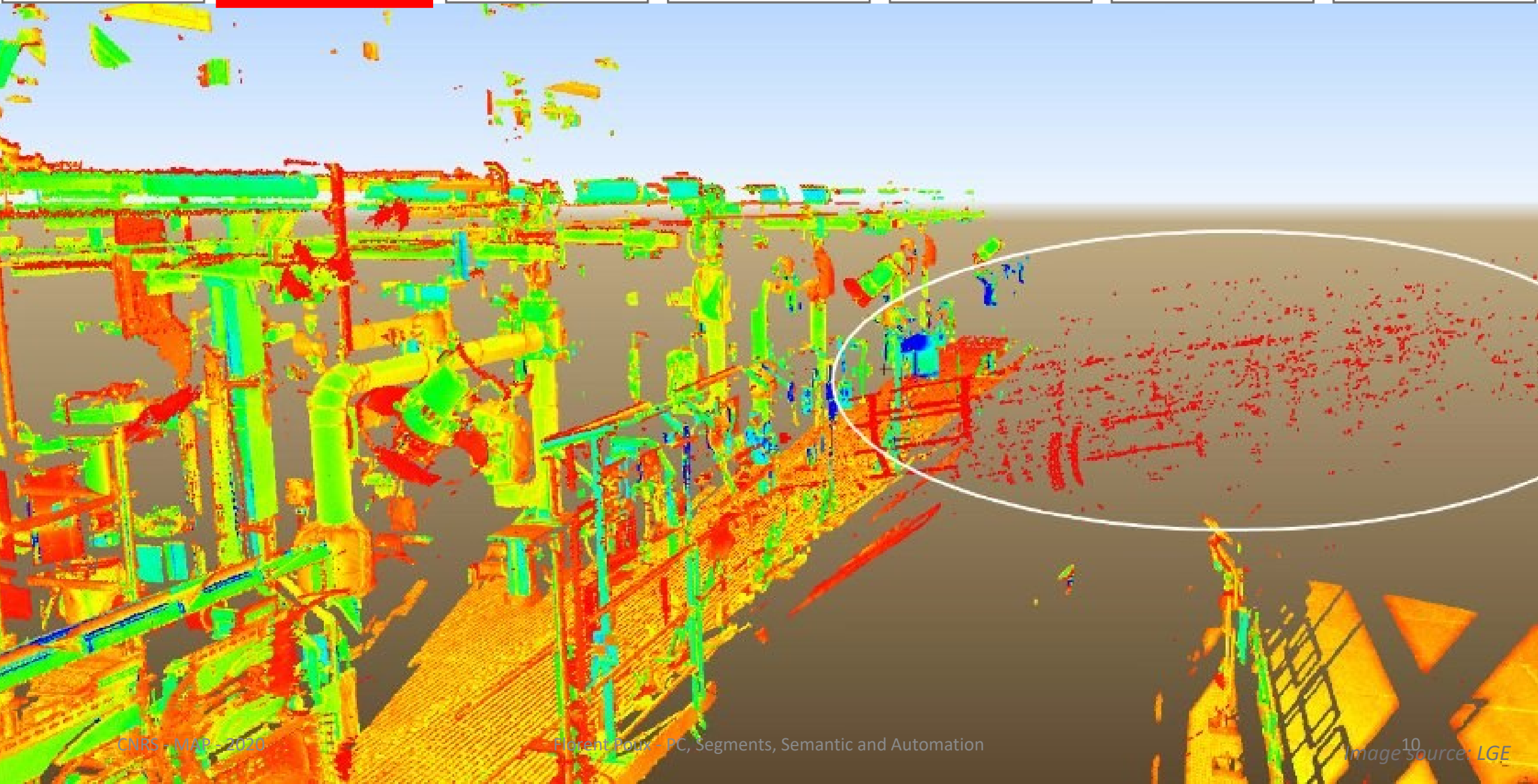


Image source: LGE

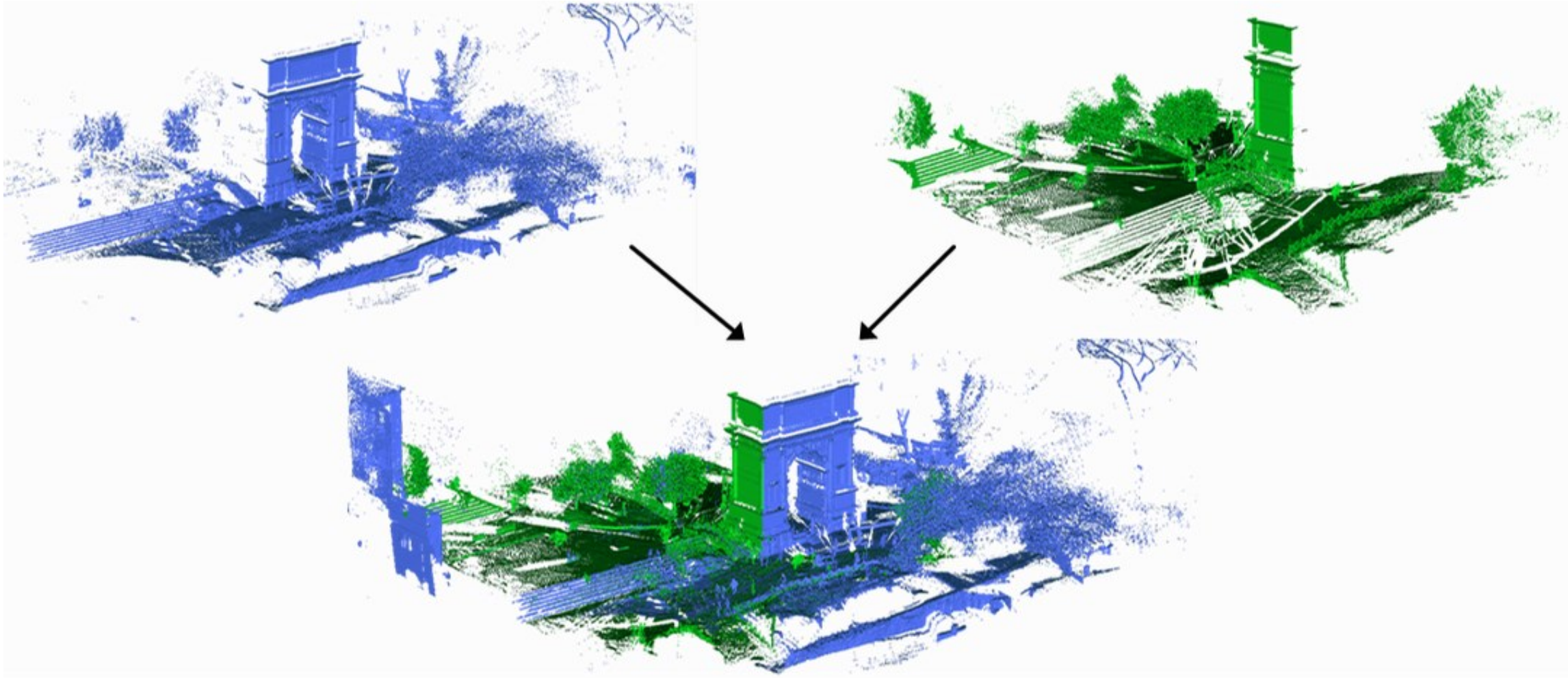
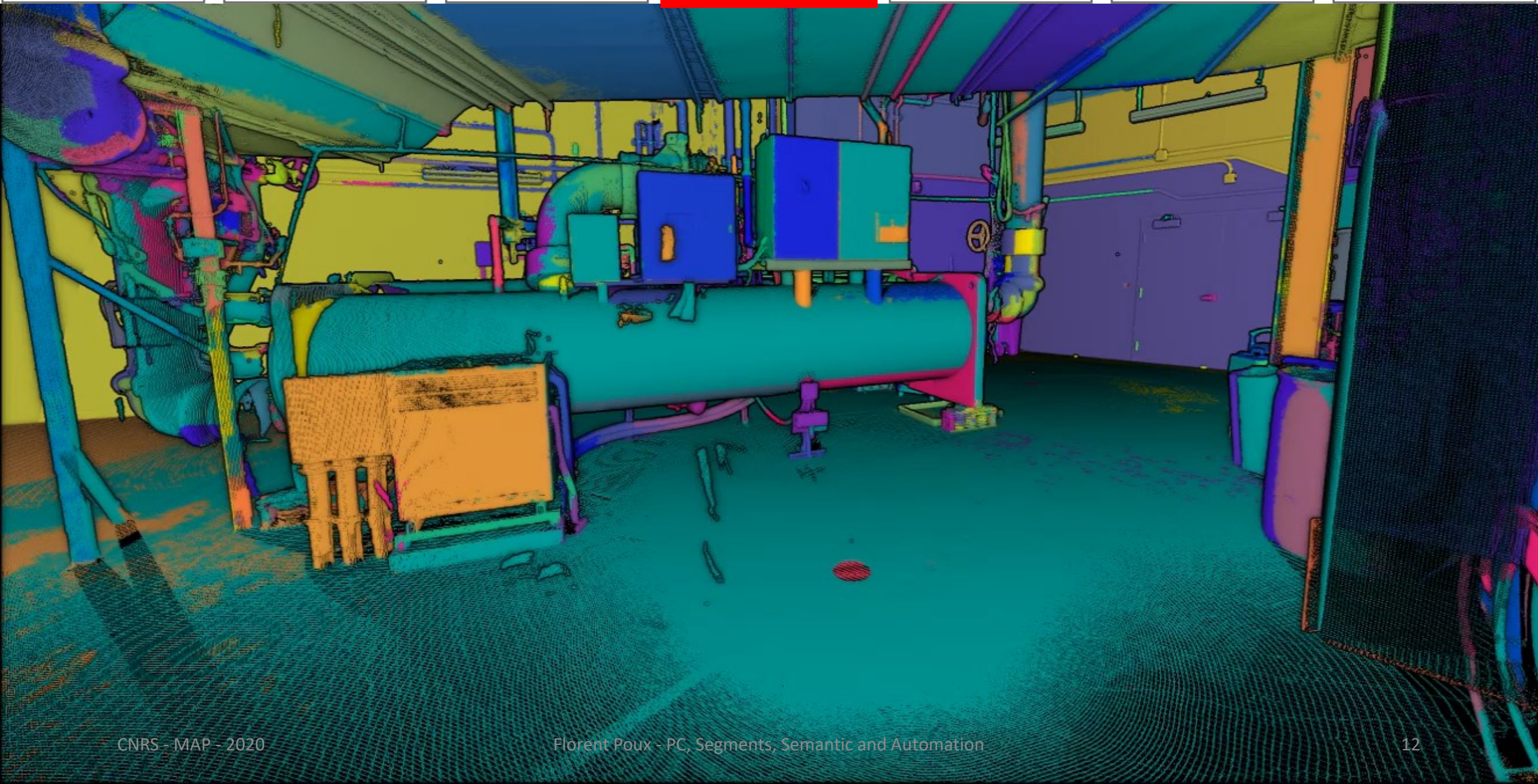
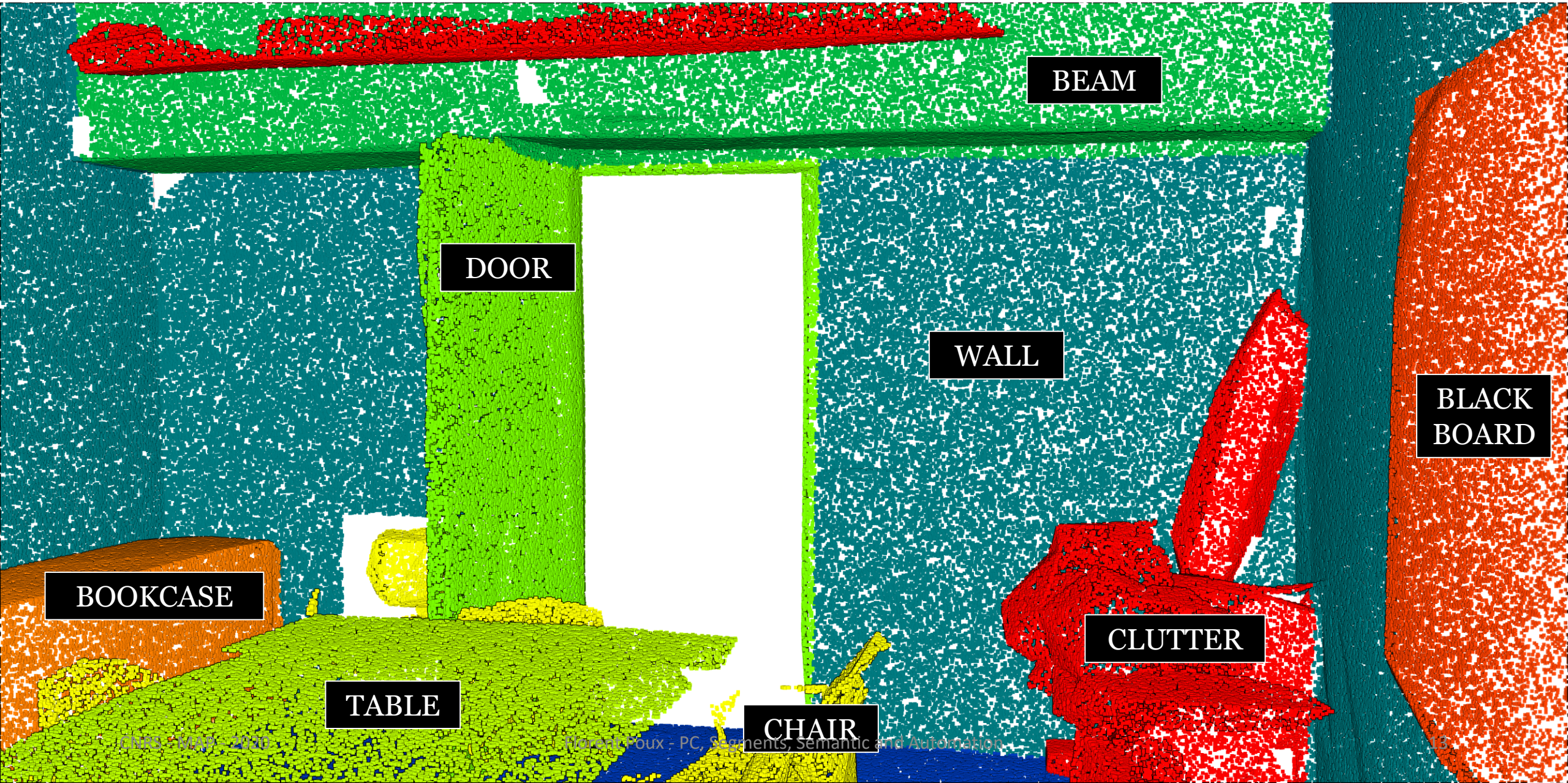
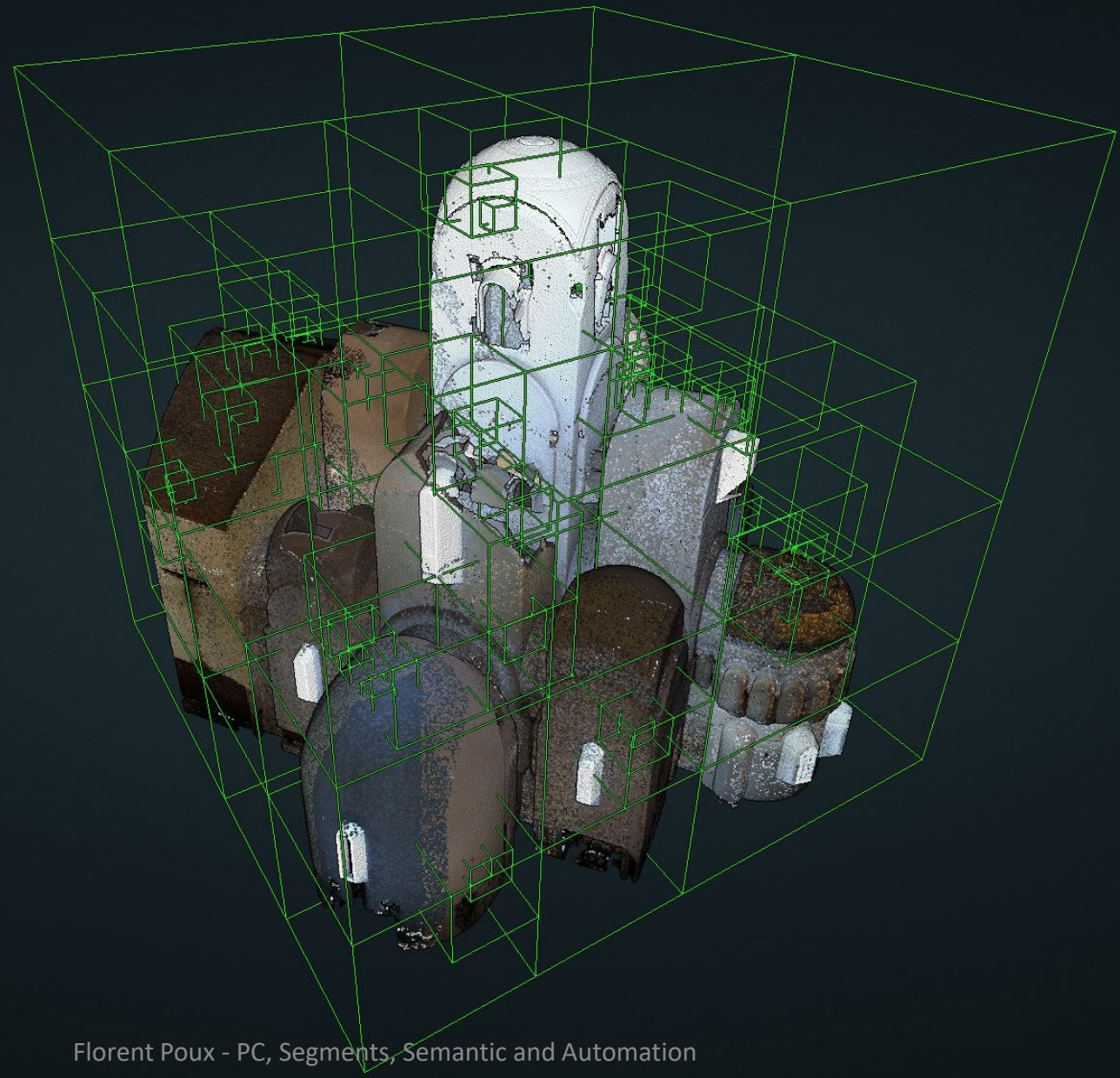
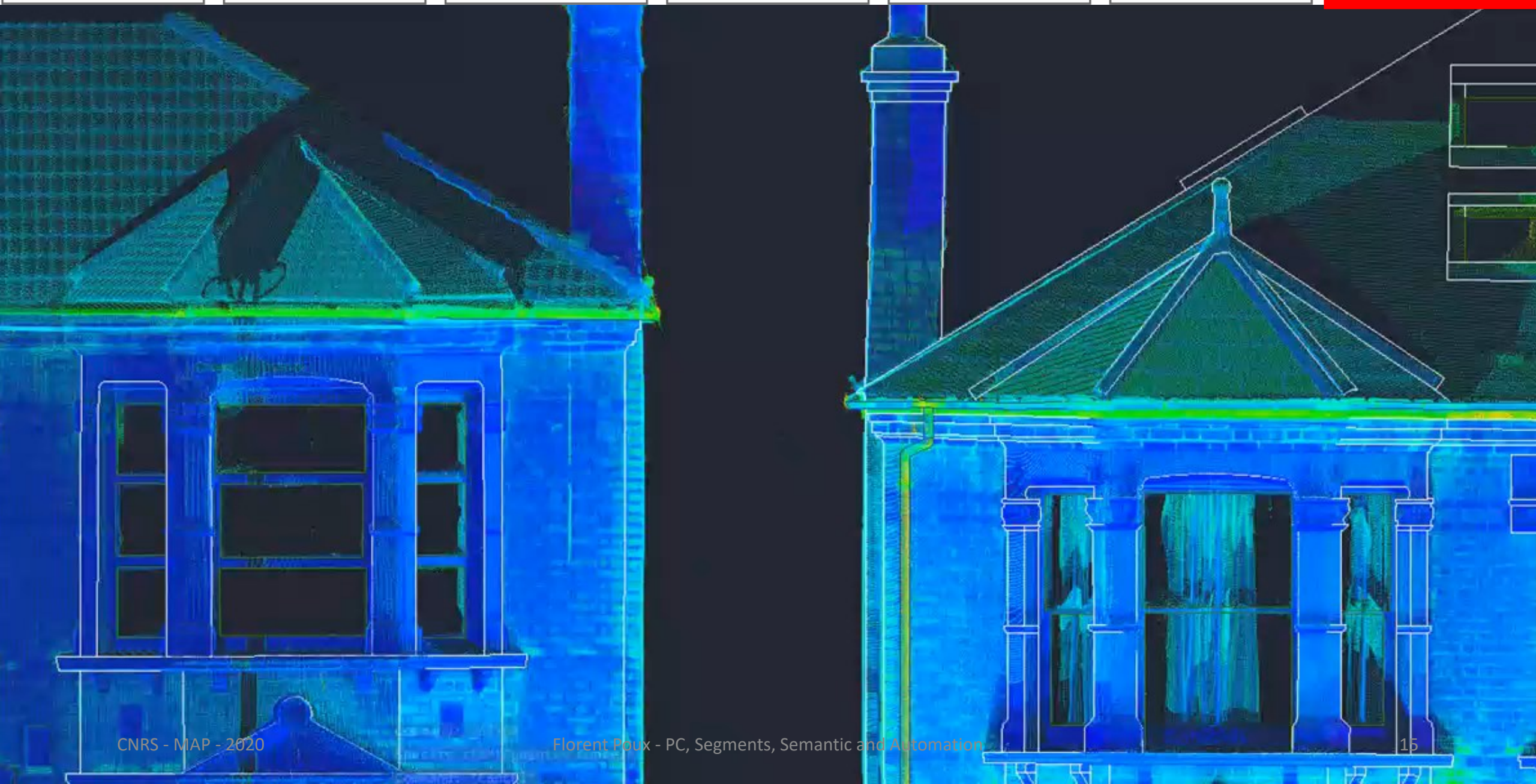


Image source: ETH Zürich



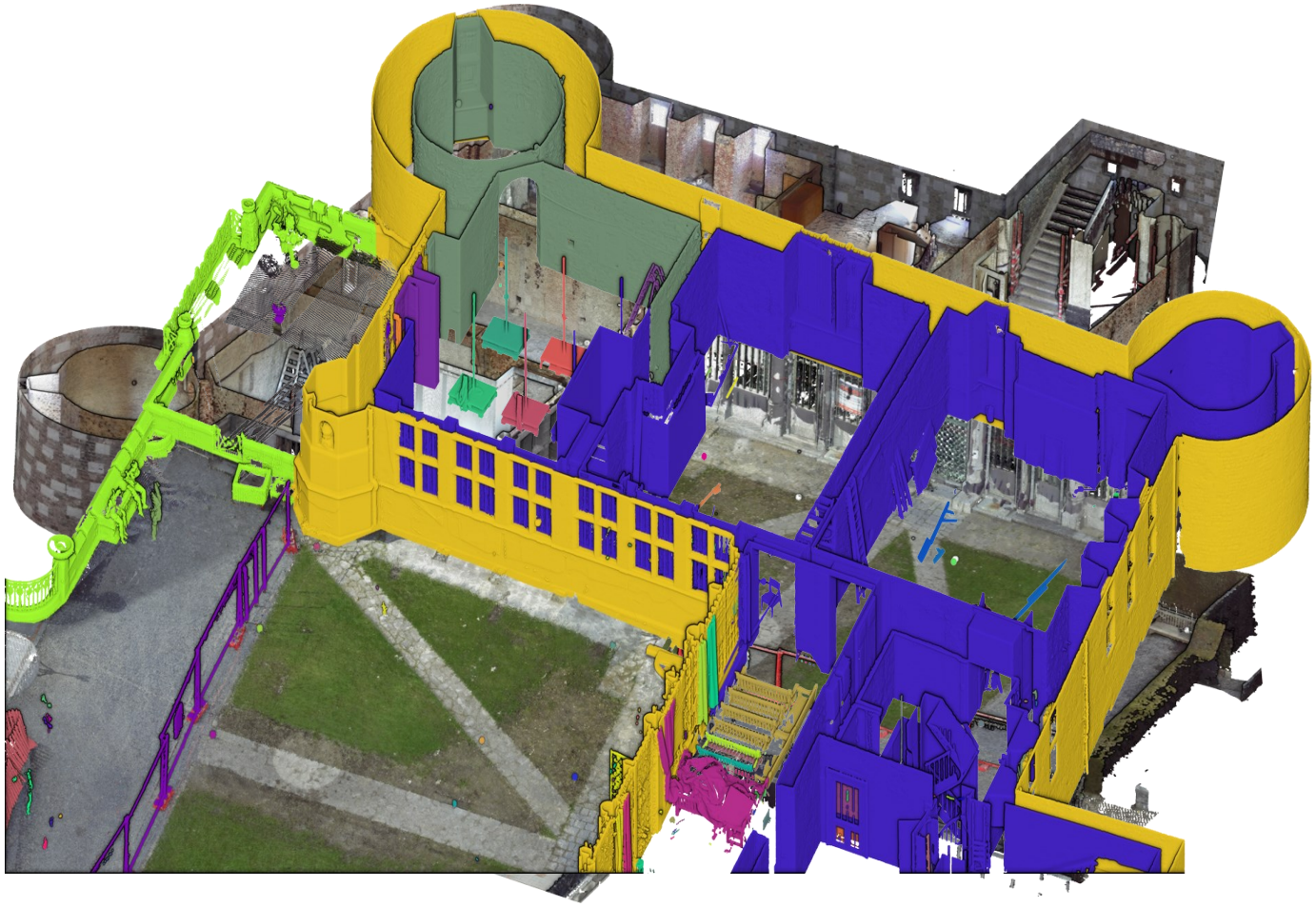

BEAM
DOOR
WALL
BLACK BOARD
BOOKCASE
CLUTTER
TABLE
CHAIR





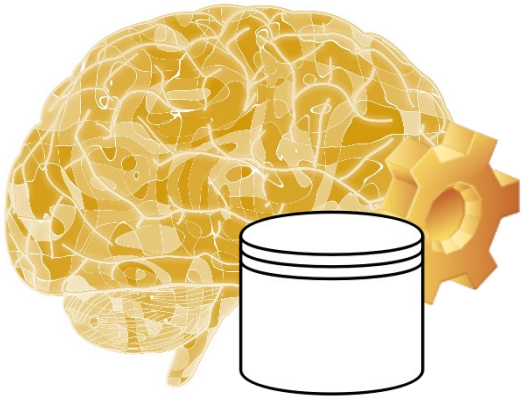
- 3D Point Cloud Specificities
- Representation & Structuration
- Automation

Semantics & Knowledge Integration



TODAY

WHAT WE WANT



KNOWLEDGE

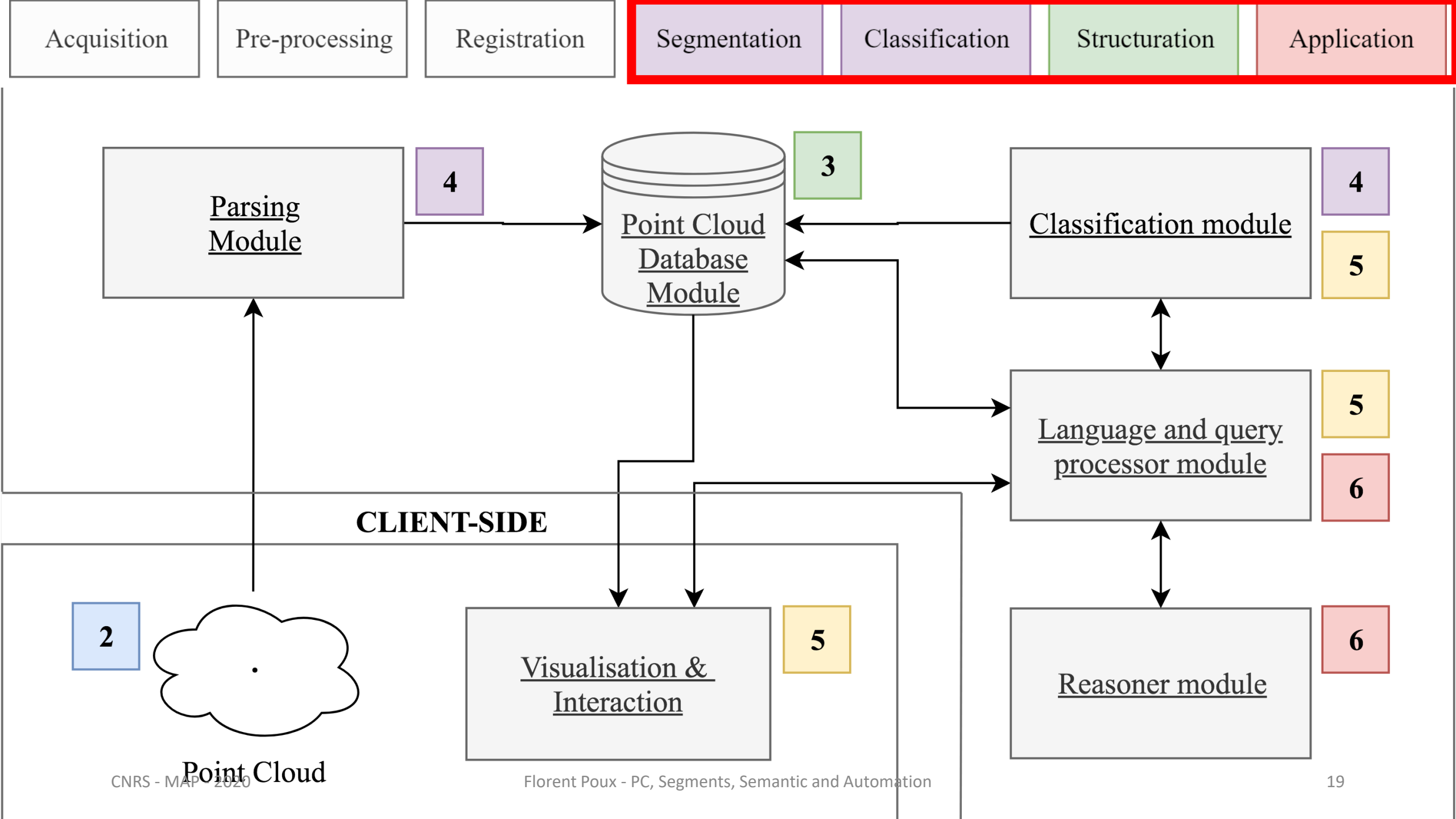
DELIVERY

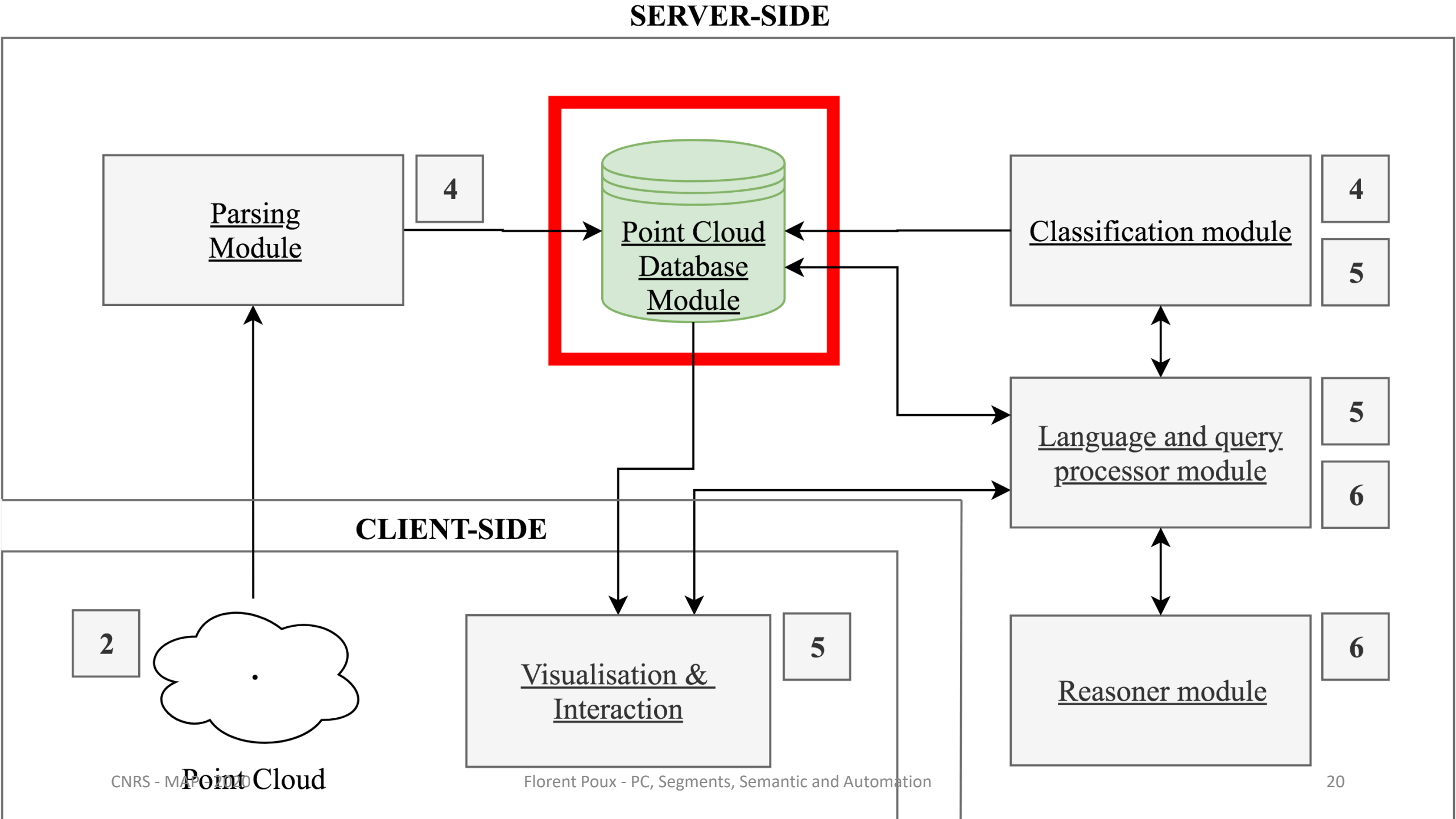
INTERPRETATION

EXTRACTION (Meshed...)

SIMULATION, Reasoning, ...

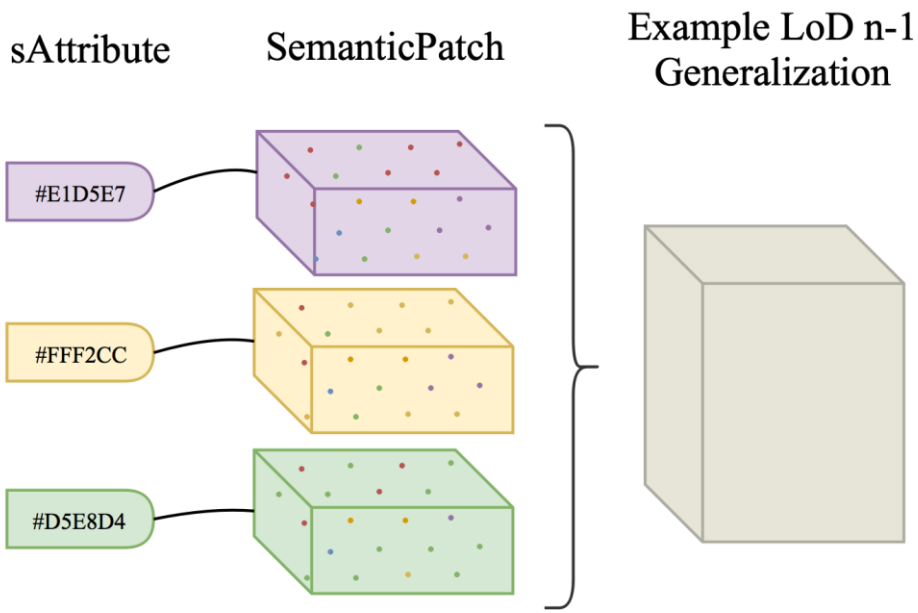
How to extract and integrate knowledge within 3D point clouds for autonomous decision-making systems?

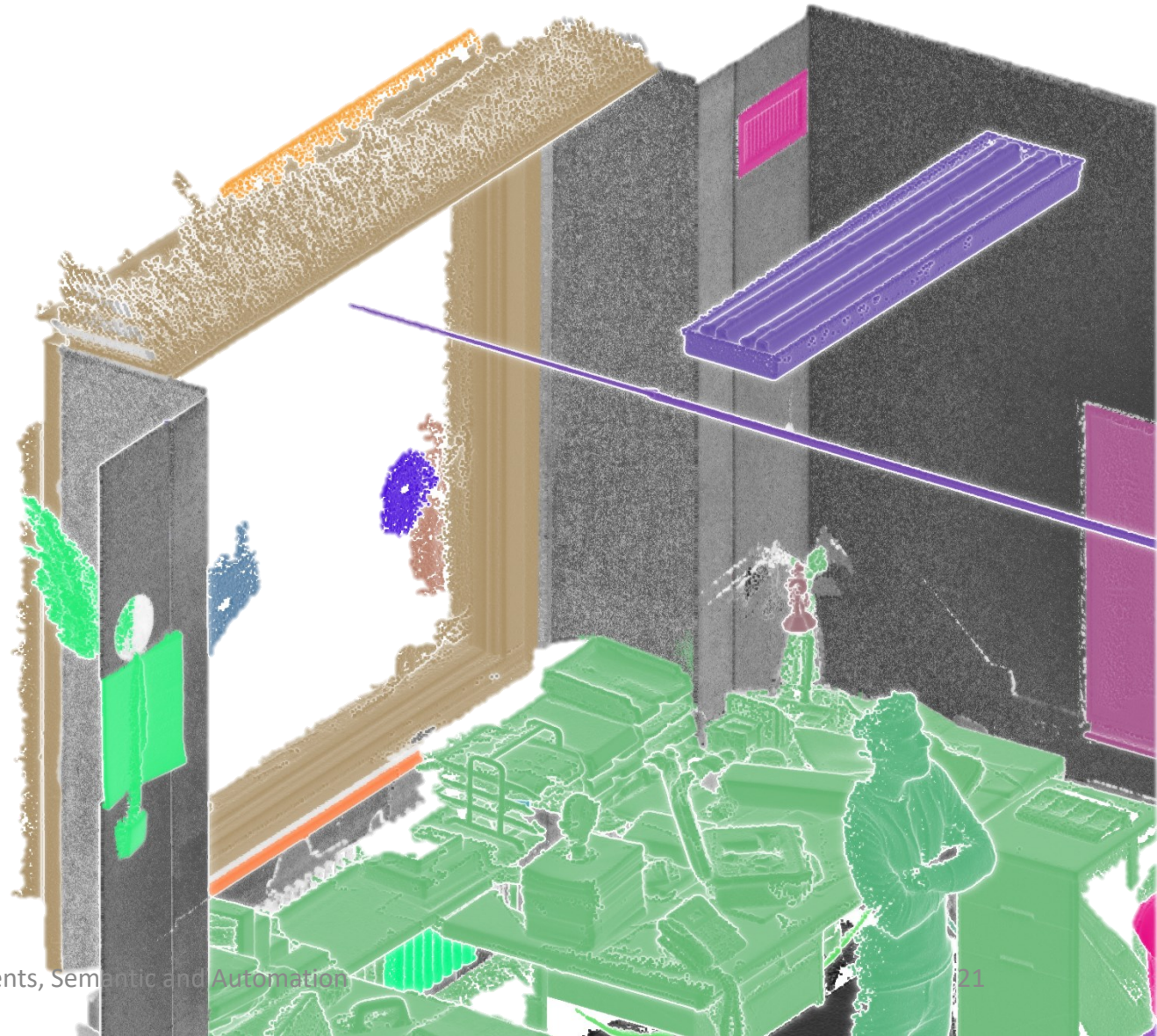

Acquisition
Pre-processing
Registration
Segmentation
Classification
Structuration
Application
Parsing Module
4
Point Cloud Database Module
3
Classification module
4
5
Language and query processor module
5
6
CLIENT-SIDE
2
Point Cloud
Visualisation & Interaction
5
Reasoner module
6

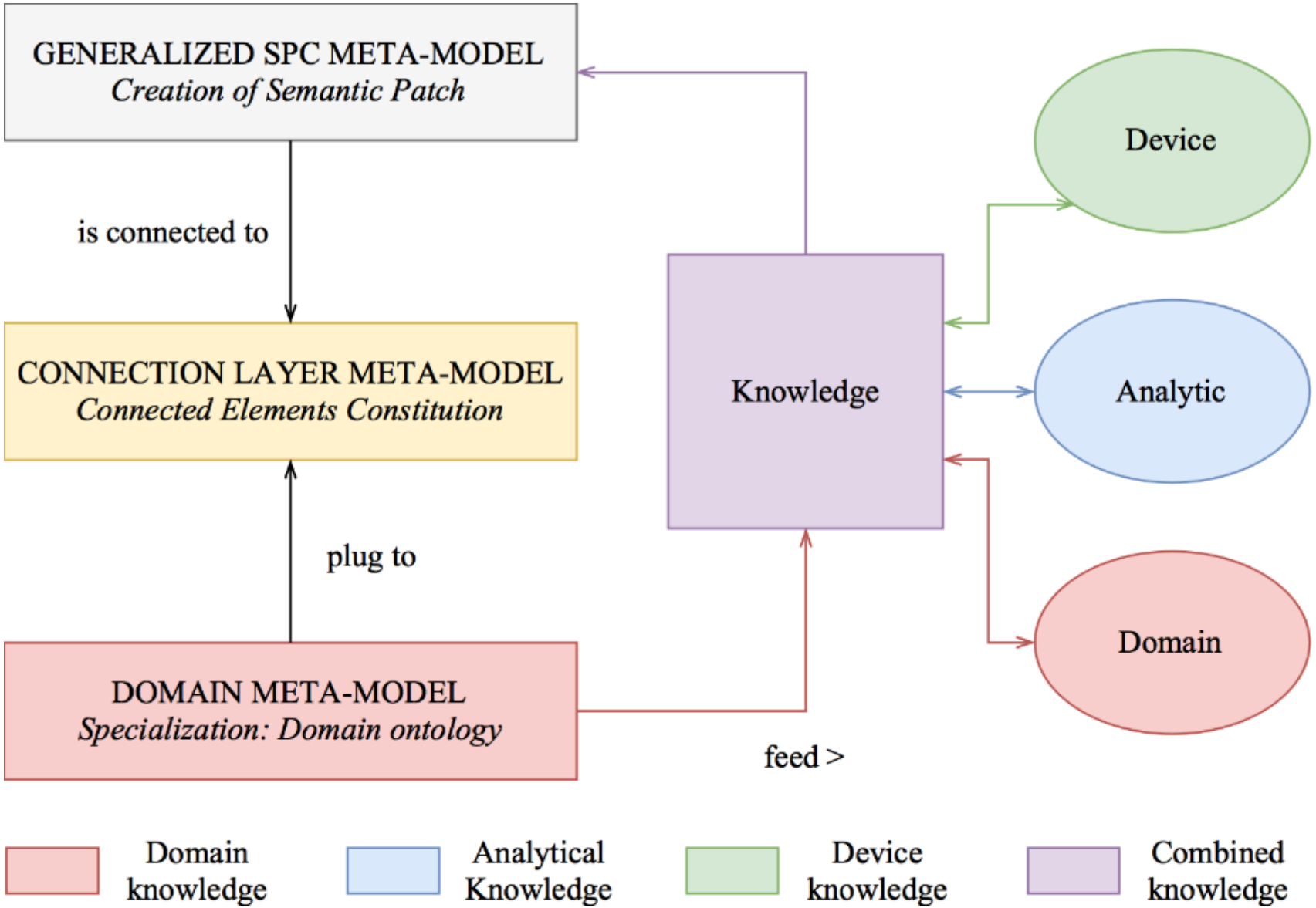

SERVER-SIDE
Parsing Module
4
Point Cloud Database Module
Classification module
4
5
Language and query processor module
5
6
Reasoner module
6
CLIENT-SIDE
2
Point Cloud
Visualisation & Interaction
5

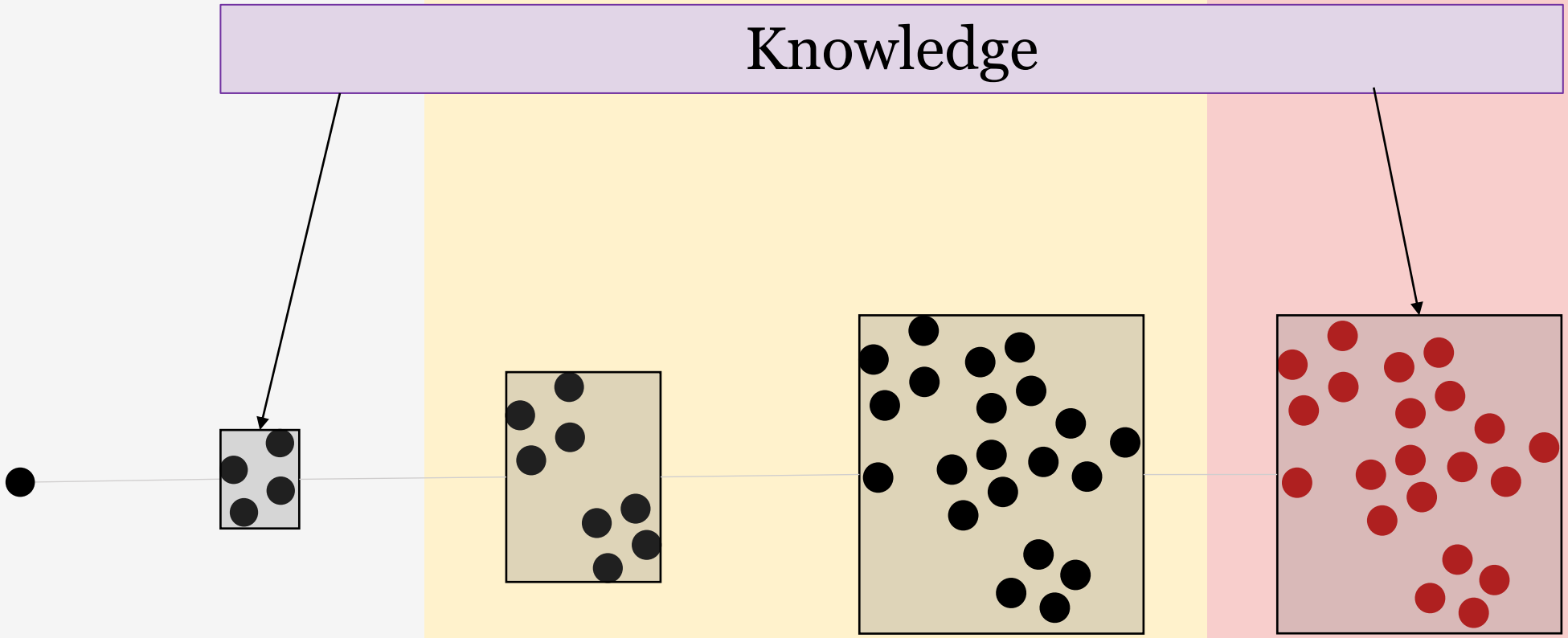
Point Cloud Specificity

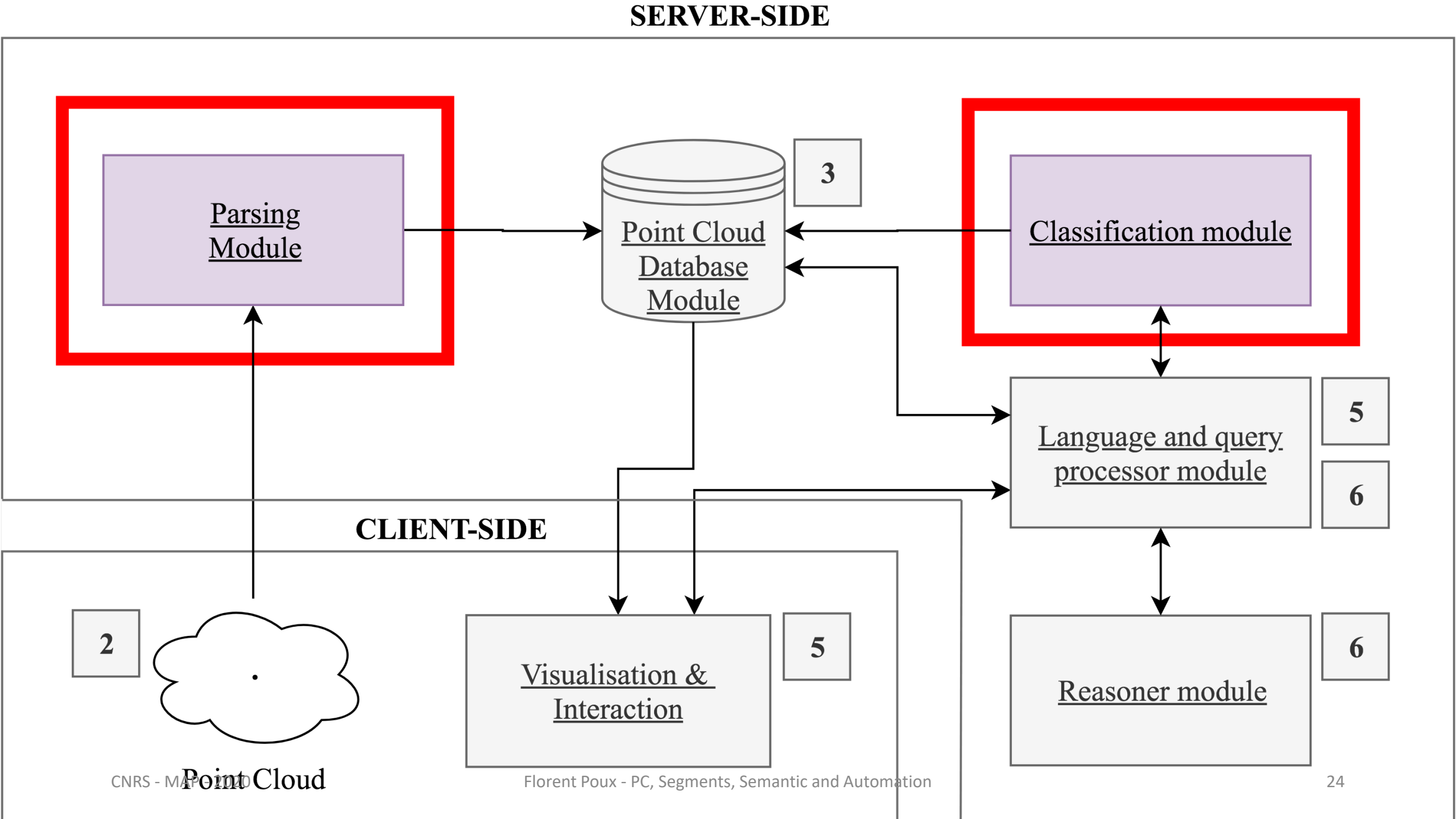
Unstructured and too sparse for DBMS per-row insertion



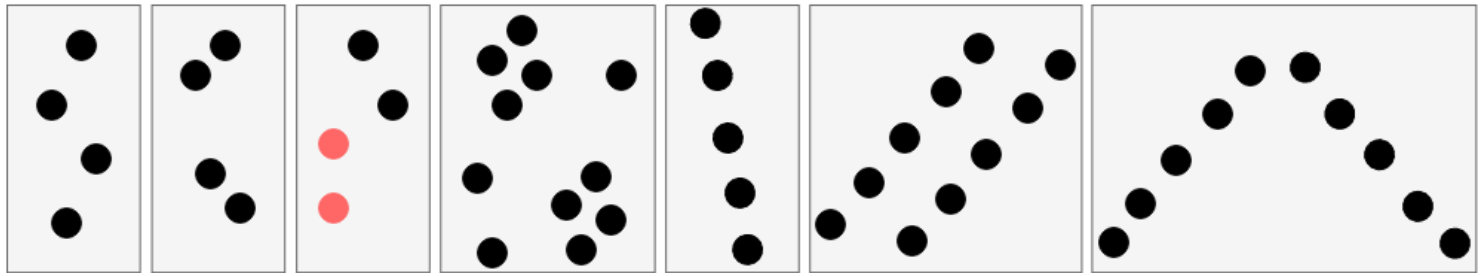



GENERALIZED SPC META-MODEL
Creation of Semantic Patch
is connected to
CONNECTION LAYER META-MODEL
Connected Elements Constitution
plug to
DOMAIN META-MODEL
Specialization: Domain ontology
Knowledge
Device
Analytic
Domain
feed >
Domain knowledge
Analytical Knowledge
Device knowledge
Combined knowledge


Knowledge
Point
Semantic Patch
Connected Element
Aggregated Element
Class Instance

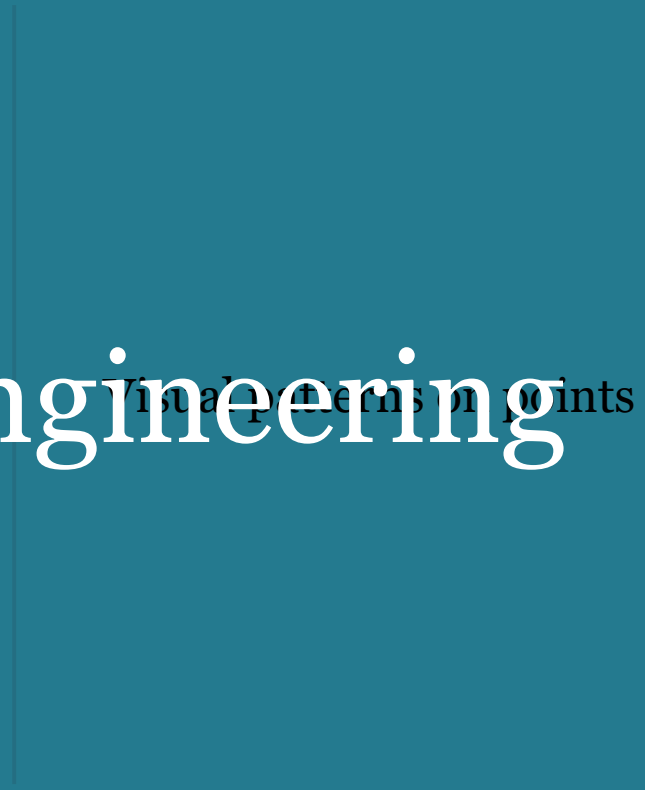

SERVER-SIDE
Parsing Module
Point Cloud Database Module
3
Classification module
Language and query processor module
5
6
CLIENT-SIDE
2
Point Cloud
Visualisation & Interaction
5
Reasoner module
6

Gestalt's theory

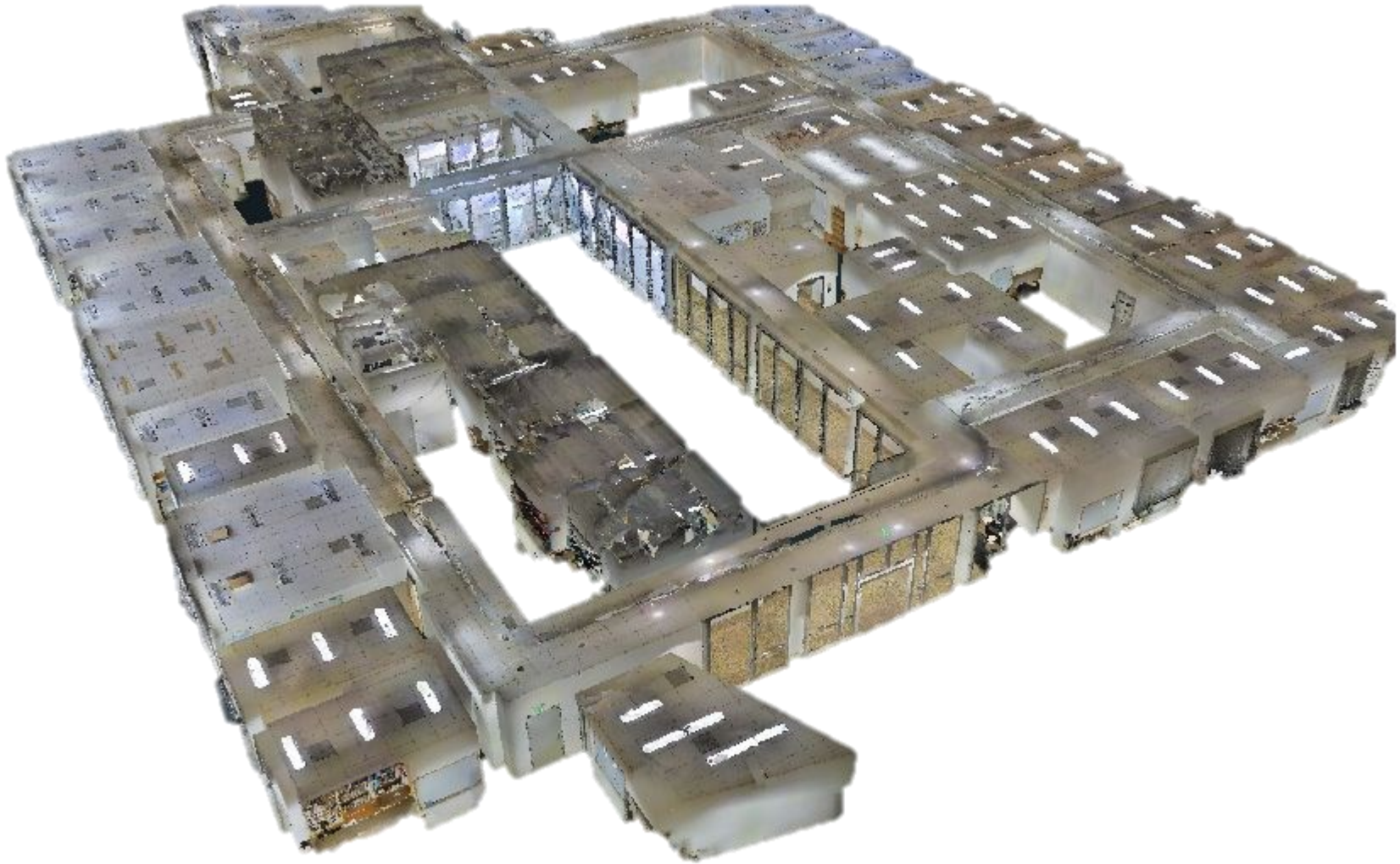


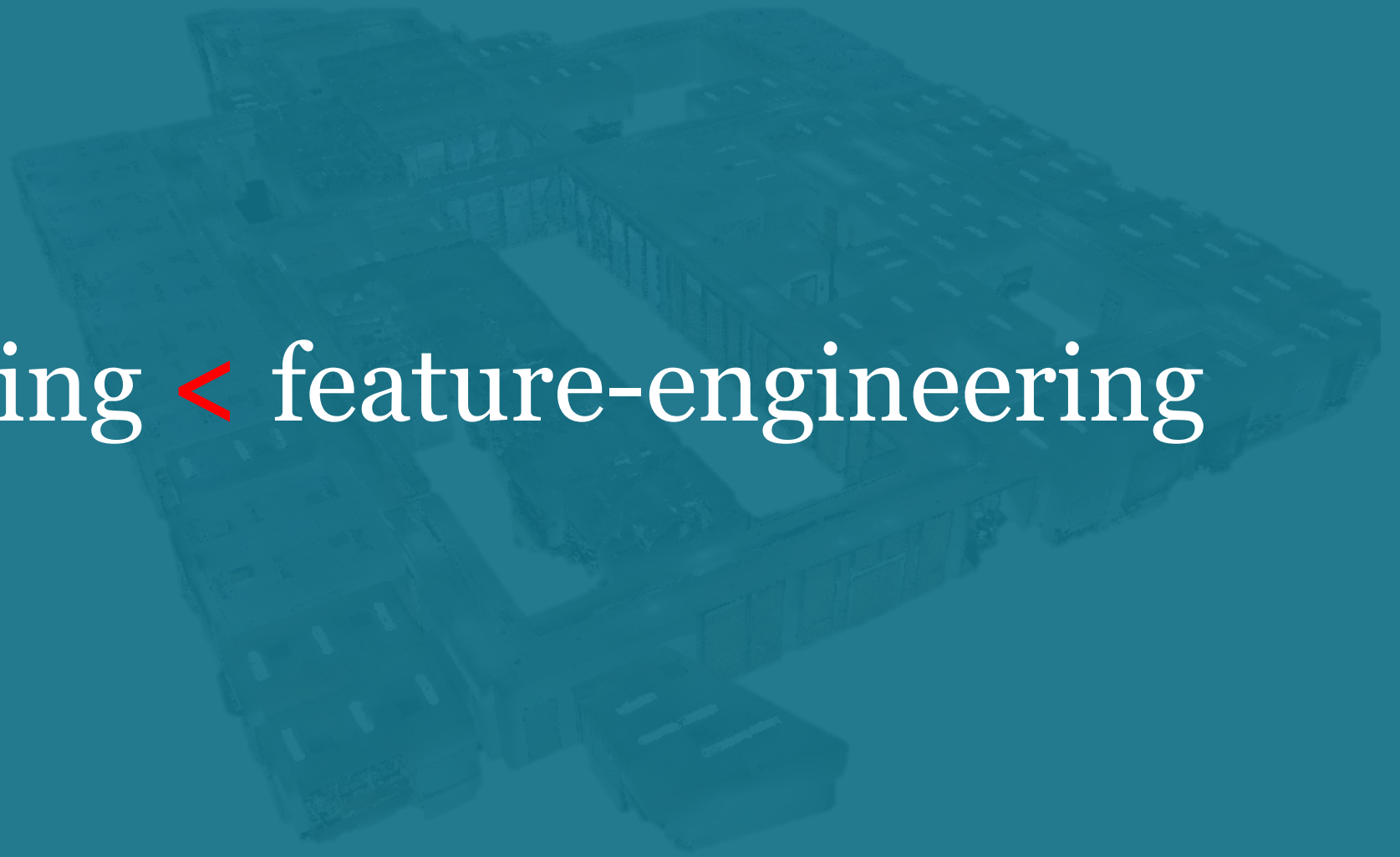
Visual patterns on points

Deep learning > feature-engineering

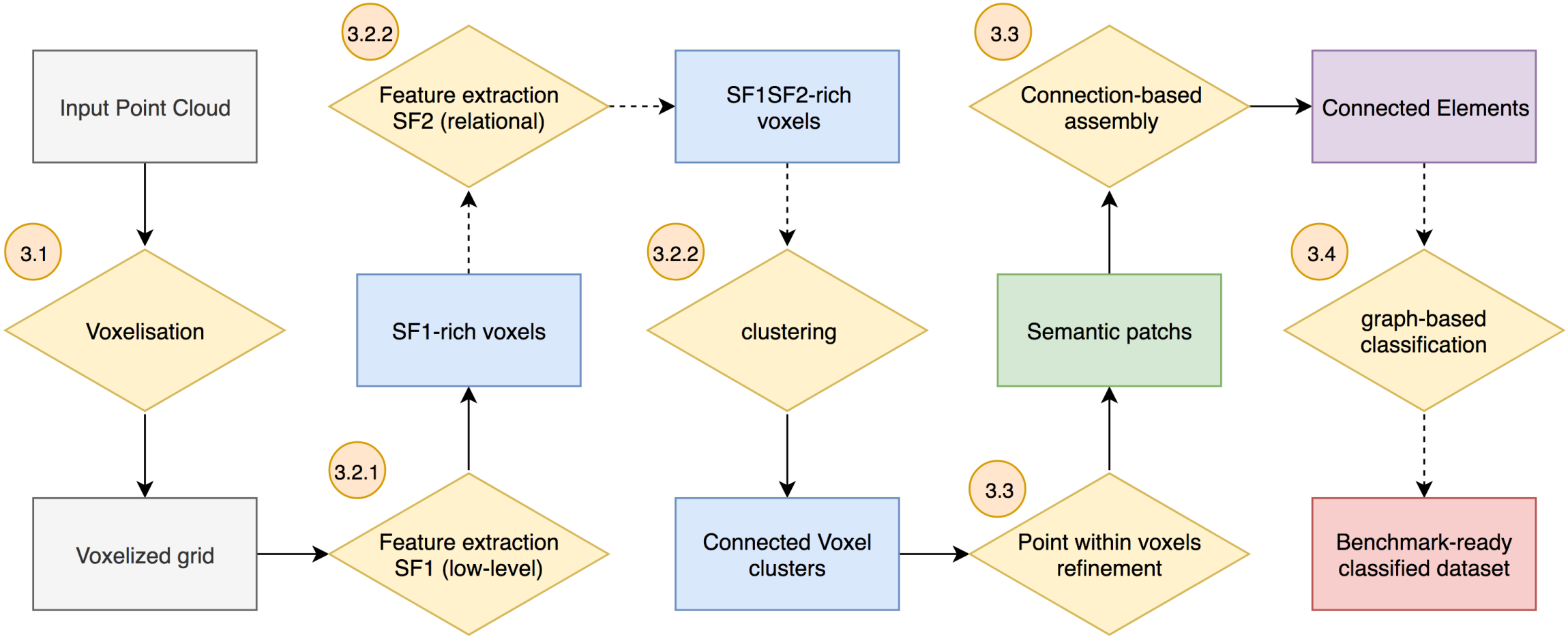


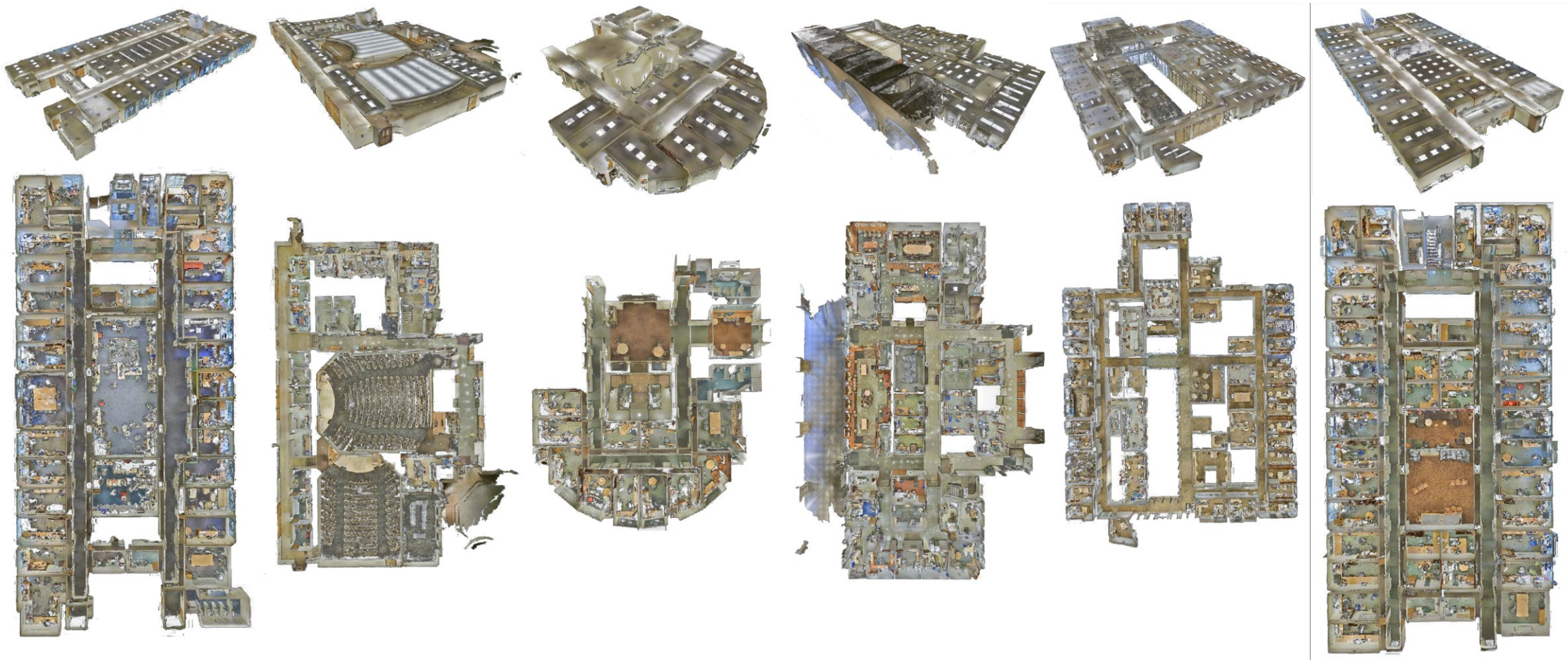
Point Cloud Datasets

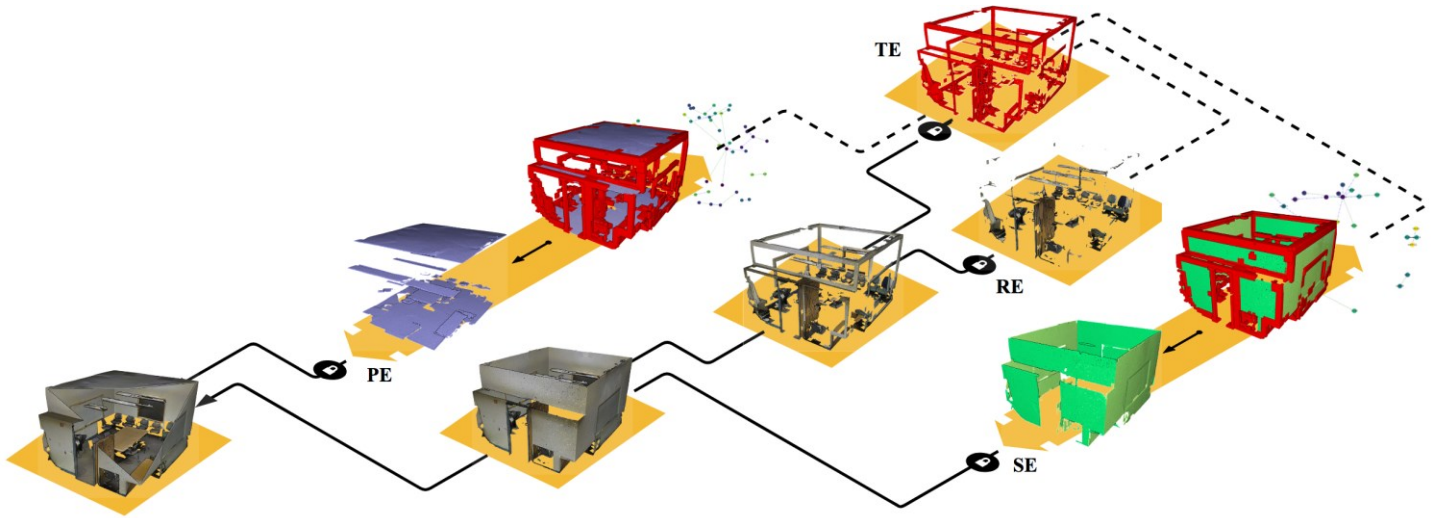




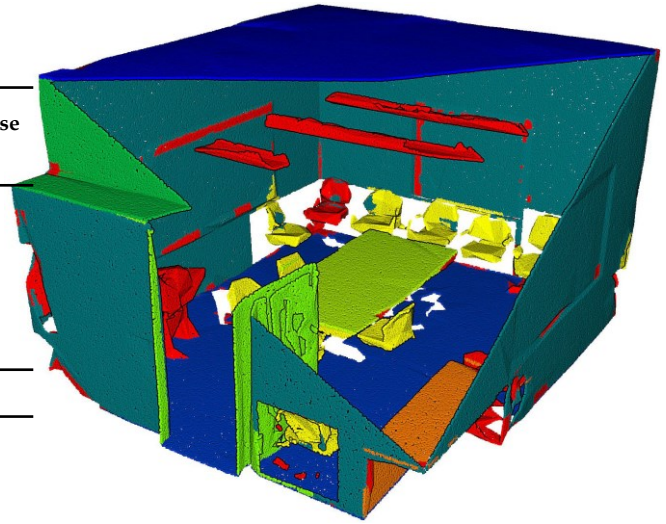
Deep learning < feature-engineering

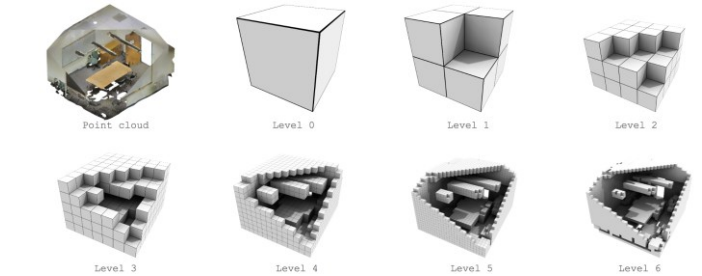

Input Point Cloud
3.1
Voxelisation
Voxelized grid
3.2.1
Feature extraction SF1 (low-level)
SF1-rich voxels
3.2.2
Feature extraction SF2 (relational)
SF1SF2-rich voxels
3.2.2
clustering
Connected Voxel clusters
3.3
Point within voxels refinement
Semantic patchs
3.3
Connection-based assembly
Connected Elements
3.4
graph-based classification
Benchmark-ready classified dataset

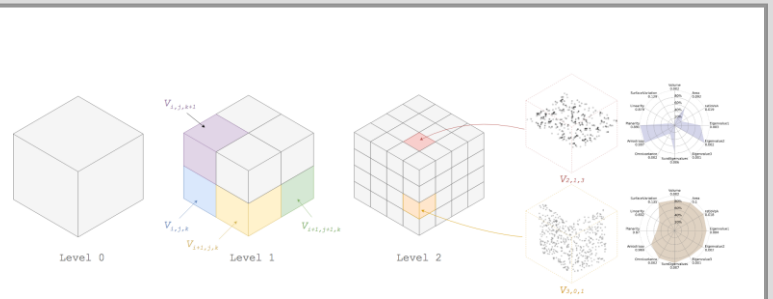


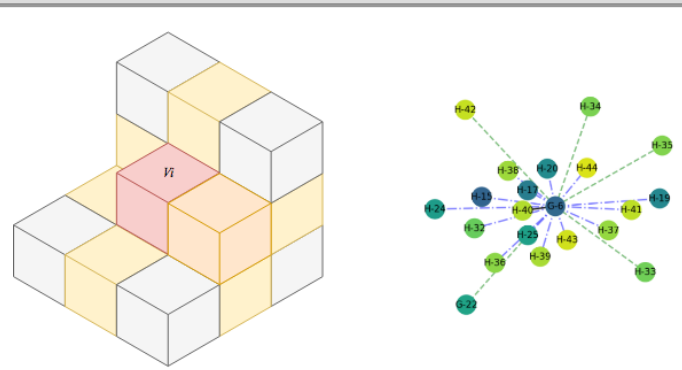


Overall Precision	Ceiling 0	Floor 1	Wall 2	Beam 3	Door 6	Table 7	Chair 8	Bookcase 10
Baseline (no colour) [16]	0.48	0.81	0.68	0.68	0.44	0.51	0.12	0.52
Baseline (full) [16]	0.72	0.89	0.73	0.67	0.54	0.46	0.16	0.55
Ours	**0.94**	**0.96**	**0.79**	0.53	0.19	**0.88**	**0.72**	0.2





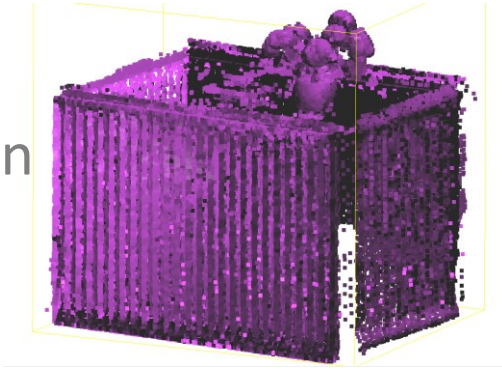




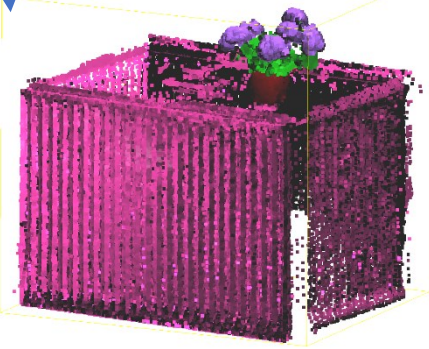
10 million points / minute

Overall Precision	Ceiling 0	Floor 1	Wall 2	Beam 3	Door 6	Table 7	Chair 8	Bookcase 10
Baseline (no colour) [16]	0.48	0.81	0.68	0.68	0.44	0.51	0.12	0.52
Baseline (full) [16]	0.72	0.89	0.73	0.67	0.54	0.46	0.16	0.55
Ours	**0.94**	**0.96**	**0.79**	0.53	0.19	**0.88**	**0.72**	0.2

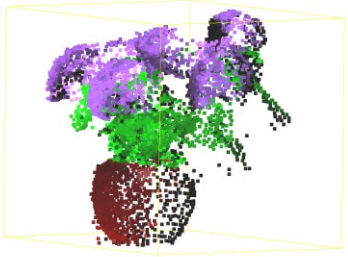
Isolation



Relation « host/guest »



Extract

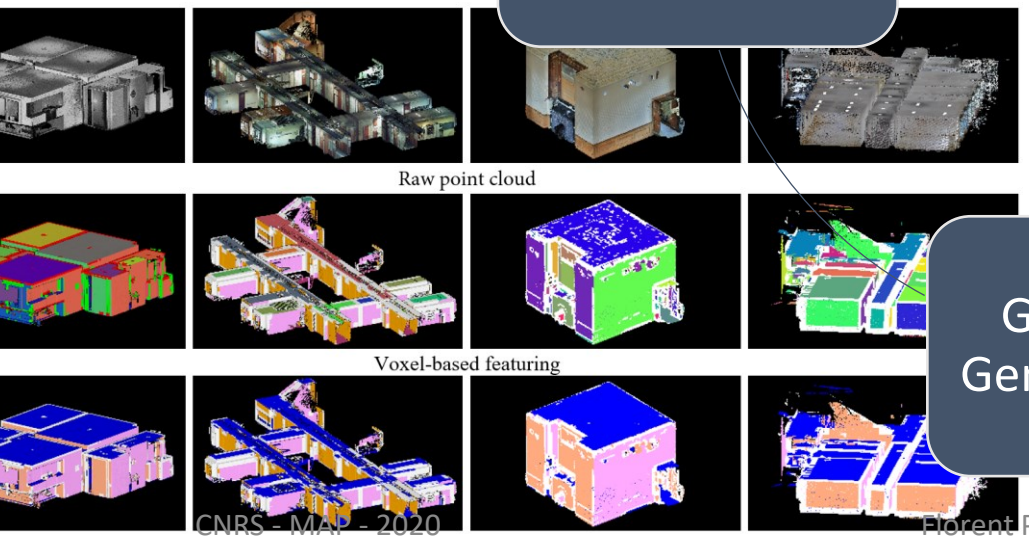


Context / Proximity

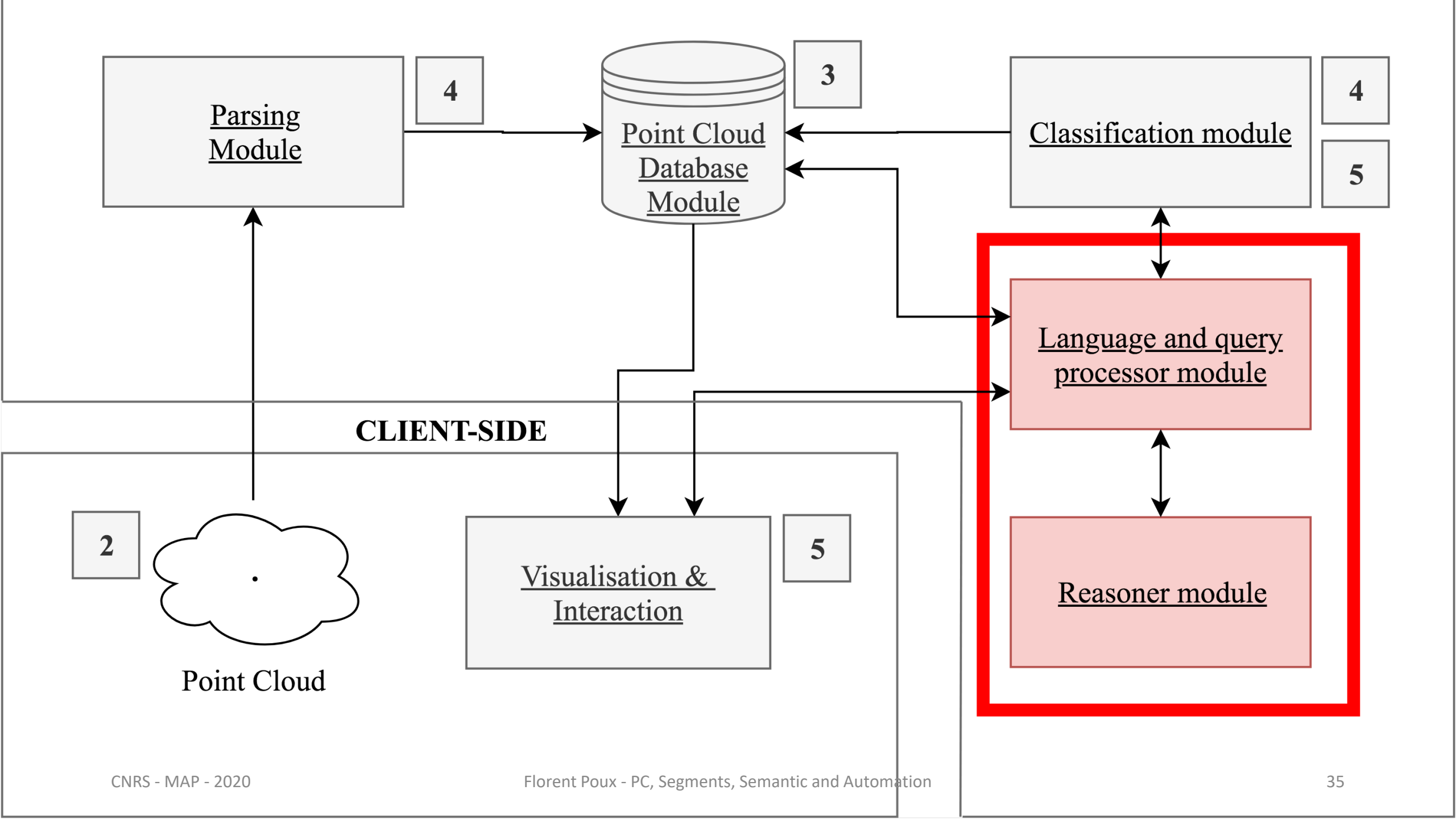
Relationships / Topology

Geometries Generalizations

Local Features



Knowledge-driven


Parsing Module
4
Point Cloud Database Module
3
Classification module
4
5
Language and query processor module
Reasoner module
CLIENT-SIDE
2
Point Cloud
Visualisation & Interaction
5

A classified entity

chair

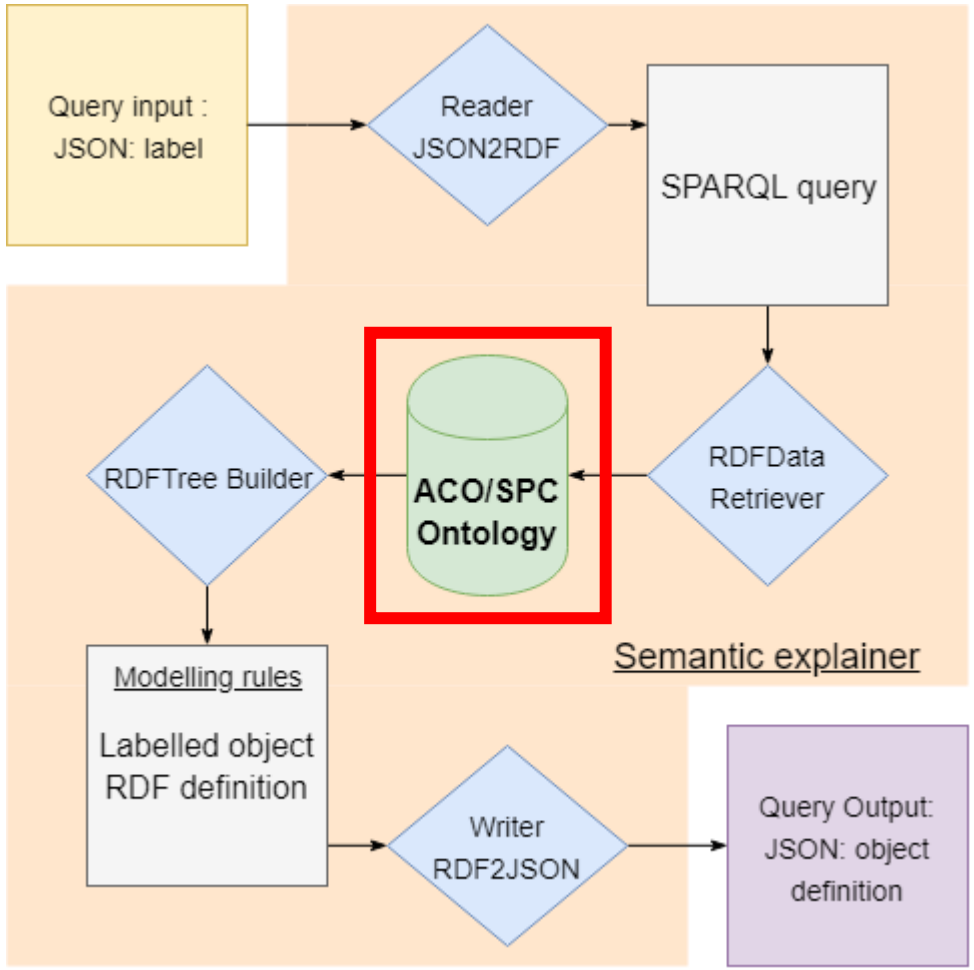
DBpedia Browse using Formats Faceted Browser Sparql Endpoint

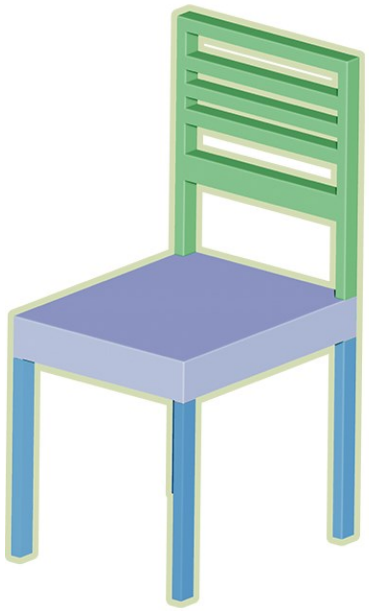
About: Chaise

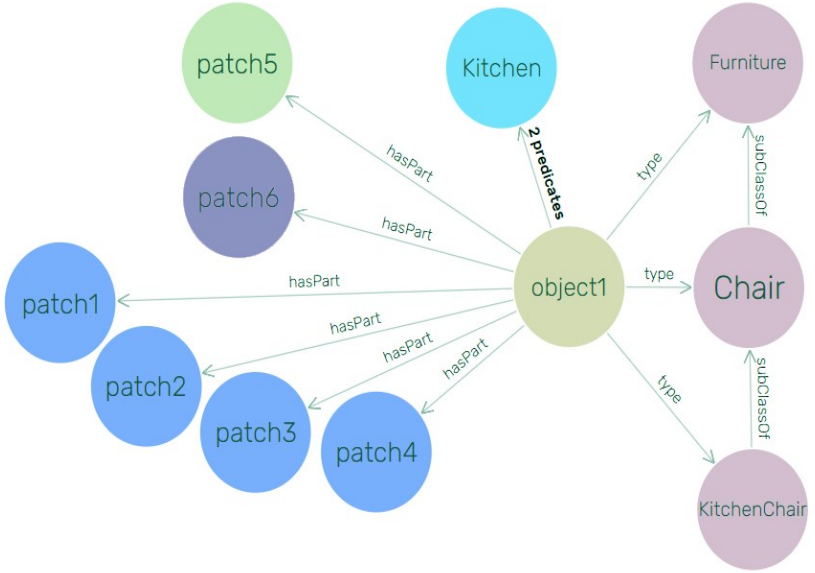
An Entity of Type : Ã□uvre musicale, from Named Graph : http://dbpedia.org, within Data Space : dbpedia.org

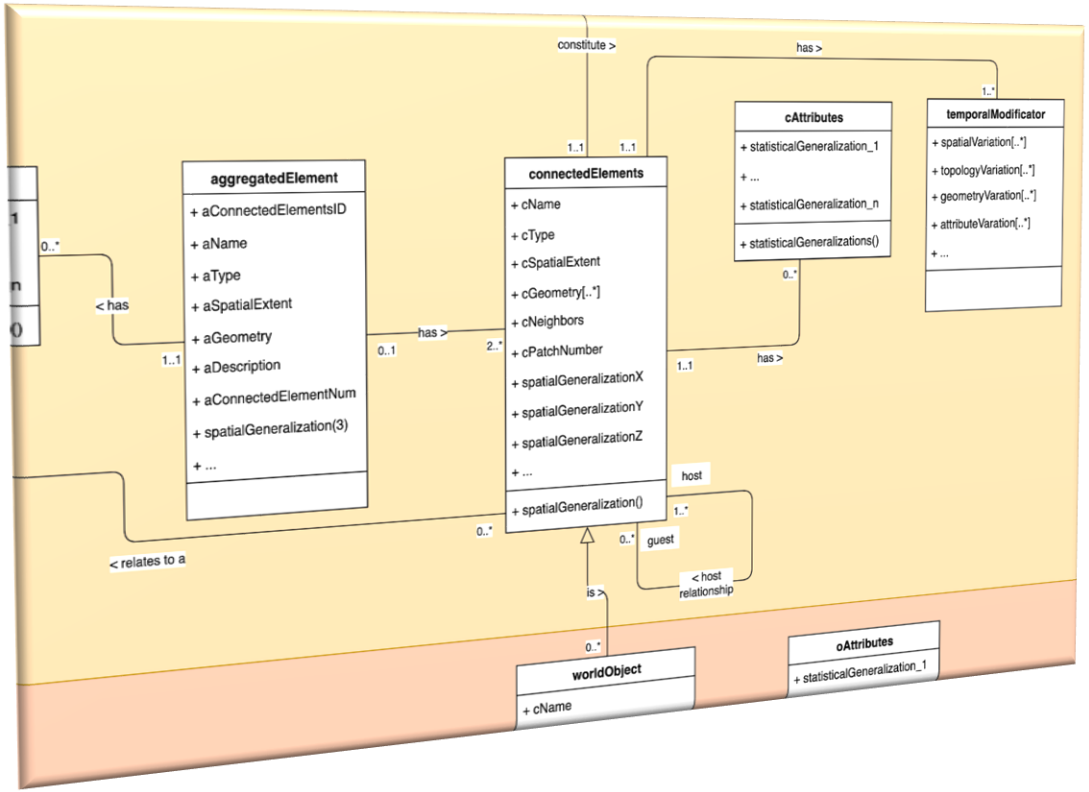
Une chaise est un type de siège, c'est-à-dire de meuble muni d'un dossier et destiné à ce qu'une personne s'assoie dessus. Un siège pour une personne sans dossier ni repose-bras est un tabouret ; pour plus d'une personne c'est un sofa ou un banc. Un repose-pieds séparé pour une chaise s'appelle un ottoman. La chaise comporte : * un piètement, généralement composé de quatre pieds, parfois renforcé par une entretoise ; * une assise, la profondeur d'assise d'une chaise est comprise entre 45 et 55 cm, et sa hauteur est normalement de 45 cm ; * un dossier.

Property	Value
dbo:abstract	▪ A chair is a piece of furniture with a raised surface, commonly used to seat a single person. Chairs are supported most often by four legs and have a back; however, a chair can have three legs or can have a different shape. Chairs are made of a wide variety of materials, ranging from wood to metal to synthetic material (e.g., plastic), and they may be padded or upholstered in various colors and fabrics, either just on the seat (as with some dining room chairs) or on the entire chair. Chairs are used in a number of rooms in homes (e.g., in living rooms, dining rooms and dens), in schools and offices (with desks), and in various other workplaces. A chair without a back or arm rests is a stool, or when raised up, a bar stool. A chair with arms is an armchair and with upholstery, reclining action, and a fold-out footrest, a recliner. A permanently fixed chair in a train or theater is a seat or, in an airplane, airline seat; when riding, it is a saddle and bicycle saddle, and for an automobile, a car seat or infant car seat. With wheels it is a wheelchair and when hung from above, a swing. An upholstered, padded chair for more than one person is a couch, sofa, settee, or "loveseat"; or if is not upholstered, a bench. A separate footrest for a chair, usually upholstered, is known as an ottoman, hassock or pouffe. (en) ▪ Une chaise est un type de siège, c'est-à-dire de meuble muni d'un dossier et destiné à ce qu'une personne s'assoie dessus. Un siège pour une personne sans dossier ni repose-bras est un tabouret ; pour plus d'une personne c'est un sofa ou un banc. Un repose-pieds séparé pour une chaise s'appelle un ottoman. Le dossier s'élève parfois au-dessus de la hauteur de la tête, et souvent ne s'étend pas jusqu'au siège, permettant une circulation d'air. Le dossier et parfois l'assise sont souvent faits de matériaux poreux ou sont ajourés à fins de décoration et de ventilation. Il y a quelquefois des repose-têtes séparés. La chaise comporte : * un piètement, généralement composé de quatre pieds, parfois renforcé par une entretoise ; * une assise, la profondeur d'assise d'une chaise est comprise entre 45 et 55 cm, et sa hauteur est normalement de 45 cm ; * un dossier. Elle ne comprend que très rarement des accotoirs (bras) réservés aux fauteuils. mais elle peut comporter un accoudoir sur le haut du dossier comme pour le Prie-Dieu ou la chaise ponteuse. (fr)
dbo:thumbnail	▪ wiki-commons:Special:FilePath/PostureFoundationGarments05fig3.png?width=300
dbo:wikiPageID	▪ 262642 (xsd:integer)
dbo:wikiPageRevisionID	▪ 744995471 (xsd:integer)
dct:subject	▪ dbc:Chairs


Query input :
JSON: label
Reader
JSON2RDF
SPARQL query
RDFTree Builder
ACO/SPC
Ontology
RDFData
Retriever
Semantic explainer
Modelling rules
Labelled object
RDF definition
Writer
RDF2JSON
Query Output:
JSON: object
definition




patch5
Kitchen
Furniture
patch6
hasPart
2 predicates
type
subClassOf
hasPart
patch1
hasPart
object1
type
Chair
hasPart
patch2
hasPart
hasPart
patch3
patch4
type
subClassOf
KitchenChair

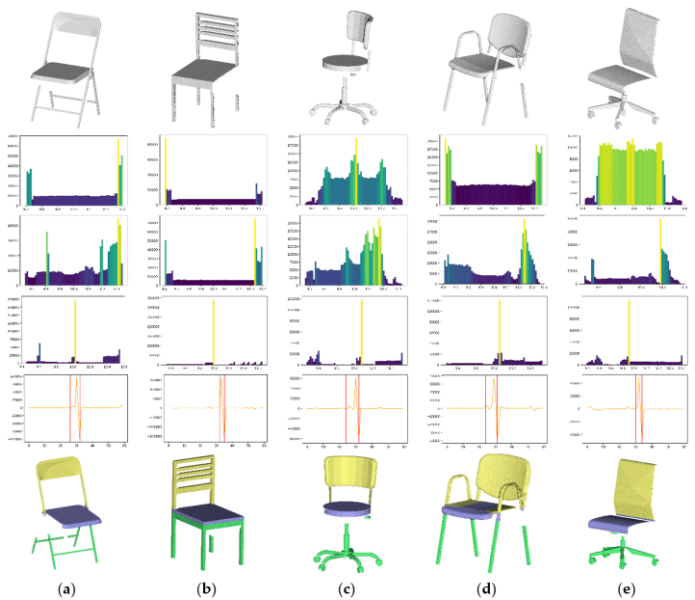


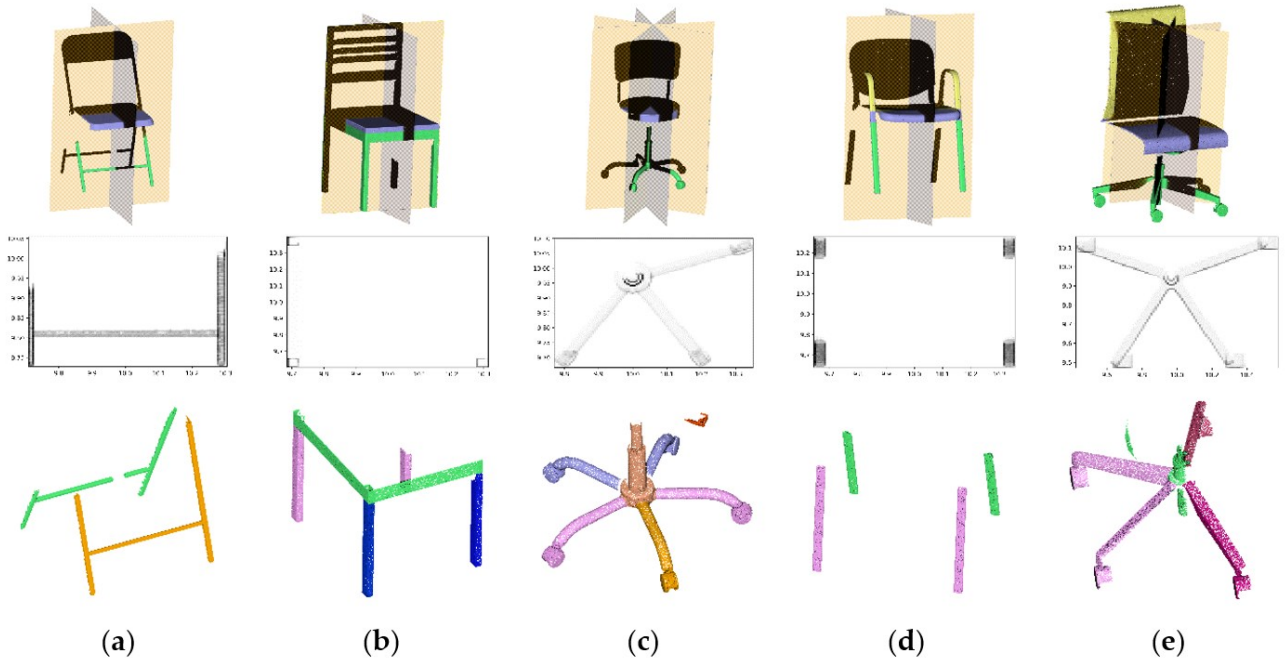
Connected Elements

- Aggregated-Element
- Normal-Element
- Sub-Element

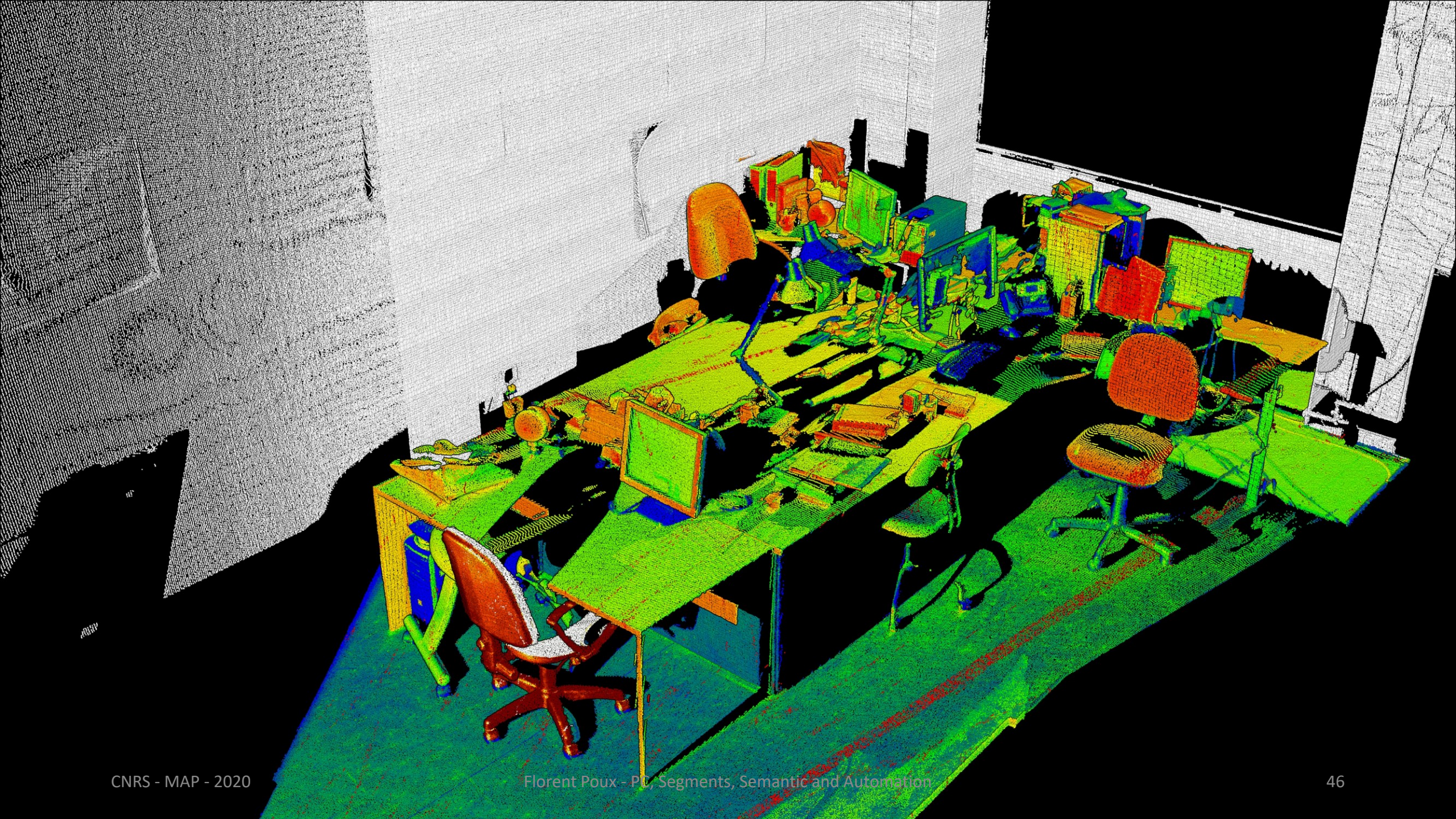
Chair = AE

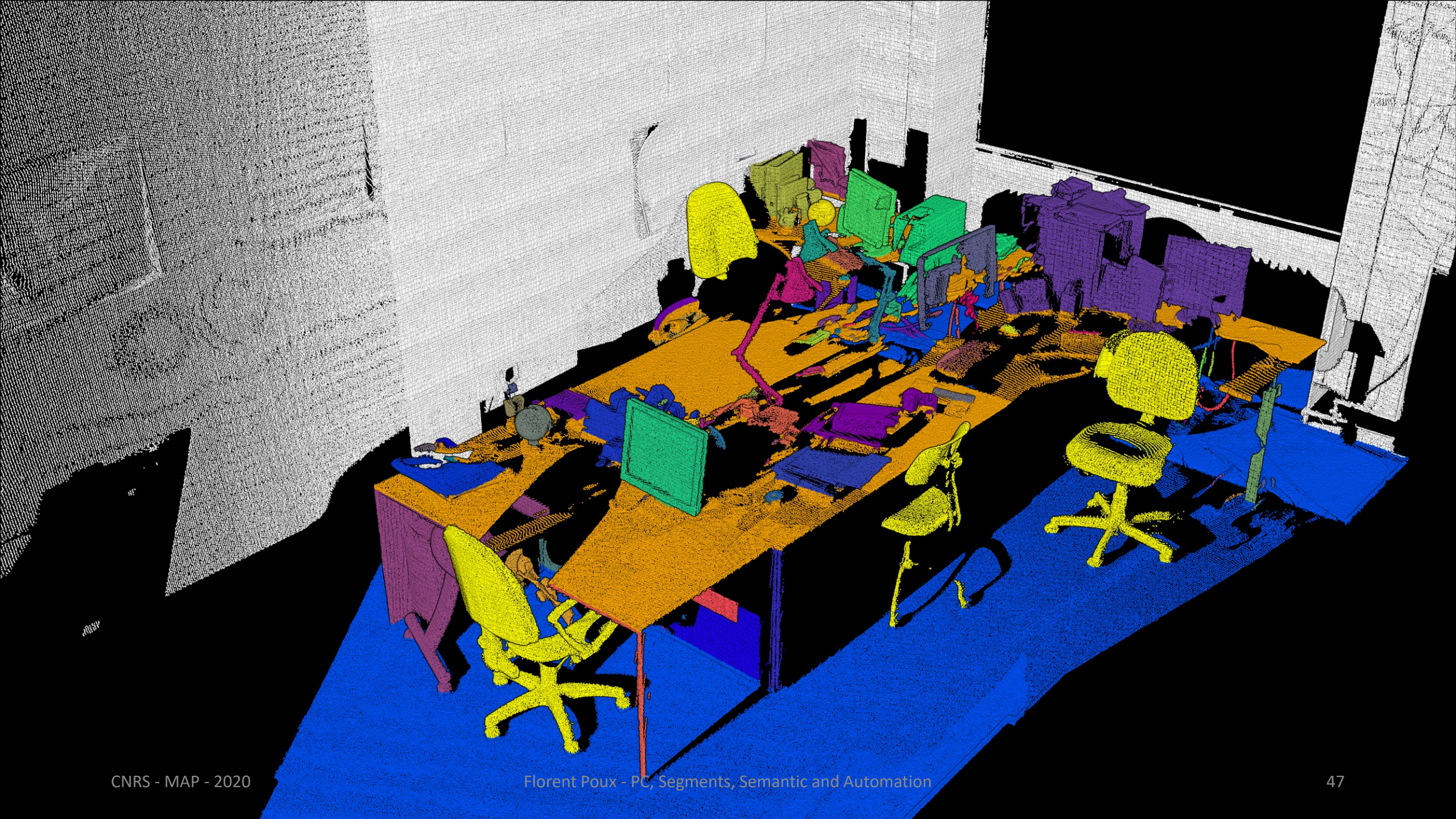
Part segmentation

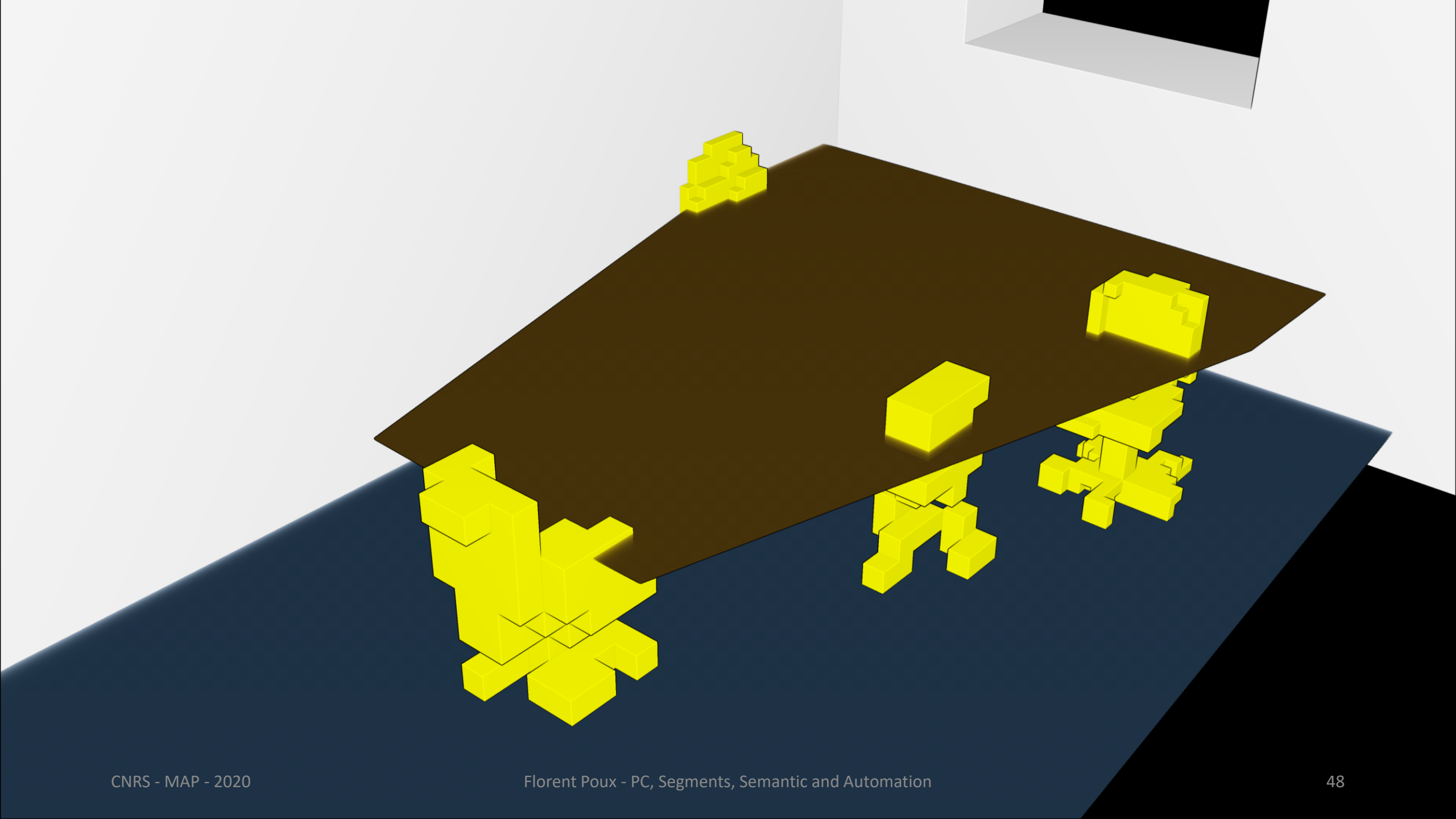

(a)
(b)
(c)
(d)
(e)

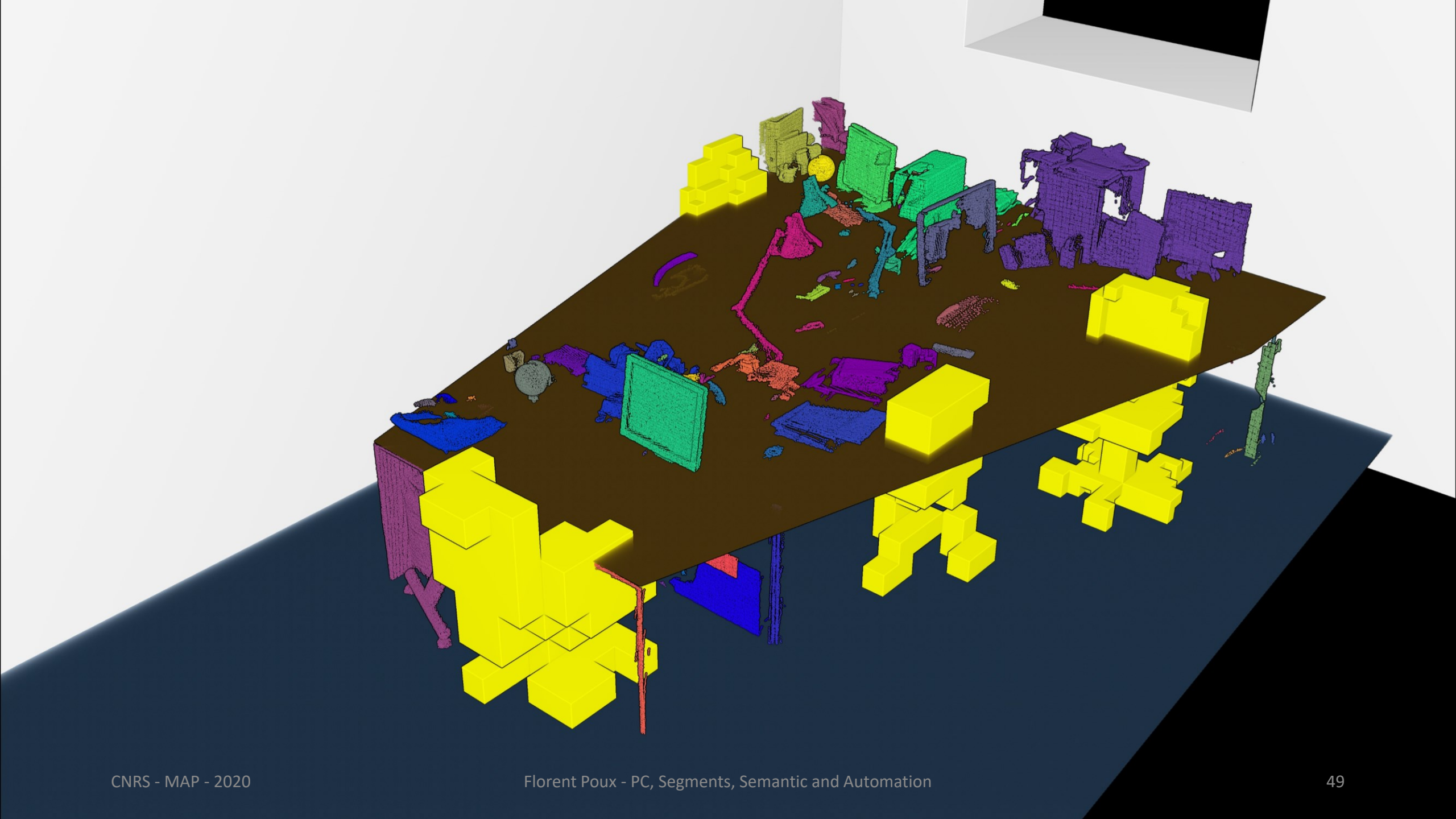

(a)
(b)
(c)
(d)
(e)

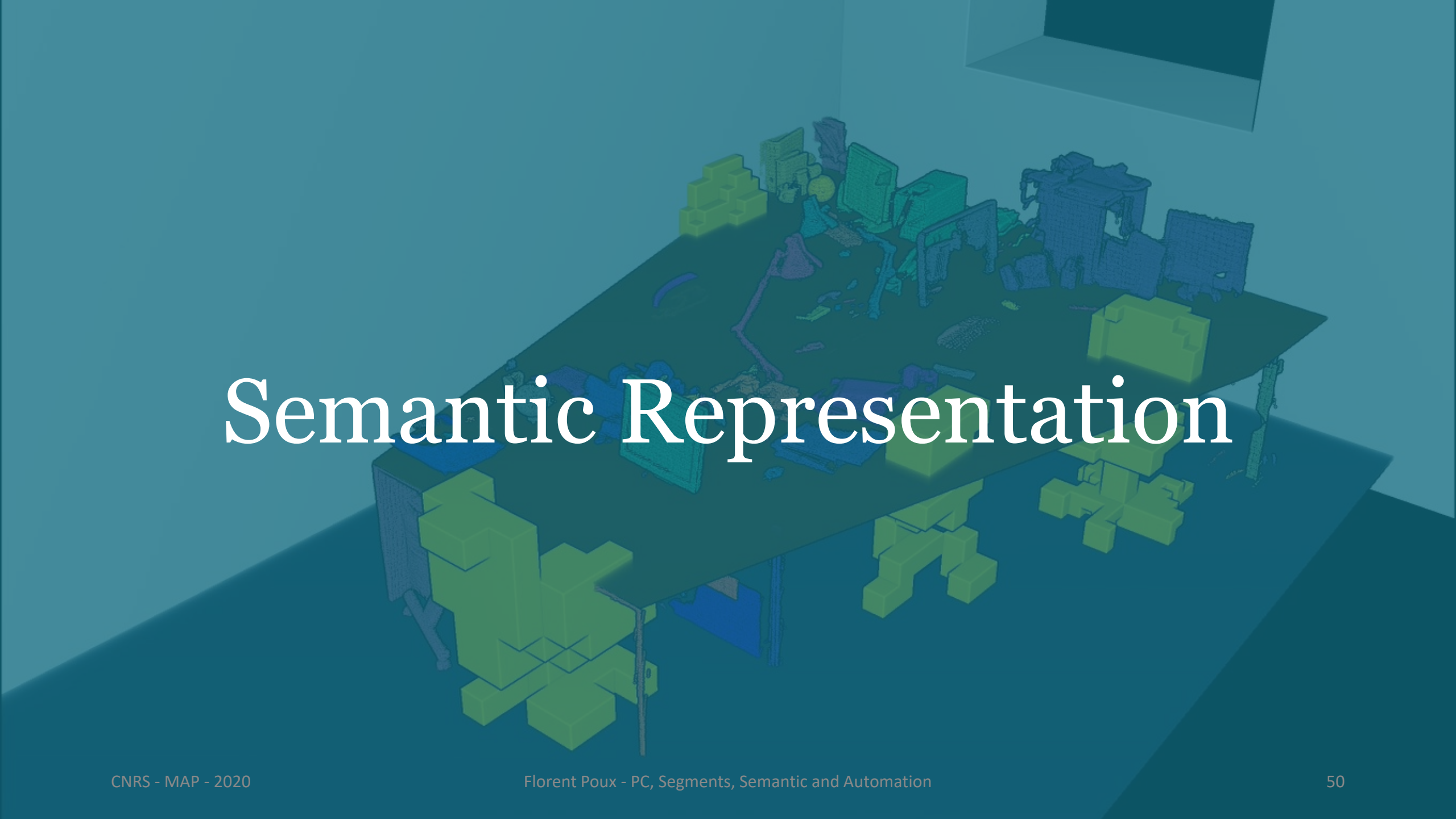
Characterization refinement









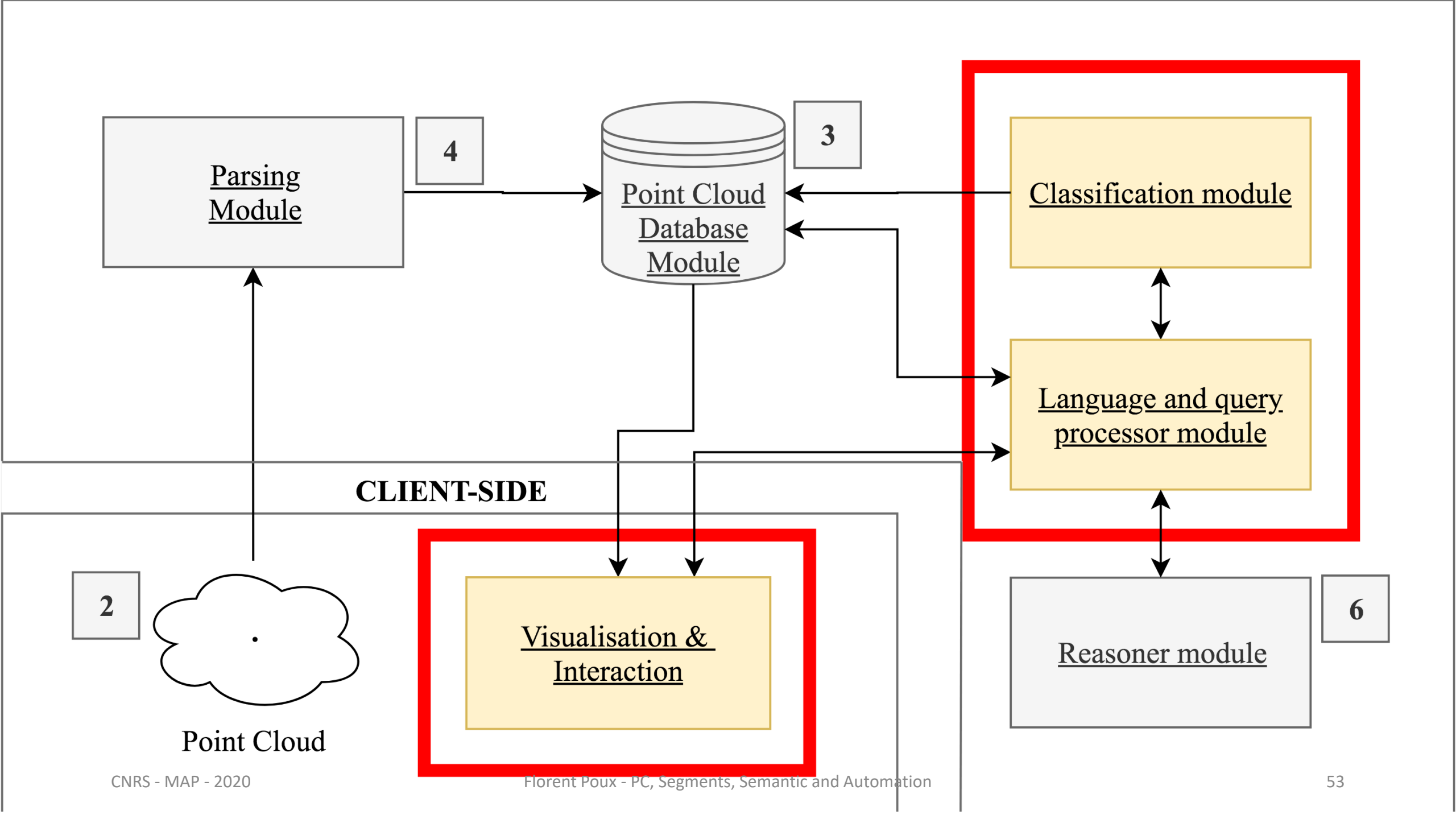


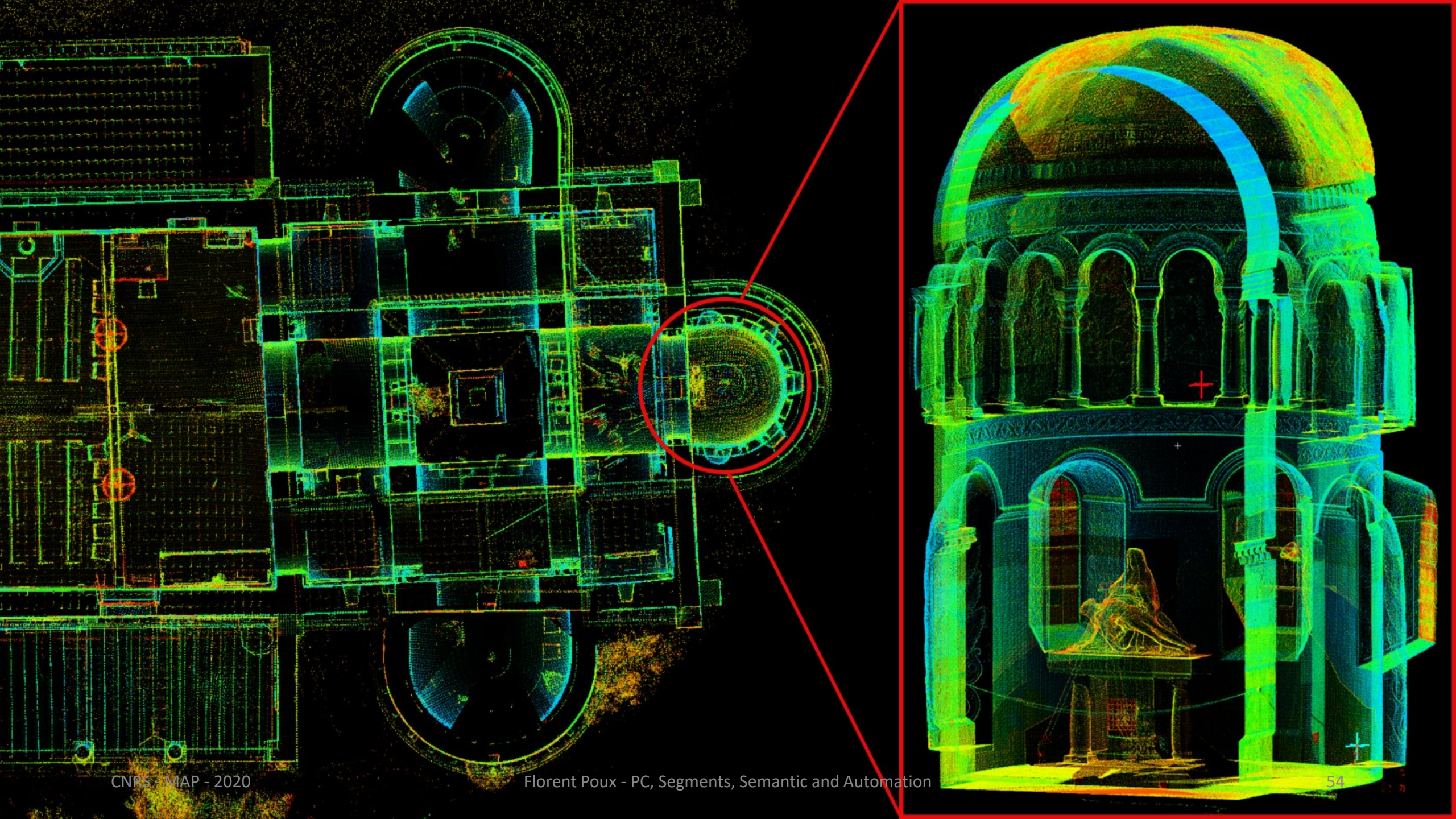
Semantic Representation

How to extract and integrate knowledge within 3D point clouds for autonomous decision-making systems?

1. Using a multi-level conceptual structure
2. Parsing PC at the lowest possible level
3. Plug a domain formalization through an ontology of classification
4. Generate a modular semantic representation

… Automatically …


Parsing Module
4
Point Cloud Database Module
3
Classification module
Language and query processor module
CLIENT-SIDE
2
Point Cloud
Visualisation & Interaction
Reasoner module
6




923B3325.CR2


923B3333.CR2


923B3340.CR2


923B3341.CR2


923B3347.CR2


923B3348.CR2


923B3354.CR2


923B3362.CR2


923B3337.CR2


923B3338.CR2


923B3343.CR2


923B3344.CR2

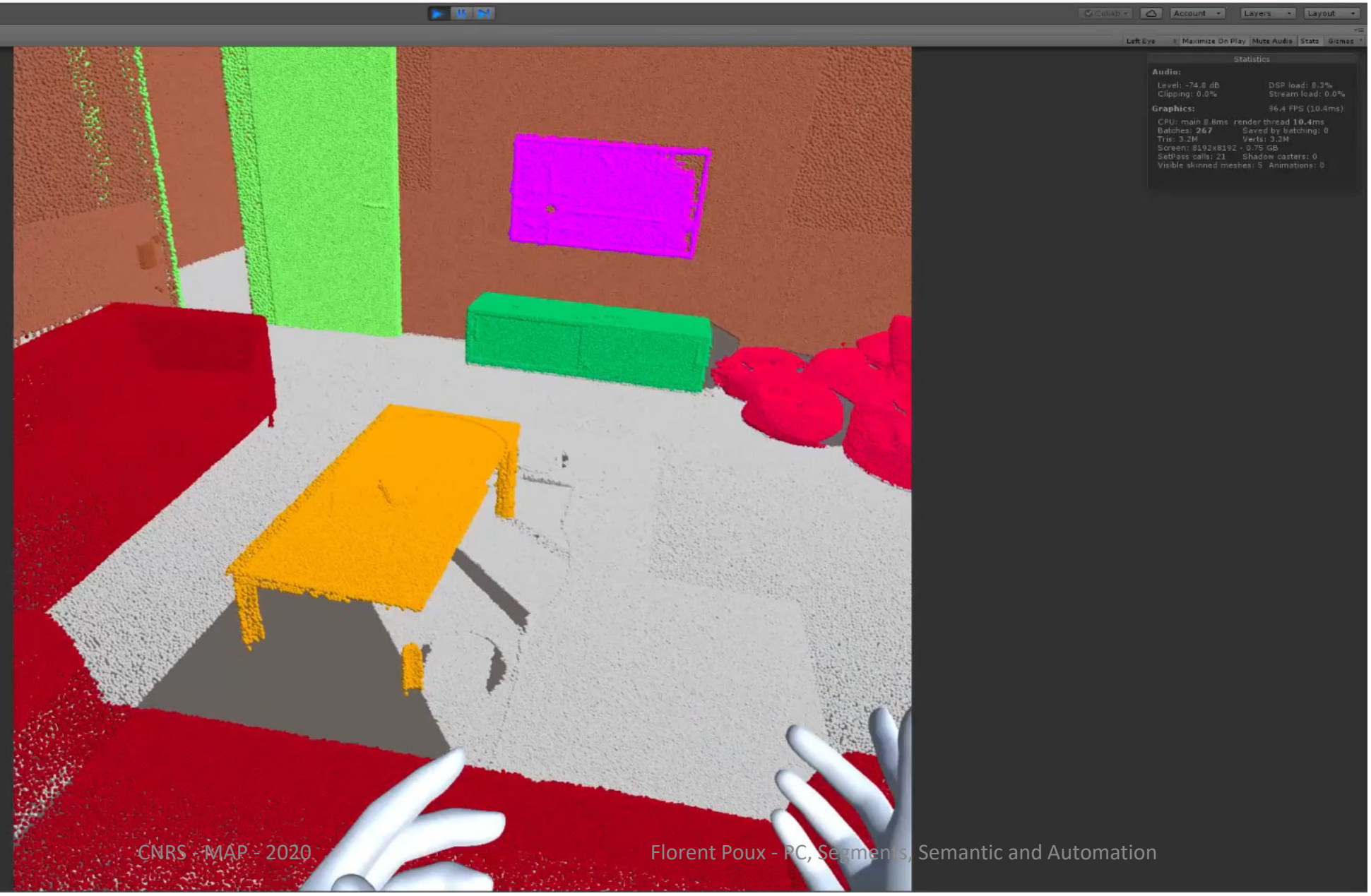

923B3351.CR2

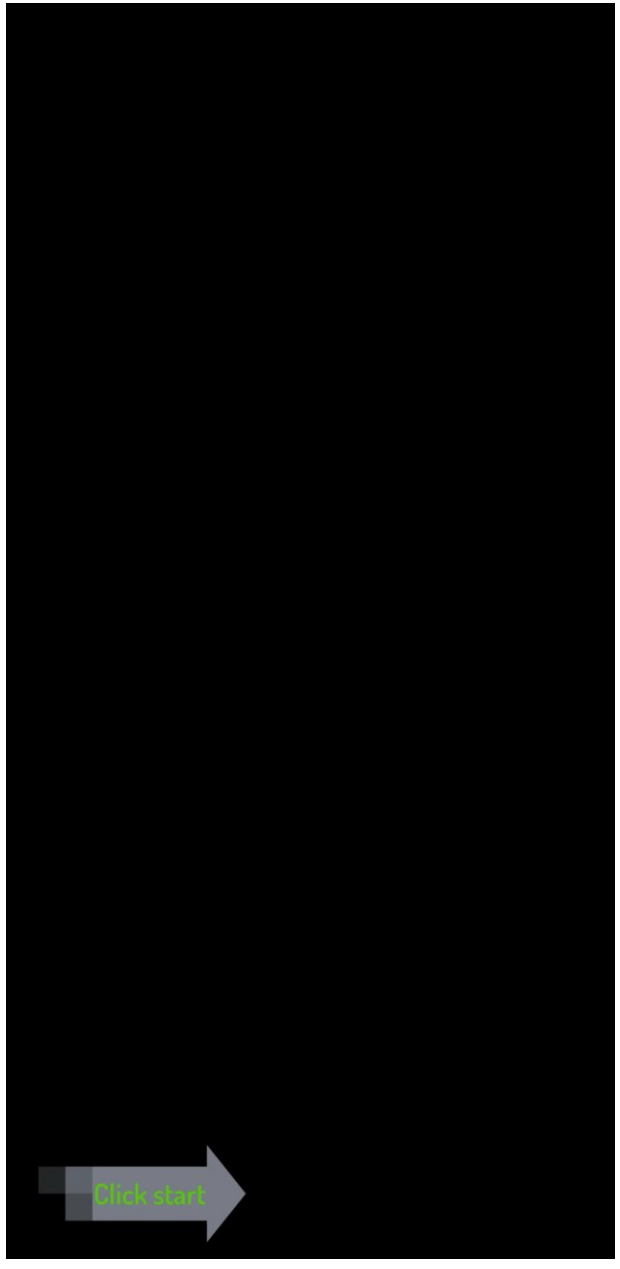

923B3352.CR2

INITIAL GOLD FAIENCE SILVER

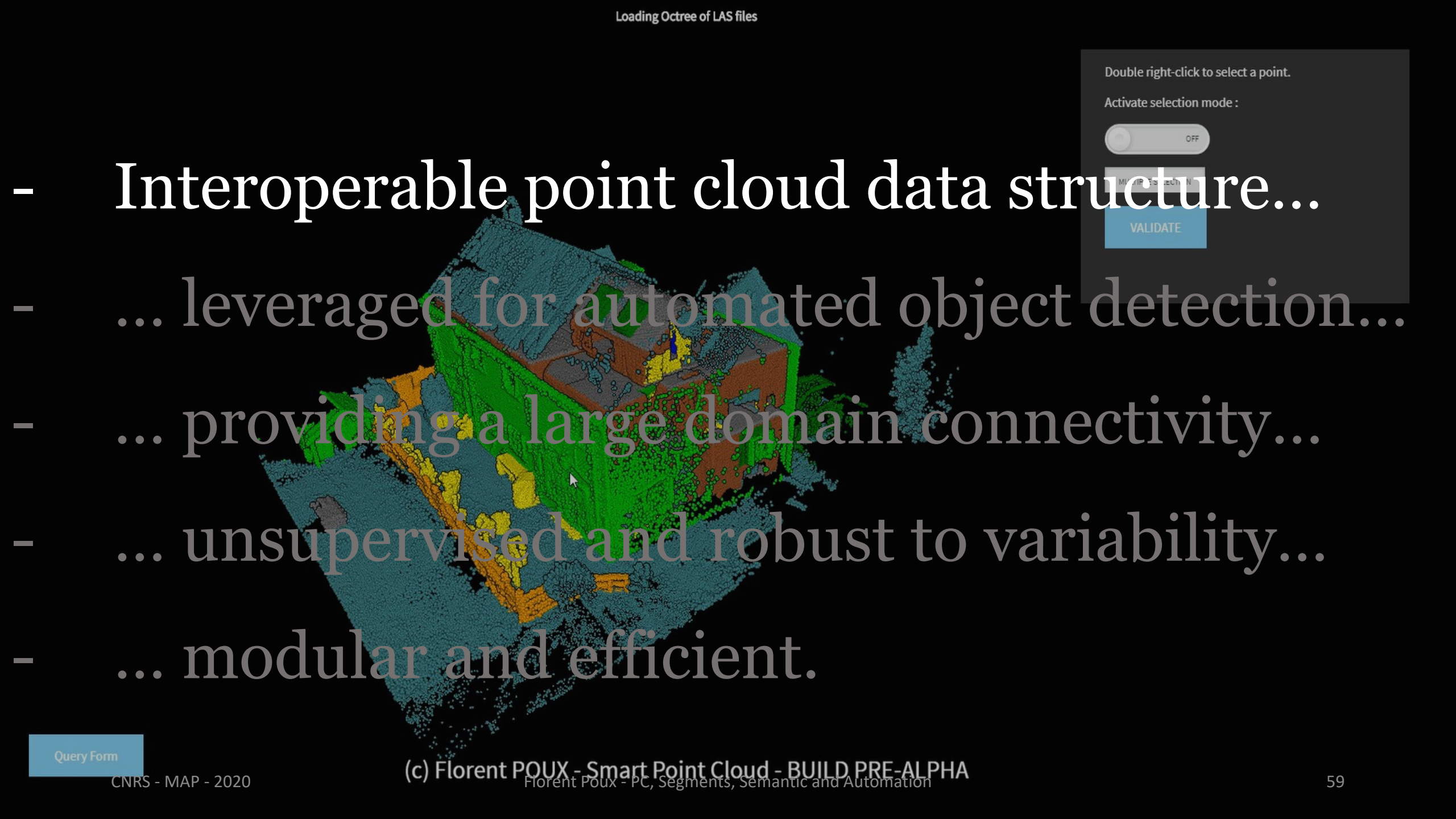
VR APPILCATION

AR APPLICATION

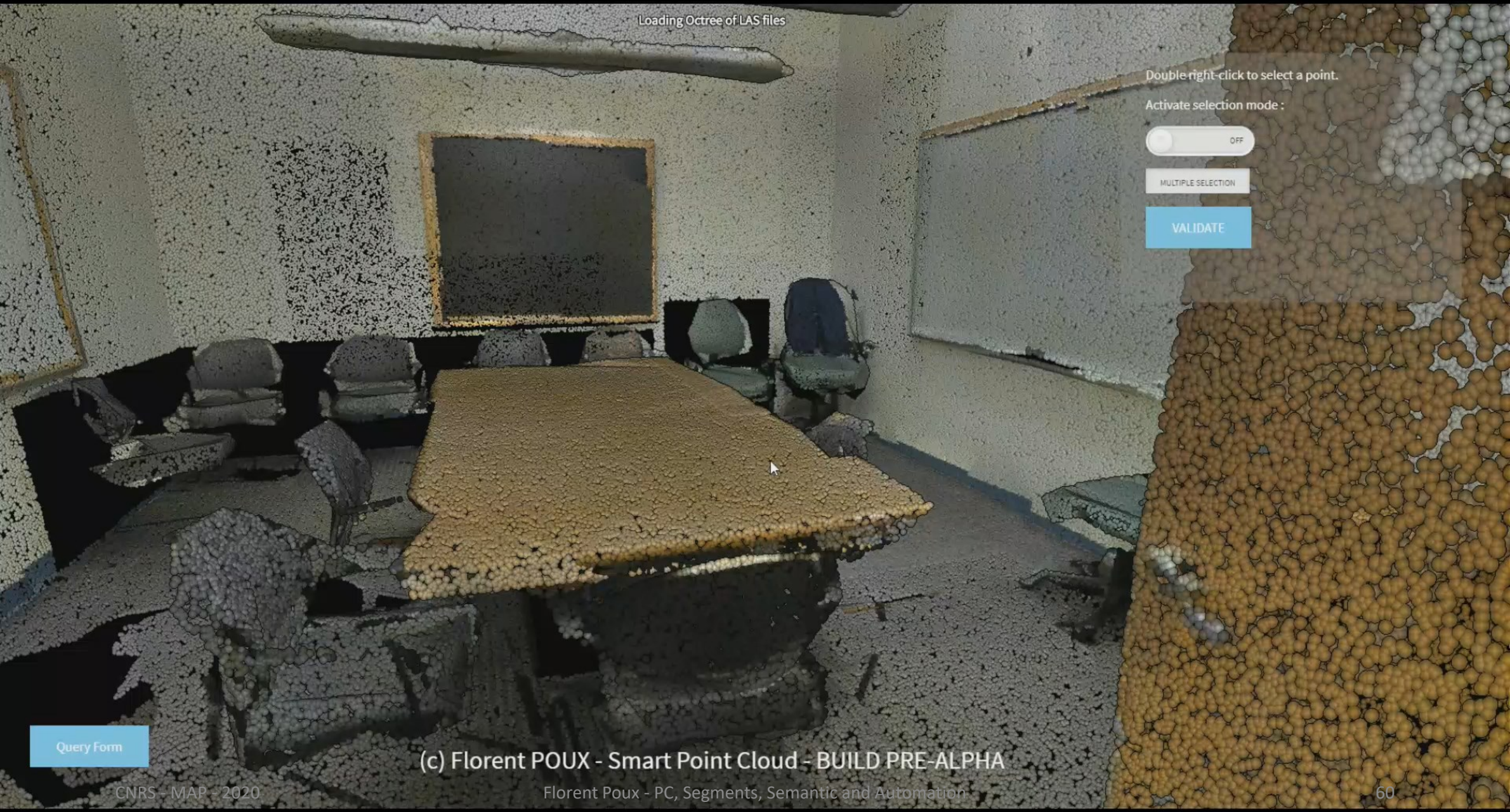




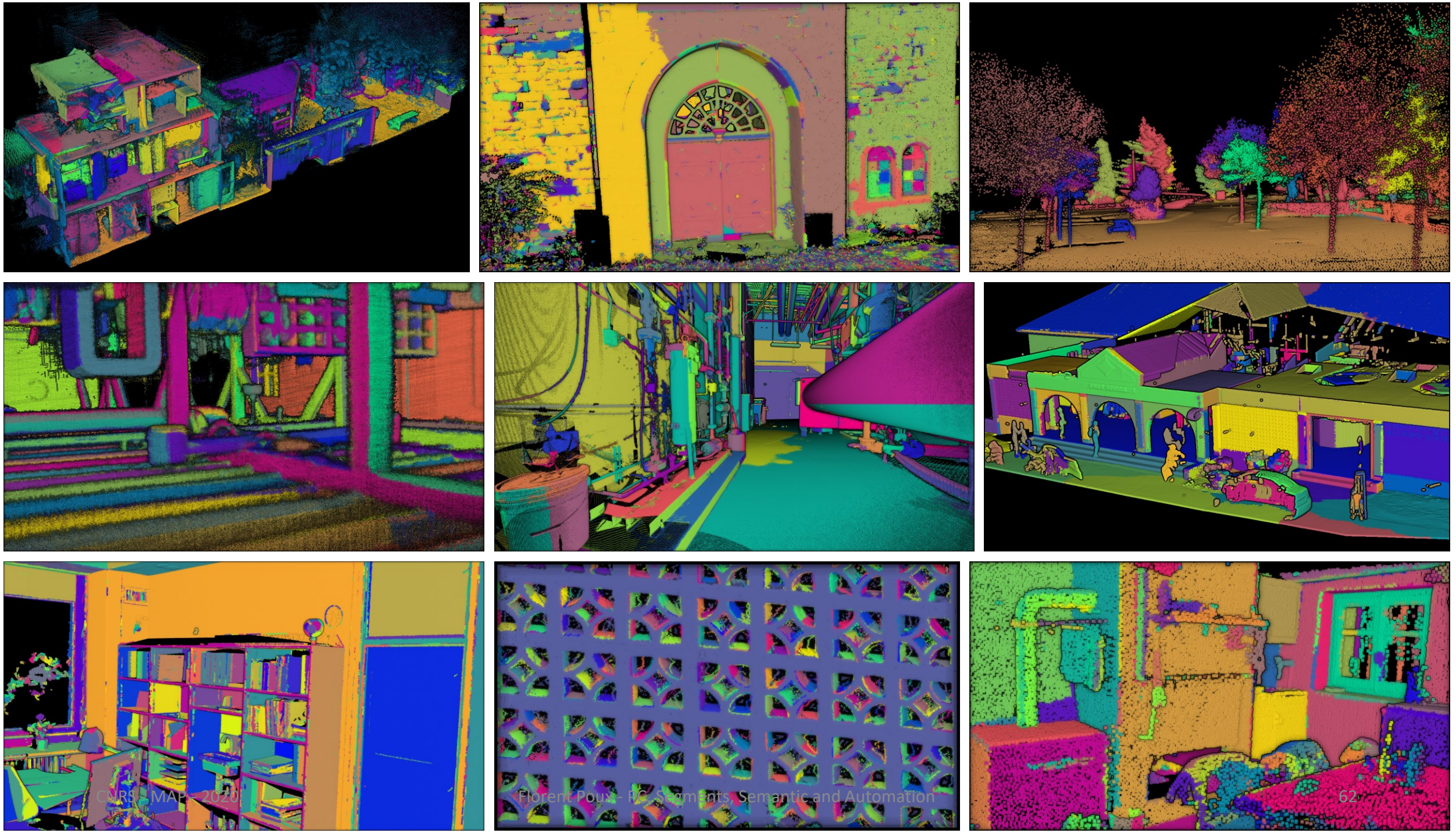
The SPC in 5 points

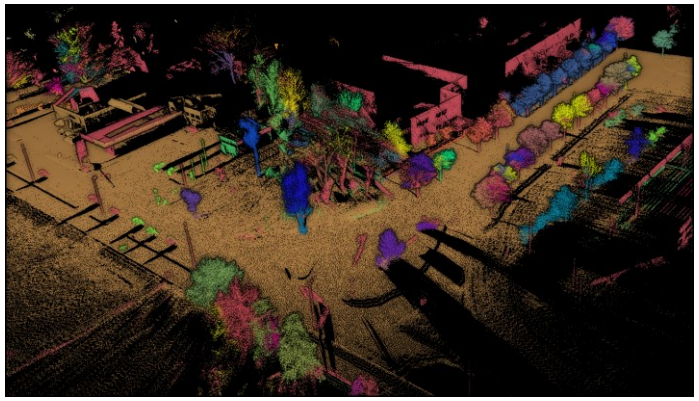


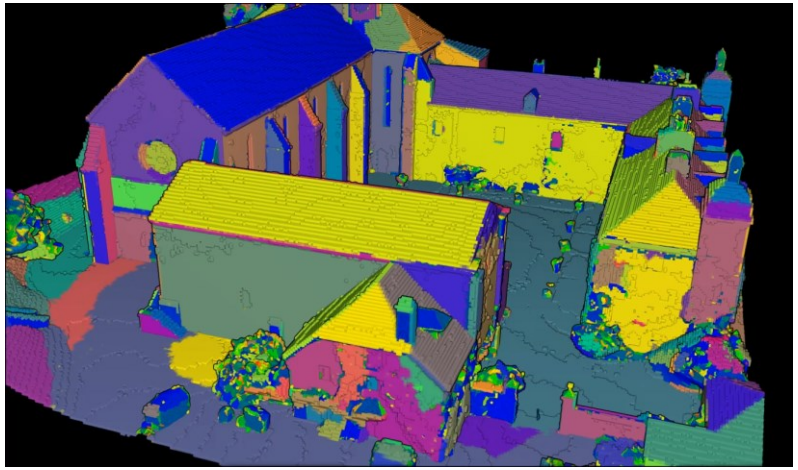
- Interoperable point cloud data structure…
- … leveraged for automated object detection…
- … providing a large domain connectivity…
- … unsupervised and robust to variability…
- … modular and efficient.

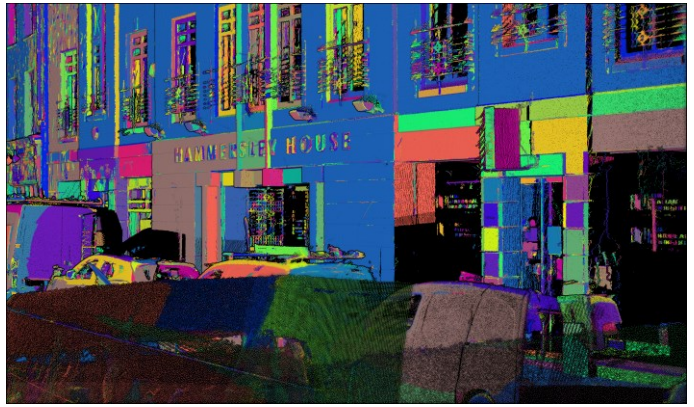

Loading Octree of LAS files
Double right-click to select a point.
Activate selection mode :
OFF
MULTIPLE SELECTION
VALIDATE
Query Form
(c) Florent POUX - Smart Point Cloud - BUILD PRE-ALPHA

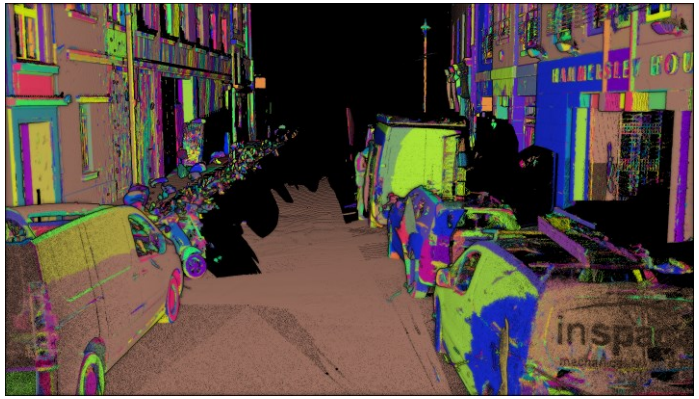
- Define powerful SPC-based AI Agents
- Increase generalization / specialization
- Dynamic data and LoD management
- Enhance unsupervised segmentation
- Enhance classification
- Integrate natural processes

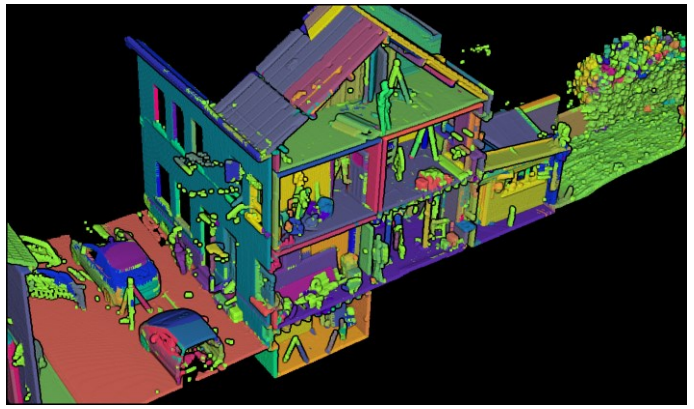


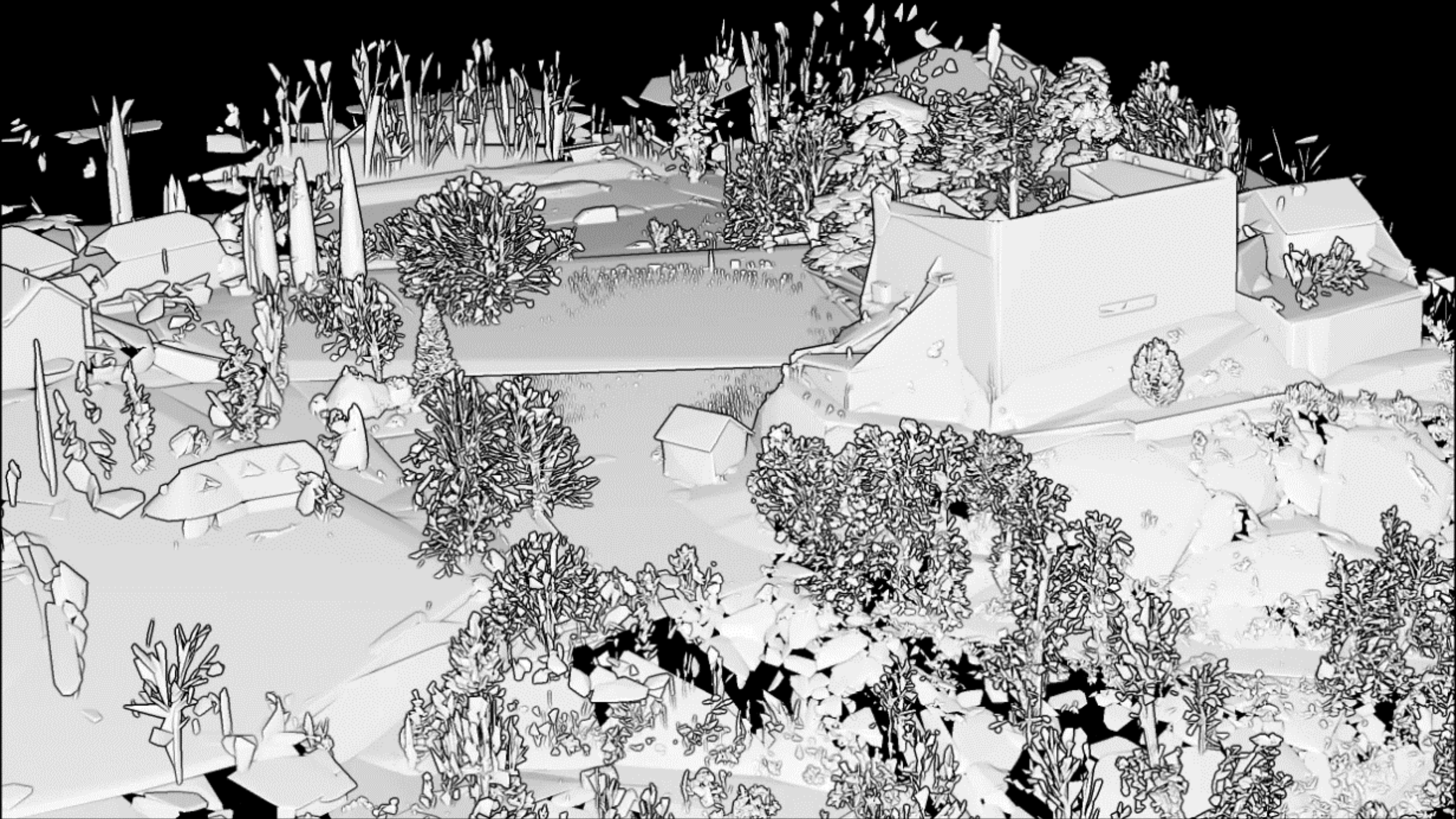





HAMMERSLEY HOUSE



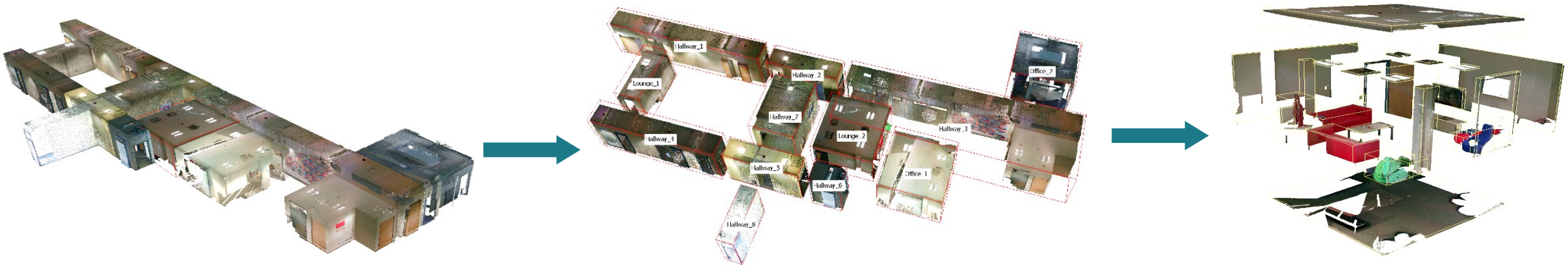





Indoor Mobile Scanning (Geomatic Unit)
© 2017 - F. Poux - Geomatics Unit


LIÈGE université
Sciences

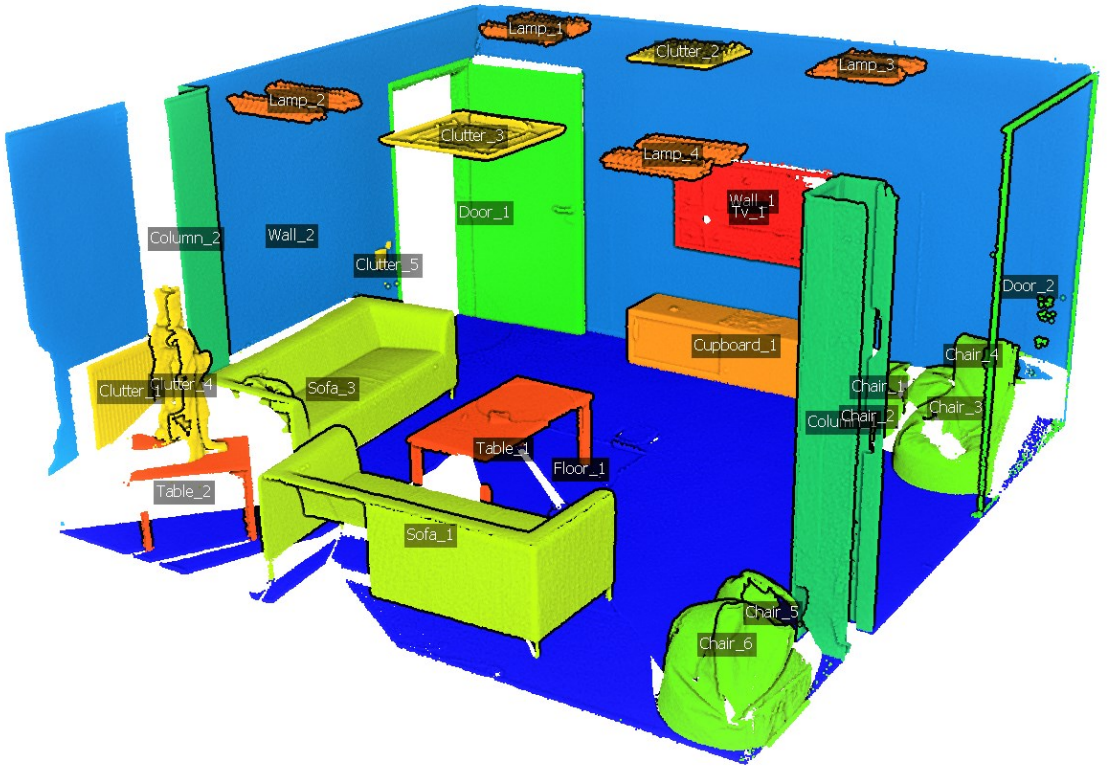
Name	Number of points	Attribute	Sensor	Size Go
CHÂTEAU_JEHAY	2.300.247.428	RGB, intensity	Leica P30	69.636
PCID10_RTWH_Exterior	312.710.687	RGB, intensity	TLS	4,907
PCID11_RTWH_CHAIR	259.101.028	RGB, intensity	TLS	4,807
PCID2_ULG_B5a	115.190.236	RGB, intensity	TLS	3,824
PCID8_NAAVIS_1	44.847.540	RGB	NavVIS	0,657
PCID6_REVO	53.800.194	Without	REVO	0,630
PCID9_NAAVIS_2	4.244.416	RGB	NavVIS	0,062



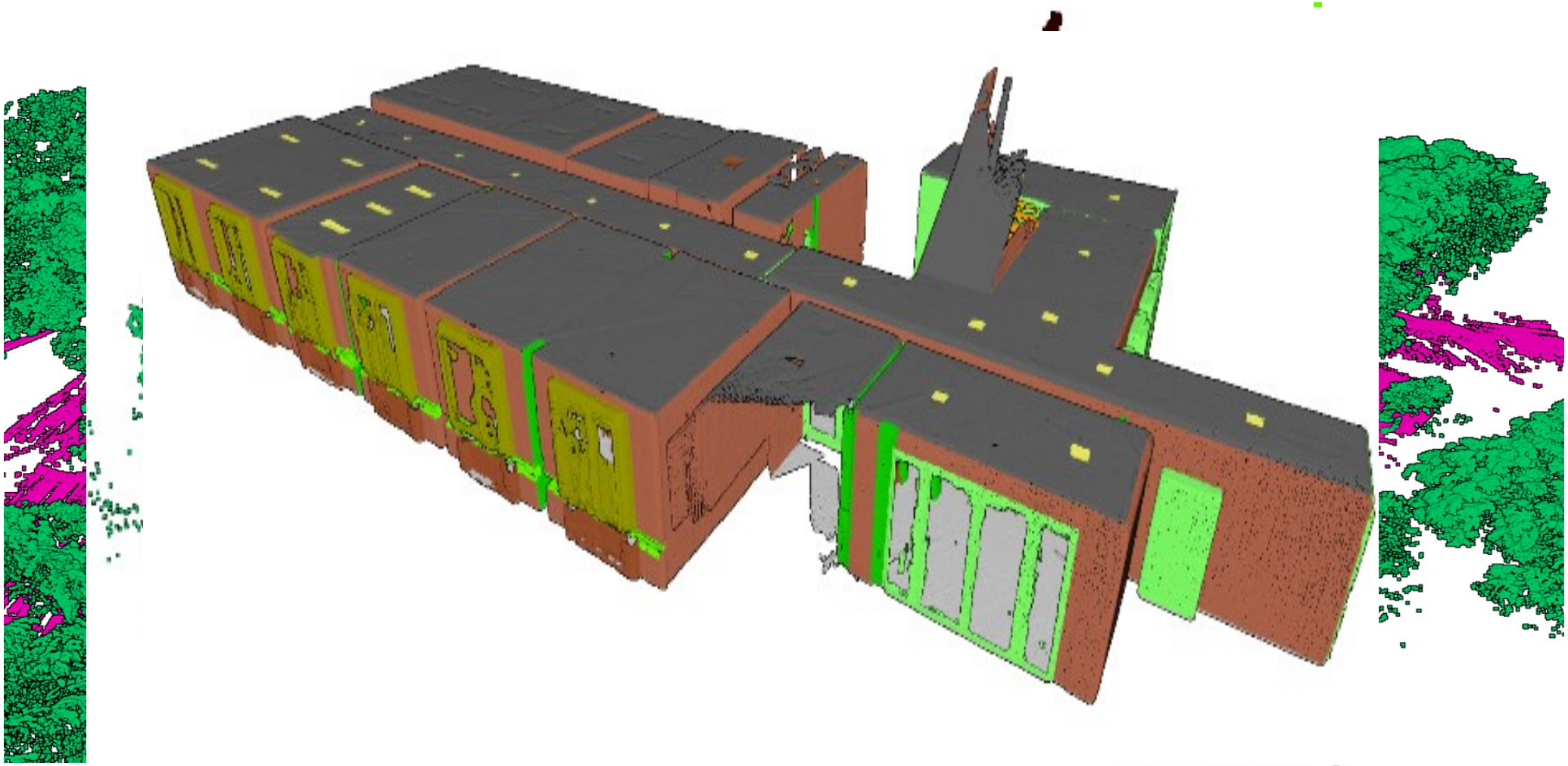
Indoor		Outdoor	
0	Floor	30	road_Sign
1	Ceiling	31	advertisingBoard
2	Wall	32	banc
3	Beam	33	bicycle
4	Column	34	bicycleStation
5	Window	35	Building_facades
6	Door	36	busStation
7	Table	37	car
11	Board	41	Humains
…	…	…	…

.las or .laz

Format specification .LAS version 1.2



Example after classification



References

1. Poux, F. The Smart Point Cloud: Structuring 3D intelligent point data, Liège, 2019.
2. Poux, F.; Billen, R. Voxel-Based 3D Point Cloud Semantic Segmentation: Unsupervised Geometric and Relationship Featuring vs Deep Learning Methods. *ISPRS Int. J. Geo-Information* **2019**, *8*, 213.
3. Poux, F.; Neuville, R.; Van Wersch, L.; Nys, G.-A.; Billen, R. 3D Point Clouds in Archaeology: Advances in Acquisition, Processing and Knowledge Integration Applied to Quasi-Planar Objects. *Geosciences* **2017**, *7*, 96.
4. Poux, F.; Billen, R. Smart point cloud: Toward an intelligent documentation of our world. In Proceedings of the PCON; Liège, 2015; p. 11.
5. Poux, F.; Neuville, R.; Hallot, P.; Billen, R. Point clouds as an efficient multiscale layered spatial representation. In Proceedings of the Eurographics Workshop on Urban Data Modelling and Visualisation; Vincent, T., Biljecki, F., Eds.; The Eurographics Association: Liège, Belgium, 2016.
6. Poux, F.; Neuville, R.; Hallot, P.; Van Wersch, L.; Jancsó, A.L.; Billen, R. Digital investigations of an archaeological smart point cloud: A real time web-based platform to manage the visualisation of semantical queries. *Int. Arch. Photogramm. Remote Sens. Spat. Inf. Sci. - ISPRS Arch.* **2017**, *XLII-5/W1*, 581–588.

References

7. Poux, F.; Neuville, R.; Hallot, P.; Billen, R. MODEL FOR SEMANTICALLY RICH POINT CLOUD DATA. *ISPRS Ann. Photogramm. Remote Sens. Spat. Inf. Sci.* **2017**, *IV-4/W5*, 107–115.

8. Poux, F.; Neuville, R.; Billen, R. POINT CLOUD CLASSIFICATION OF TESSERAE FROM TERRESTRIAL LASER DATA COMBINED WITH DENSE IMAGE MATCHING FOR ARCHAEOLOGICAL INFORMATION EXTRACTION. *ISPRS Ann. Photogramm. Remote Sens. Spat. Inf. Sci.* **2017**, *IV-2/W2*, 203–211.

9. Poux, F.; Neuville, R.; Nys, G.-A.; Billen, R. 3D Point Cloud Semantic Modelling: Integrated Framework for Indoor Spaces and Furniture. *Remote Sens.* **2018**, *10*, 1412.

10. Poux, F.; Billen, R. A Smart Point Cloud Infrastructure for intelligent environments. In *Laser scanning: an emerging technology in structural engineering*; Lindenbergh, R., Belen, R., Eds.; ISPRS Book Series; Taylor & Francis Group/CRC Press: United States, 2019 ISBN in generation.

11. Poux, F.; Hallot, P.; Neuville, R.; Billen, R. SMART POINT CLOUD: DEFINITION AND REMAINING CHALLENGES. *ISPRS Ann. Photogramm. Remote Sens. Spat. Inf. Sci.* **2016**, *IV-2/W1*, 119–127.

12. Poux, F. Vers de nouvelles perspectives lasergrammétriques : optimisation et automatisation de la chaîne de production de modèles 3D Florent Poux To cite this version : HAL Id : dumas-00941990. **2014**.

13. Novel, C.; Keriven, R.; Poux, F.; Graindorge, P. Comparing Aerial Photogrammetry and 3D Laser Scanning Methods for Creating 3D Models of Complex Objects. In Proceedings of the Capturing Reality Forum; Bentley Systems: Salzburg, 2015; p. 15.