LIÈGE université
Geomatics

Extraction et Gestion Automatique de la sémantique dans les nuages de points

Florent Poux

Hyper-Automation

Reality / Virtuality

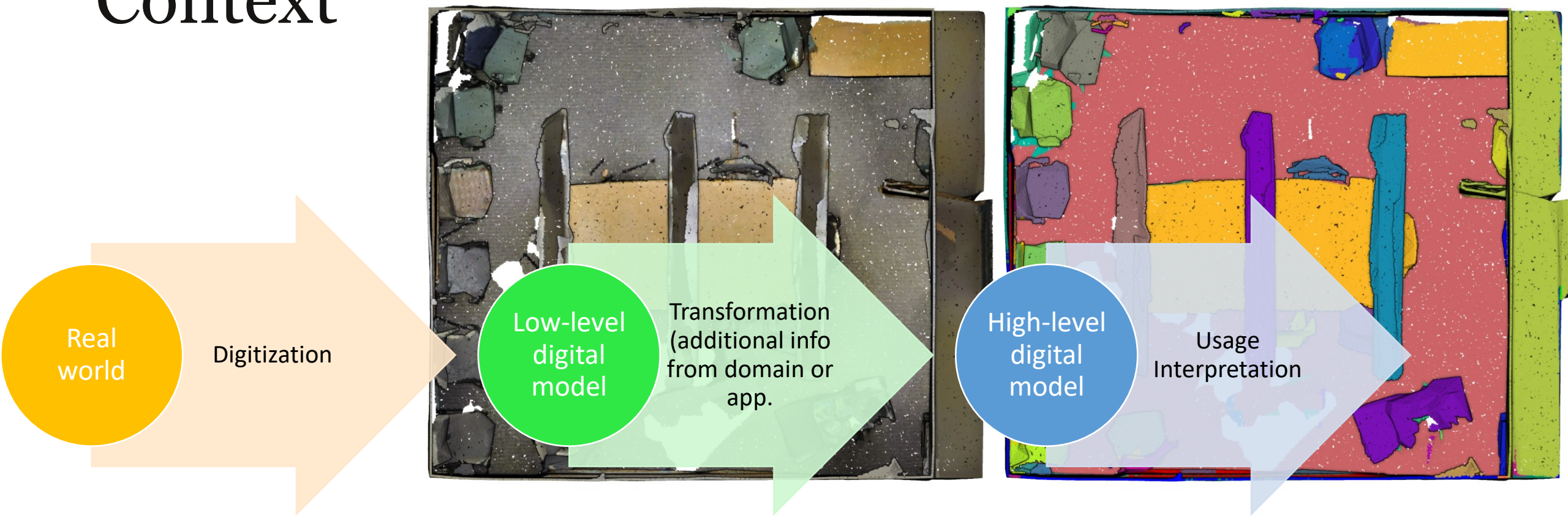
Key concepts

Point Cloud

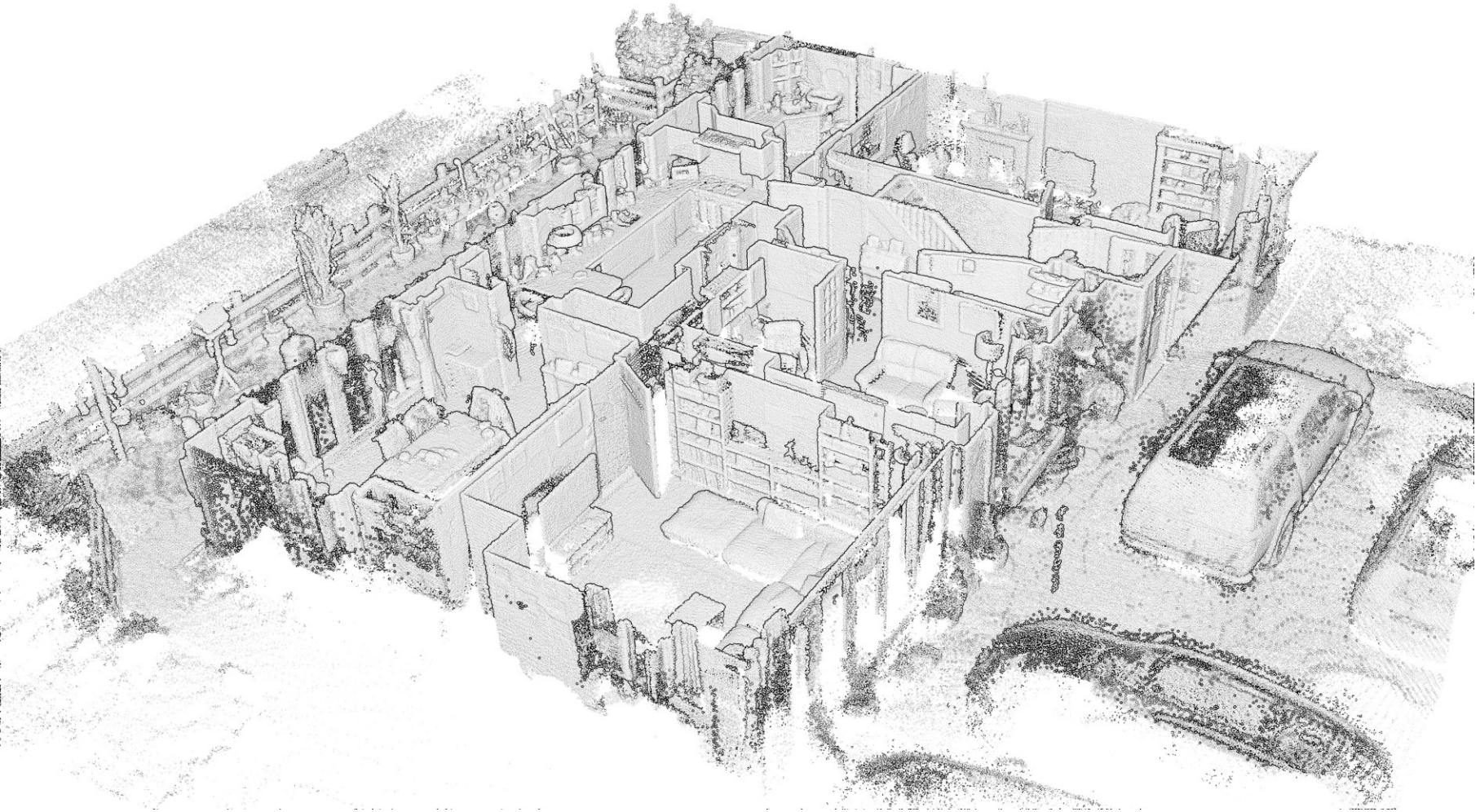
Added-value

Generalization

Context


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

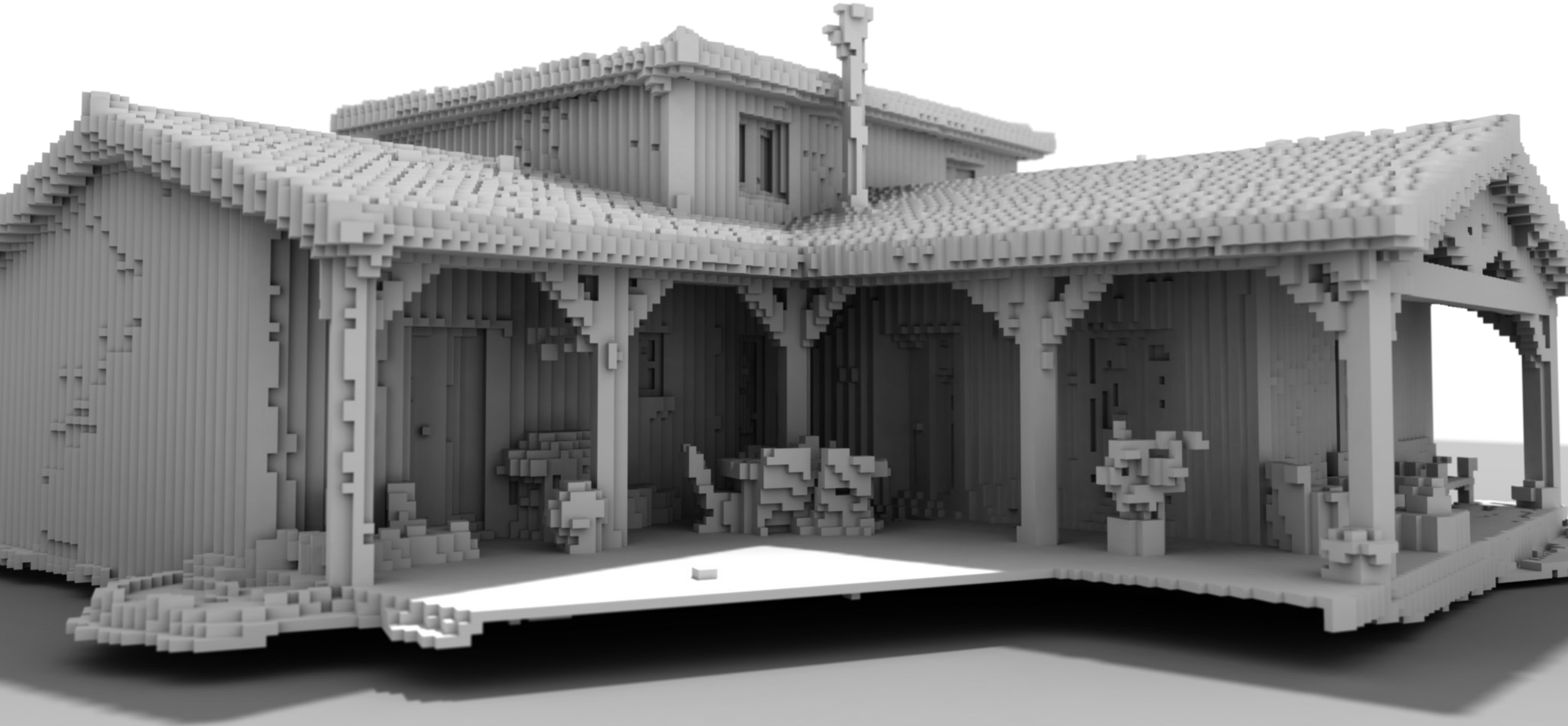
Automation

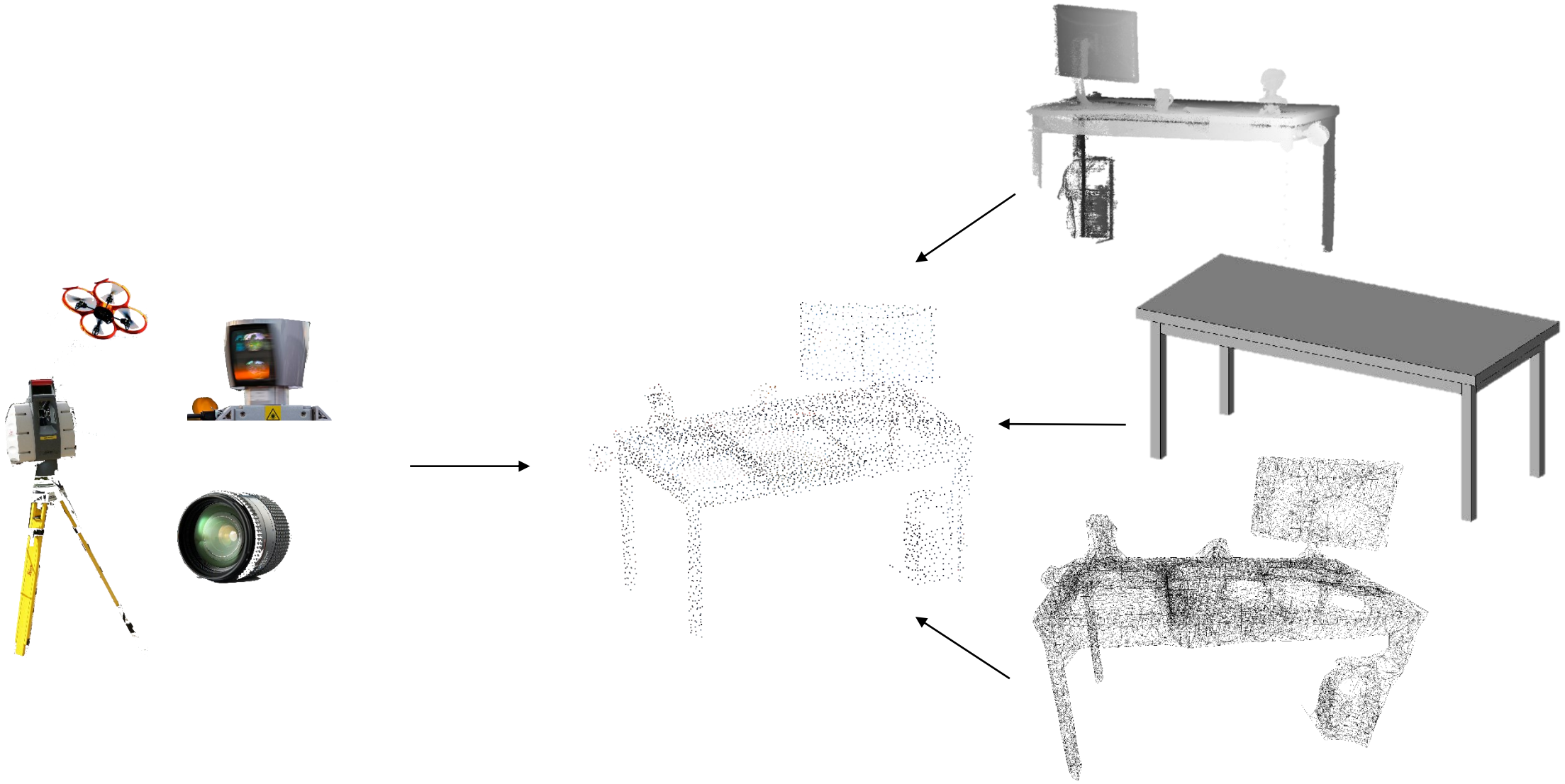


+ Increased productivity
+ Higher quality output
+ Shorter workweeks

3D Point Cloud Specificities

Representation & Structuration





Automation

Video Source : Emescent

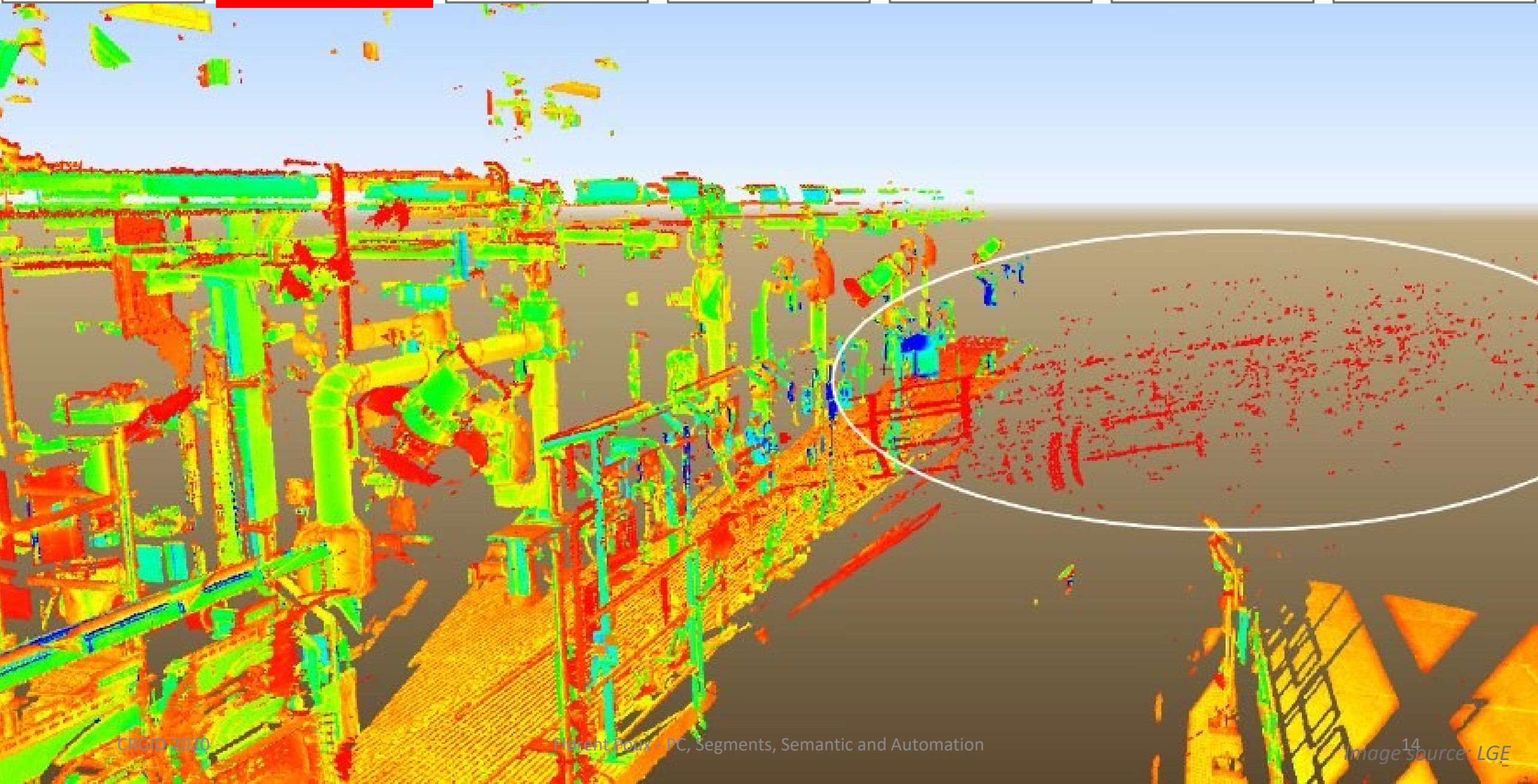


Image source: LGE

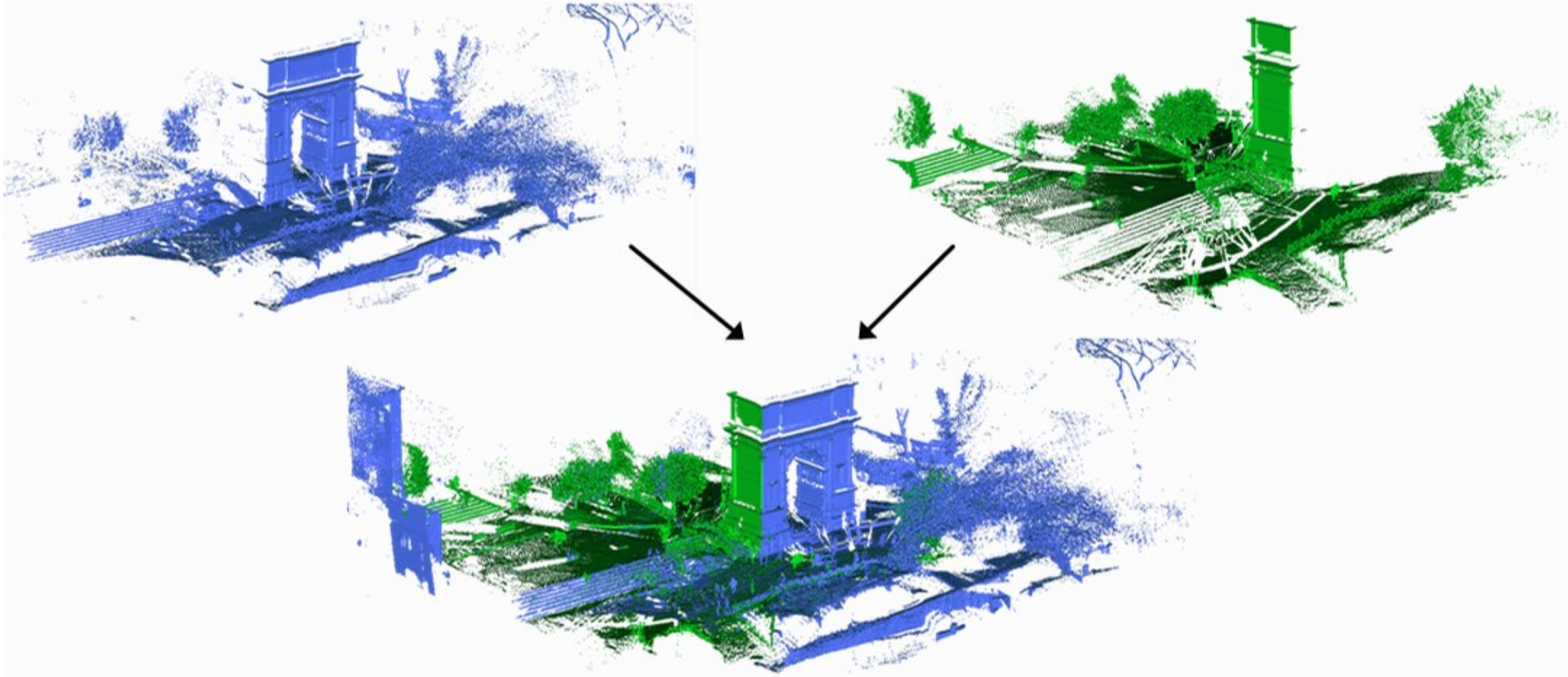
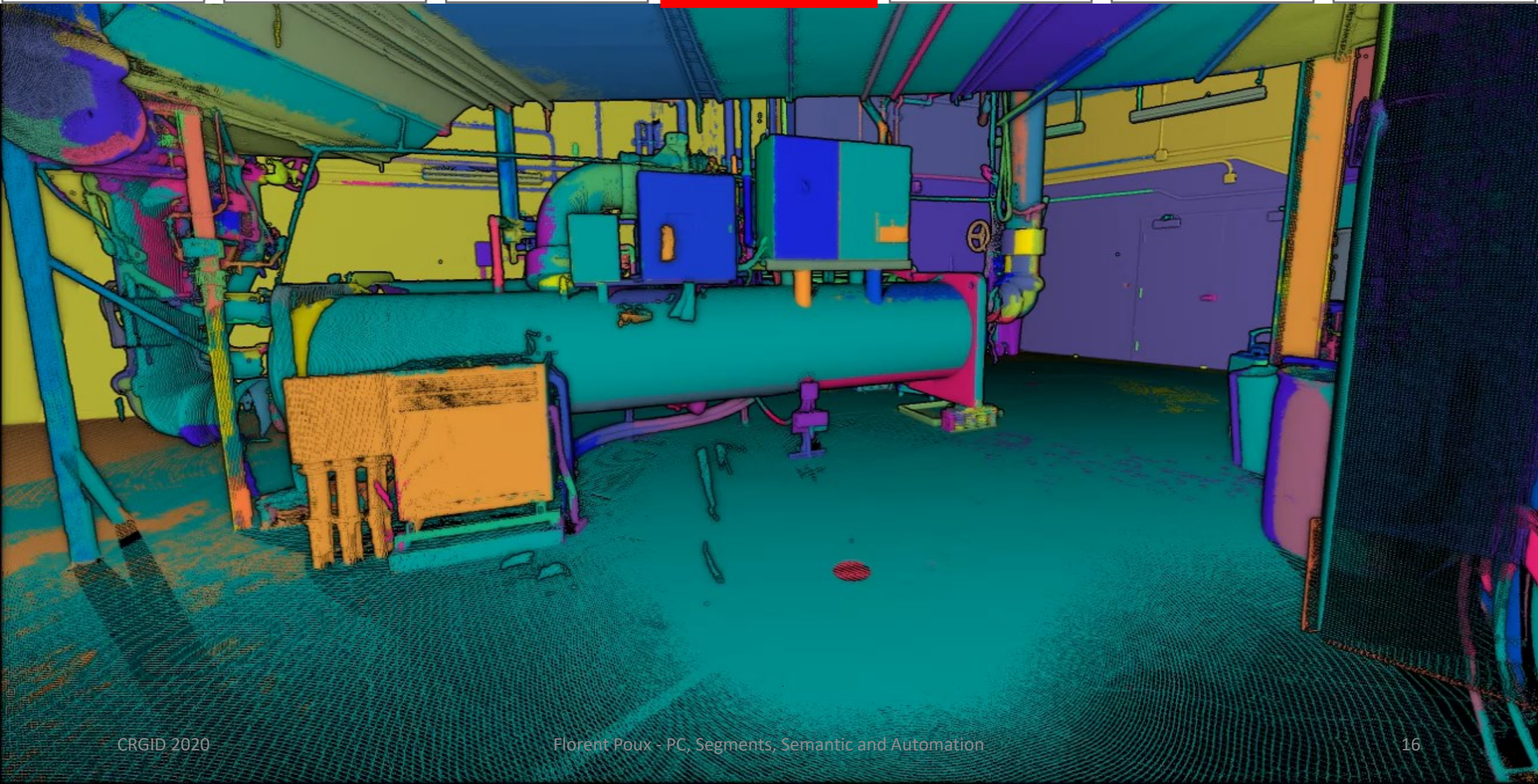
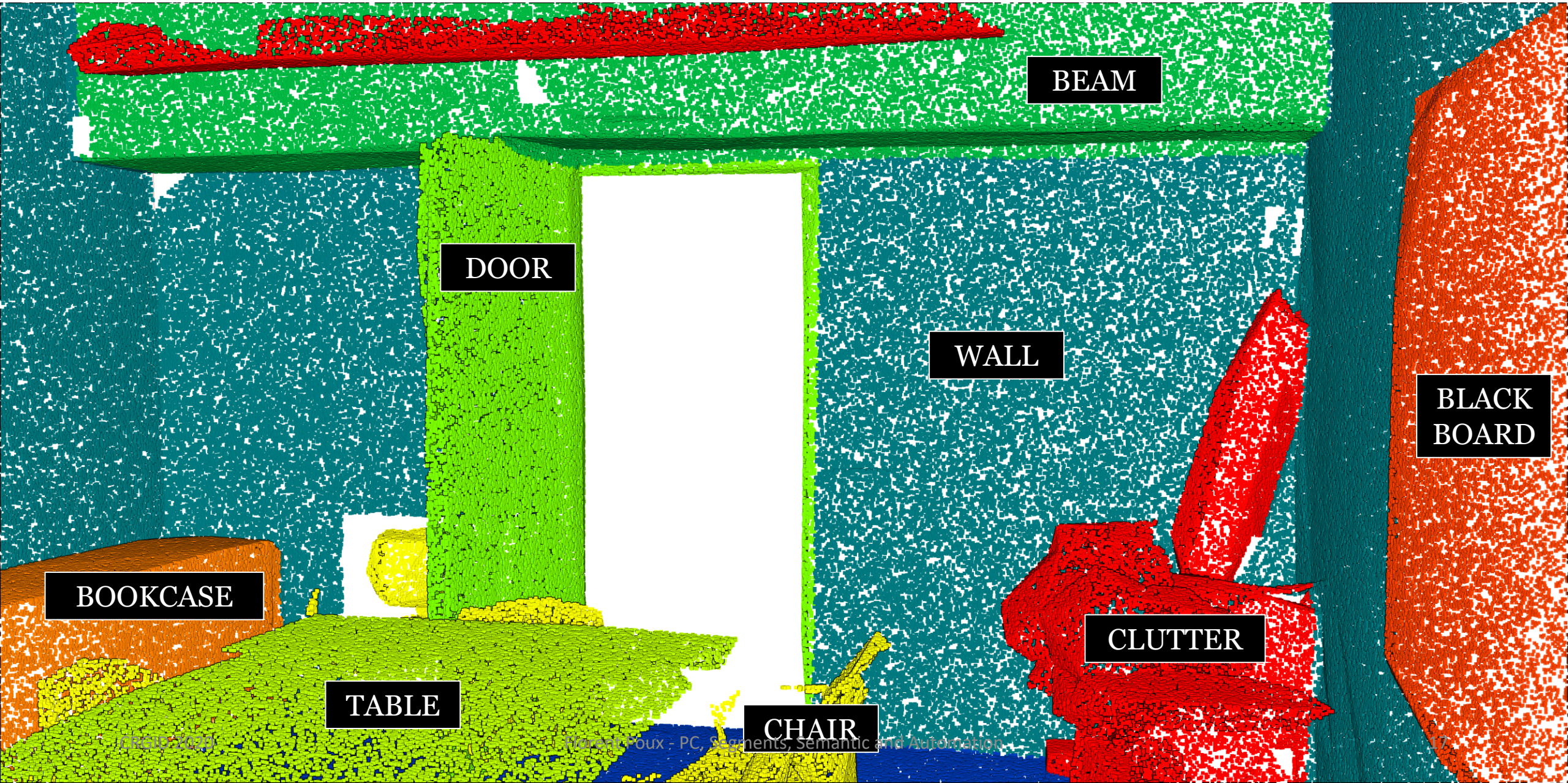
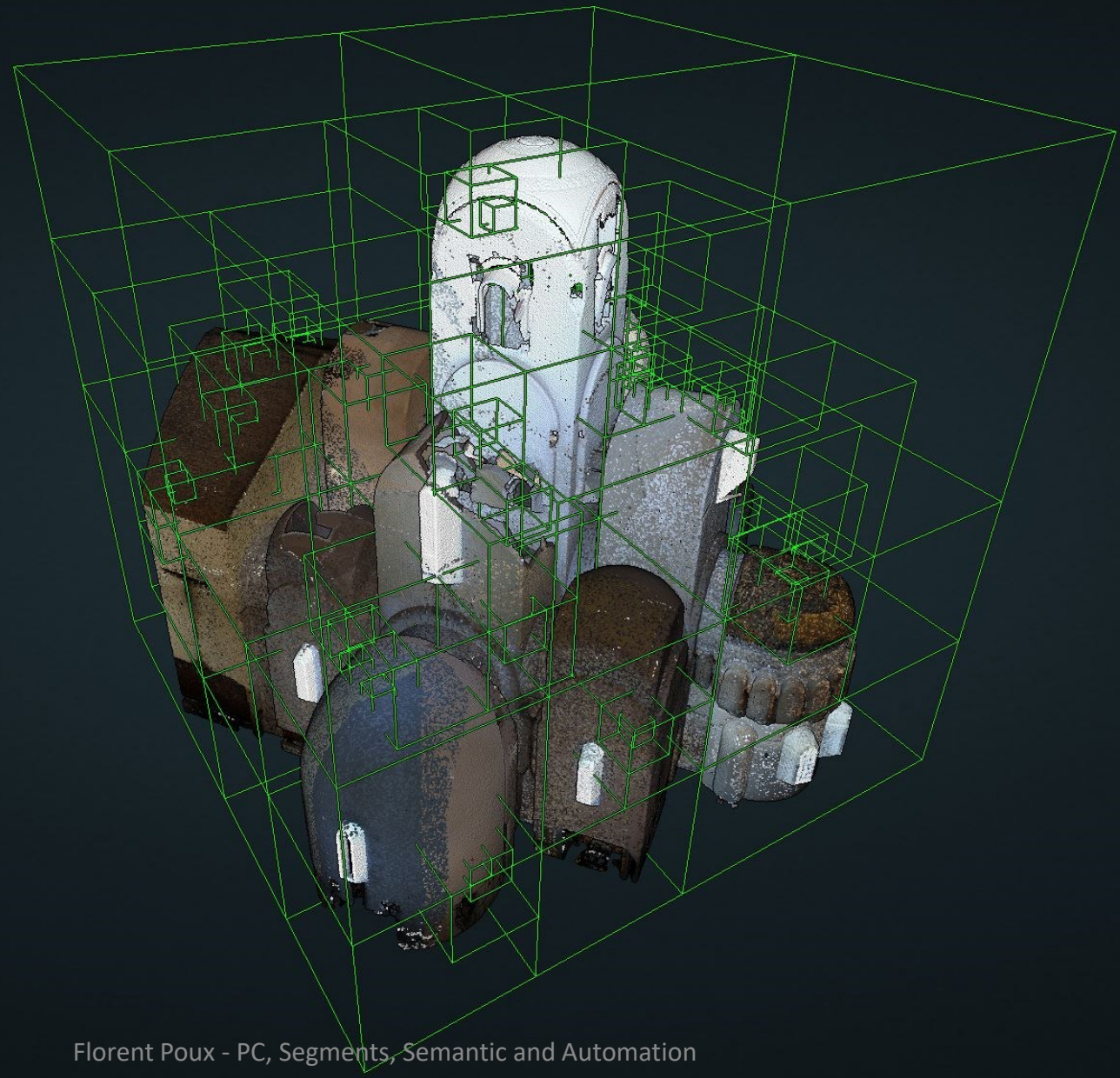
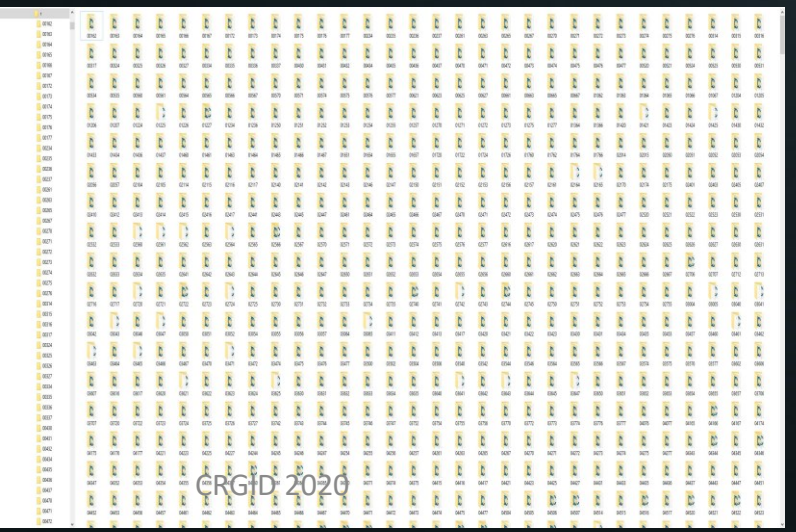


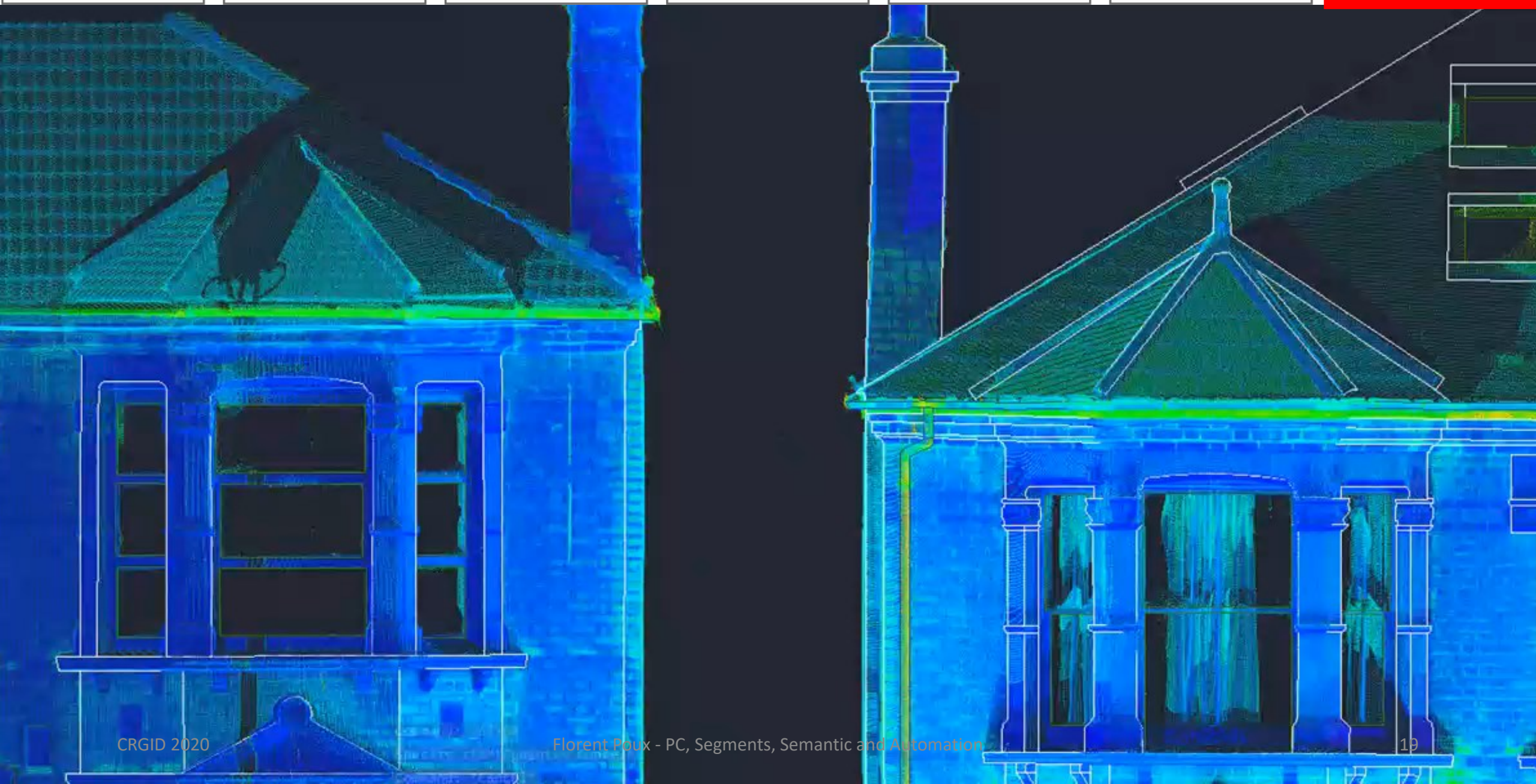
Image source: ETH Zürich

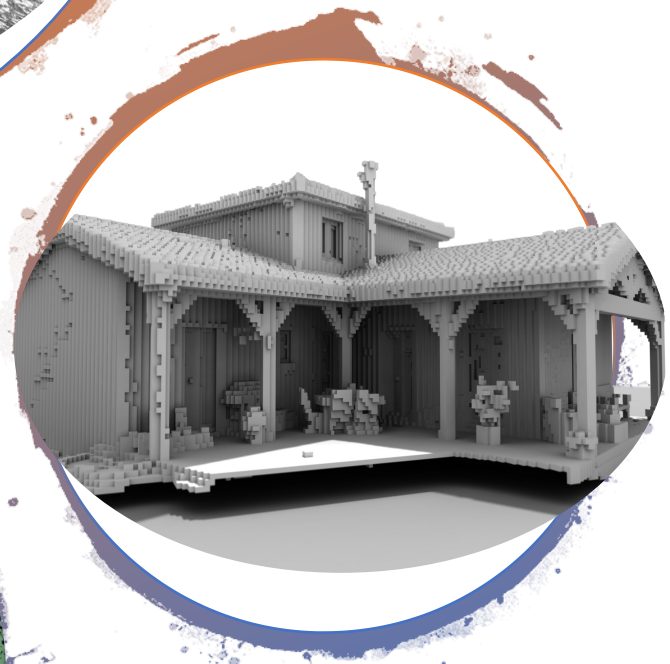


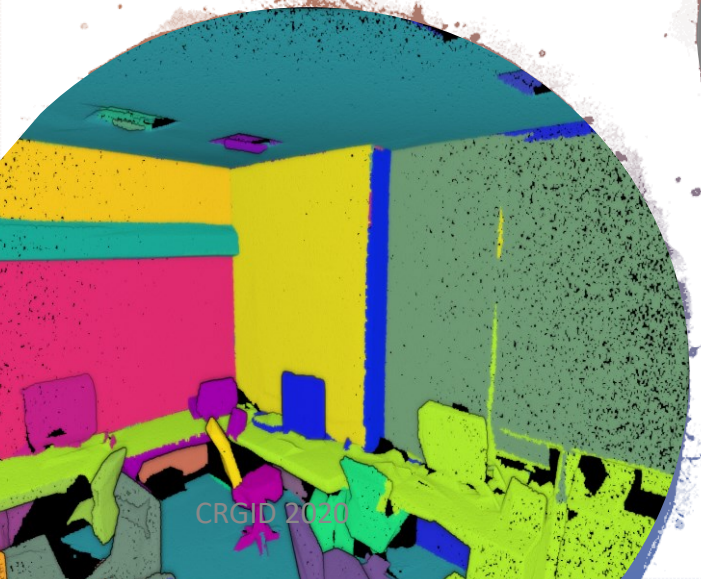

BEAM
DOOR
WALL
BLACK BOARD
BOOKCASE
CLUTTER
TABLE
CHAIR







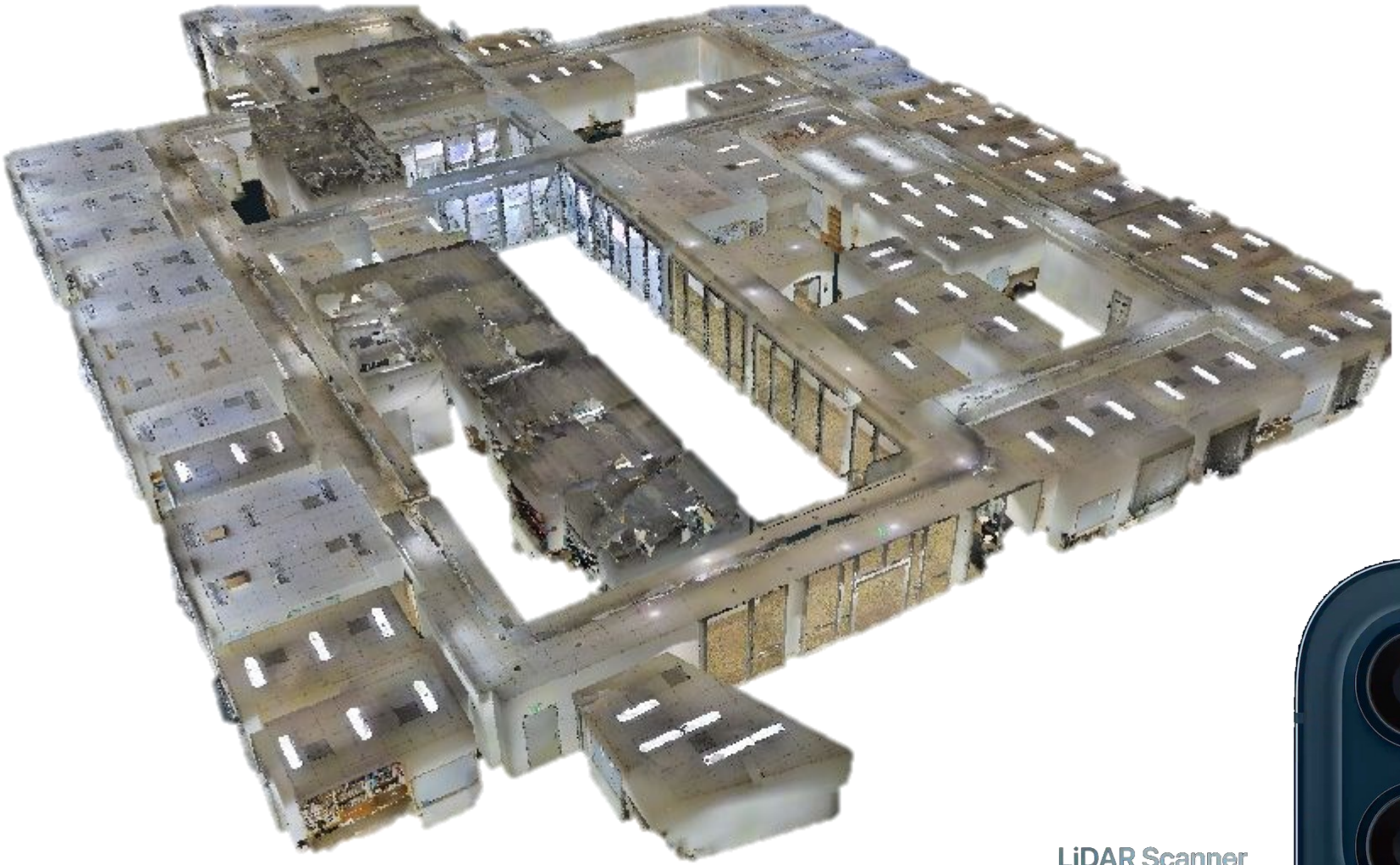




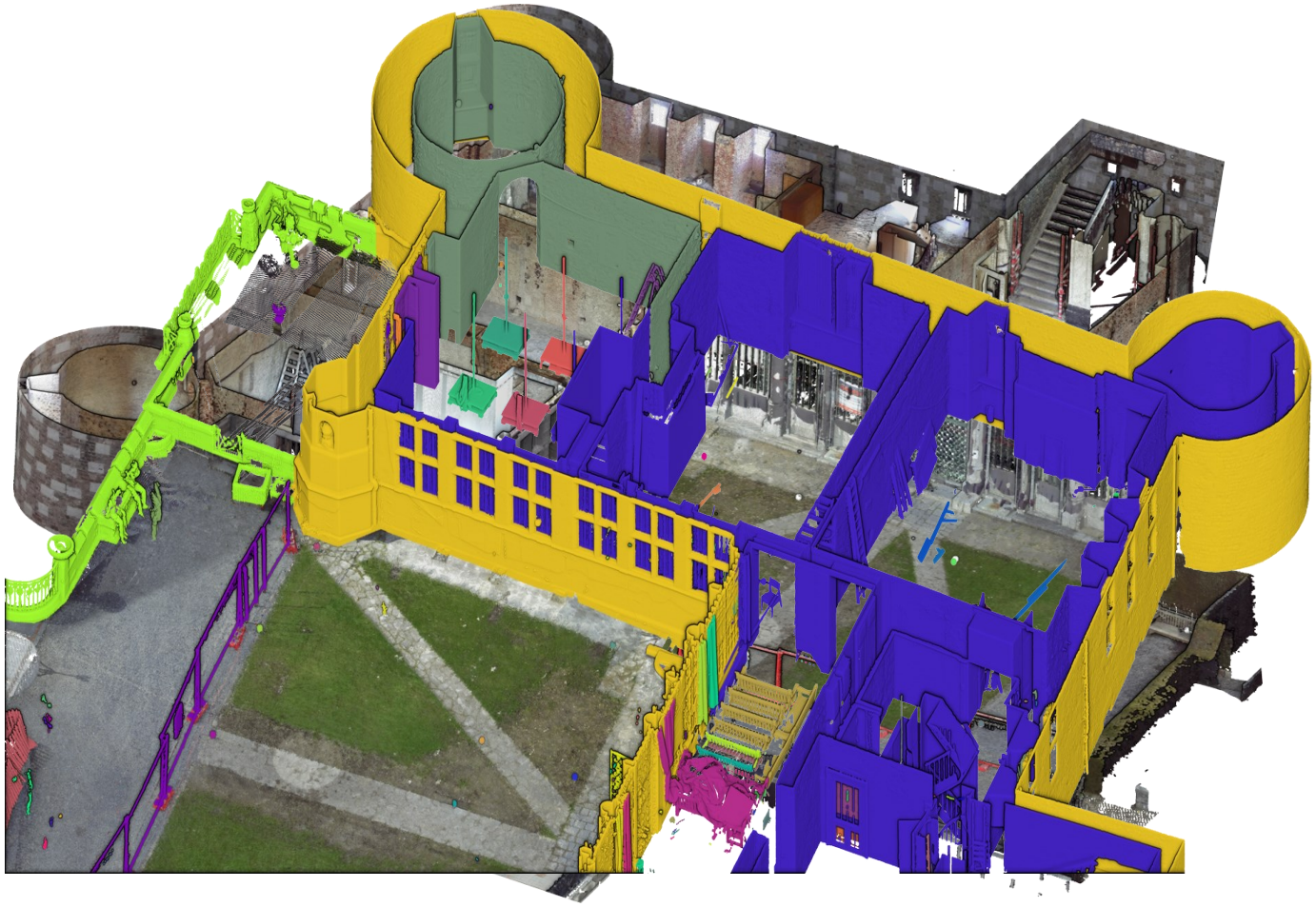
Point Clouds

1. Specificities
2. Representation
3. Automation

Low-level digital model

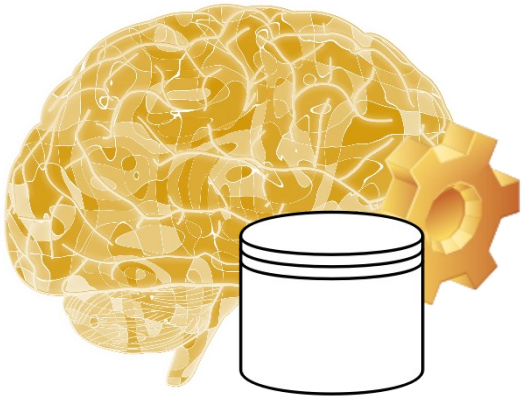


Semantics & Knowledge Integration



TODAY

WHAT WE WANT



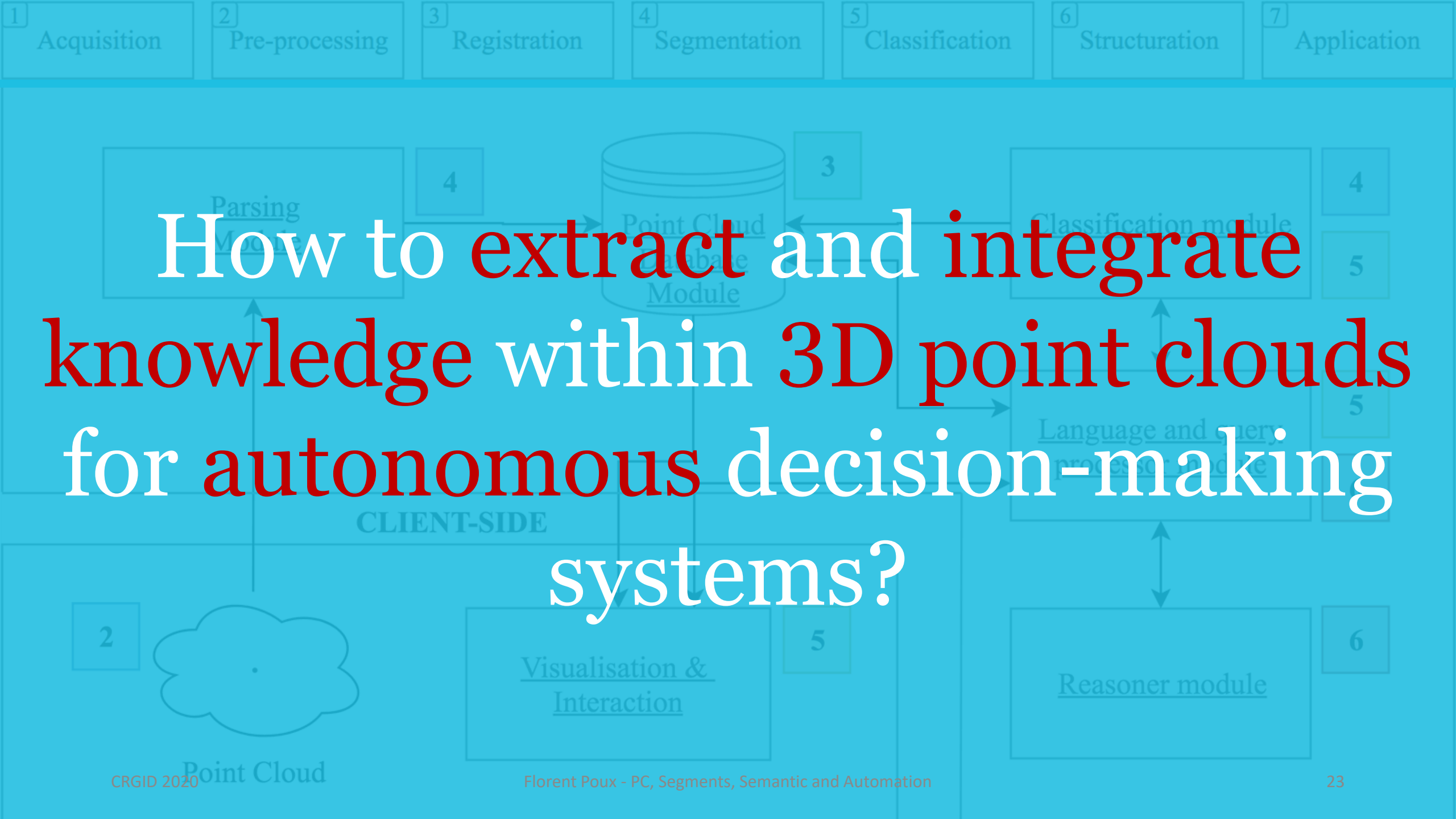
KNOWLEDGE

DELIVERY

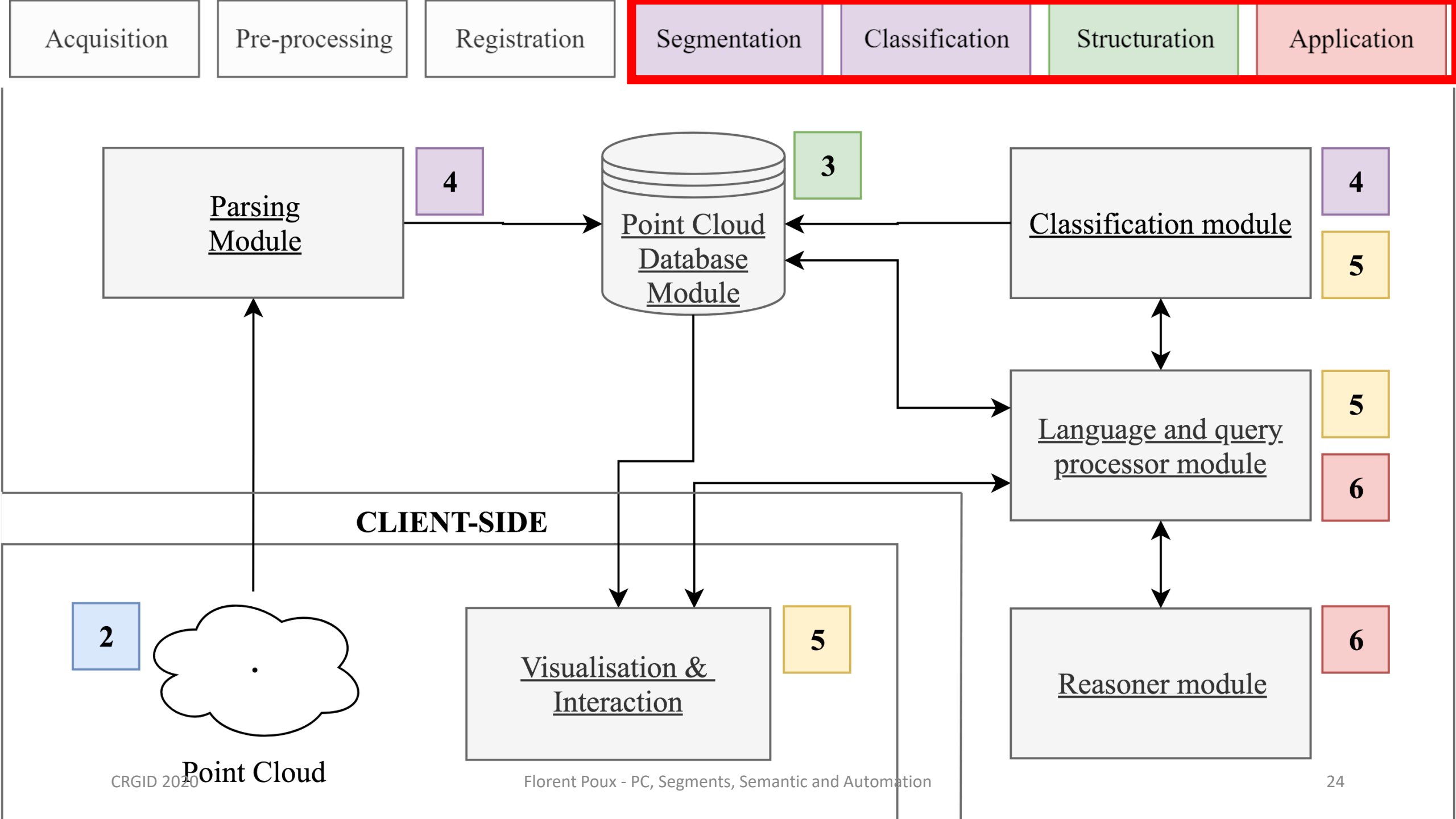
INTERPRETATION

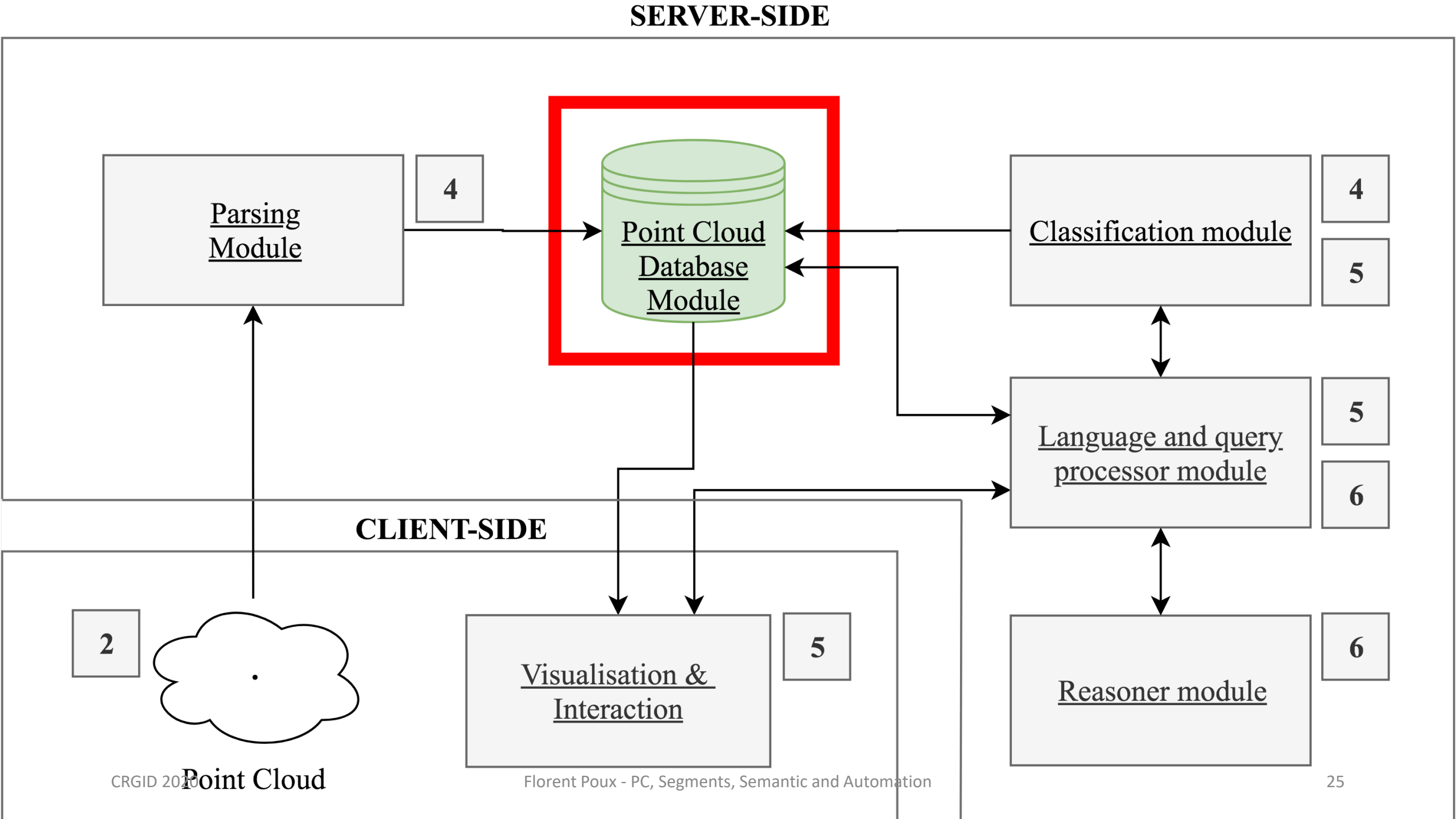
EXTRACTION (Meshed...)

SIMULATION, Reasoning, ...



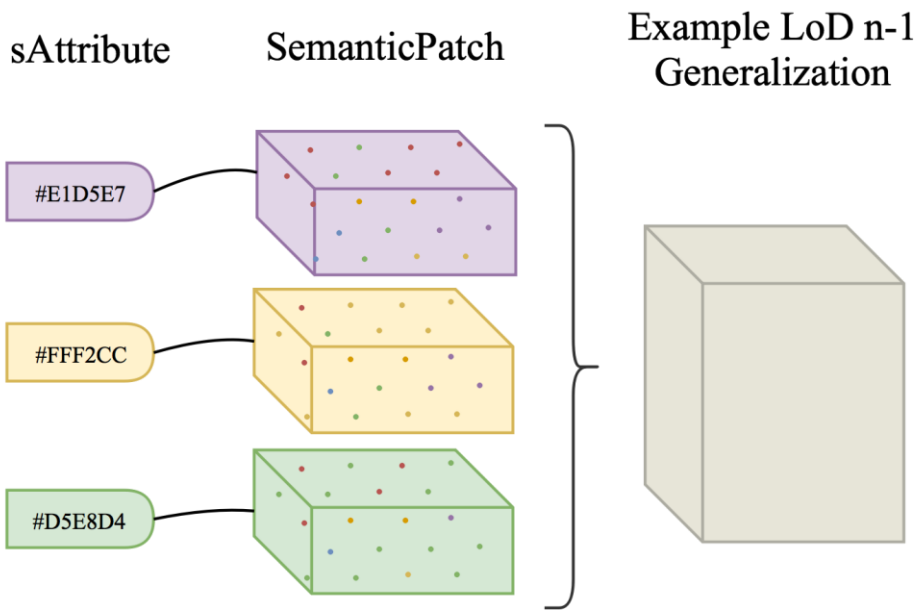
How to extract and integrate knowledge within 3D point clouds for autonomous decision-making systems?

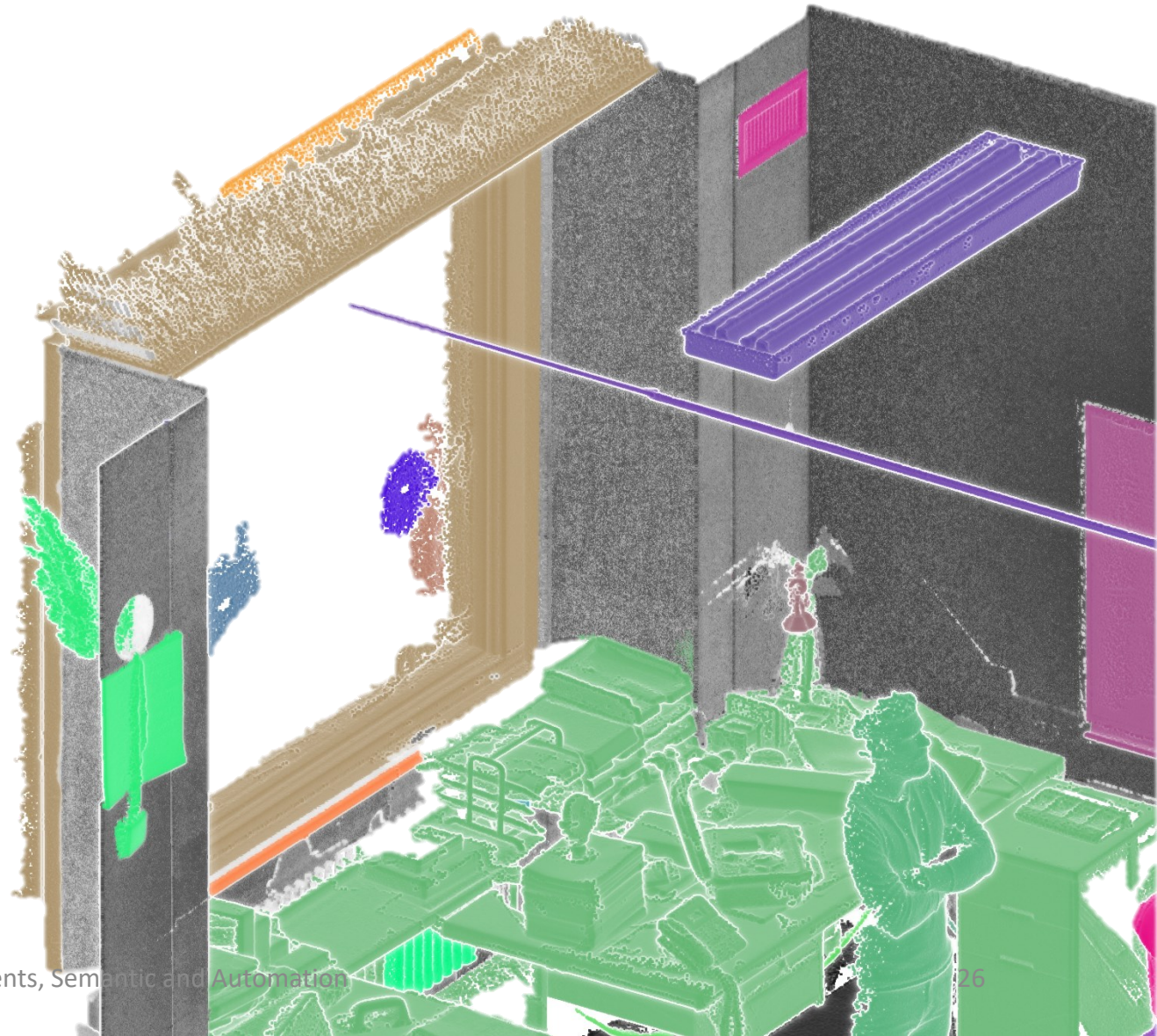

Acquisition
Pre-processing
Registration
Segmentation
Classification
Structuration
Application
Parsing Module
4
Point Cloud Database Module
3
Classification module
4
5
Language and query processor module
5
6
CLIENT-SIDE
2
Point Cloud
Visualisation & Interaction
5
Reasoner module
6

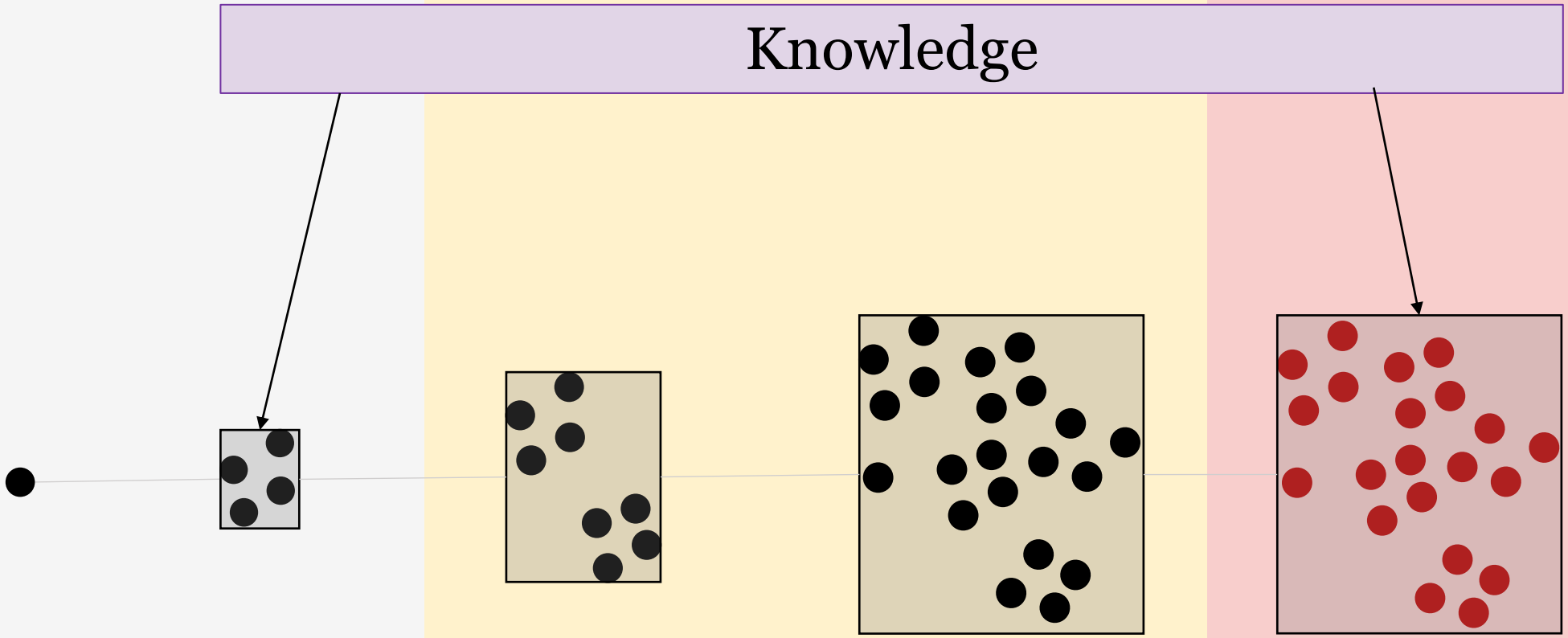

SERVER-SIDE
Parsing Module
4
Point Cloud Database Module
Classification module
4
5
Language and query processor module
5
6
Reasoner module
6
CLIENT-SIDE
2
Point Cloud
Visualisation & Interaction
5

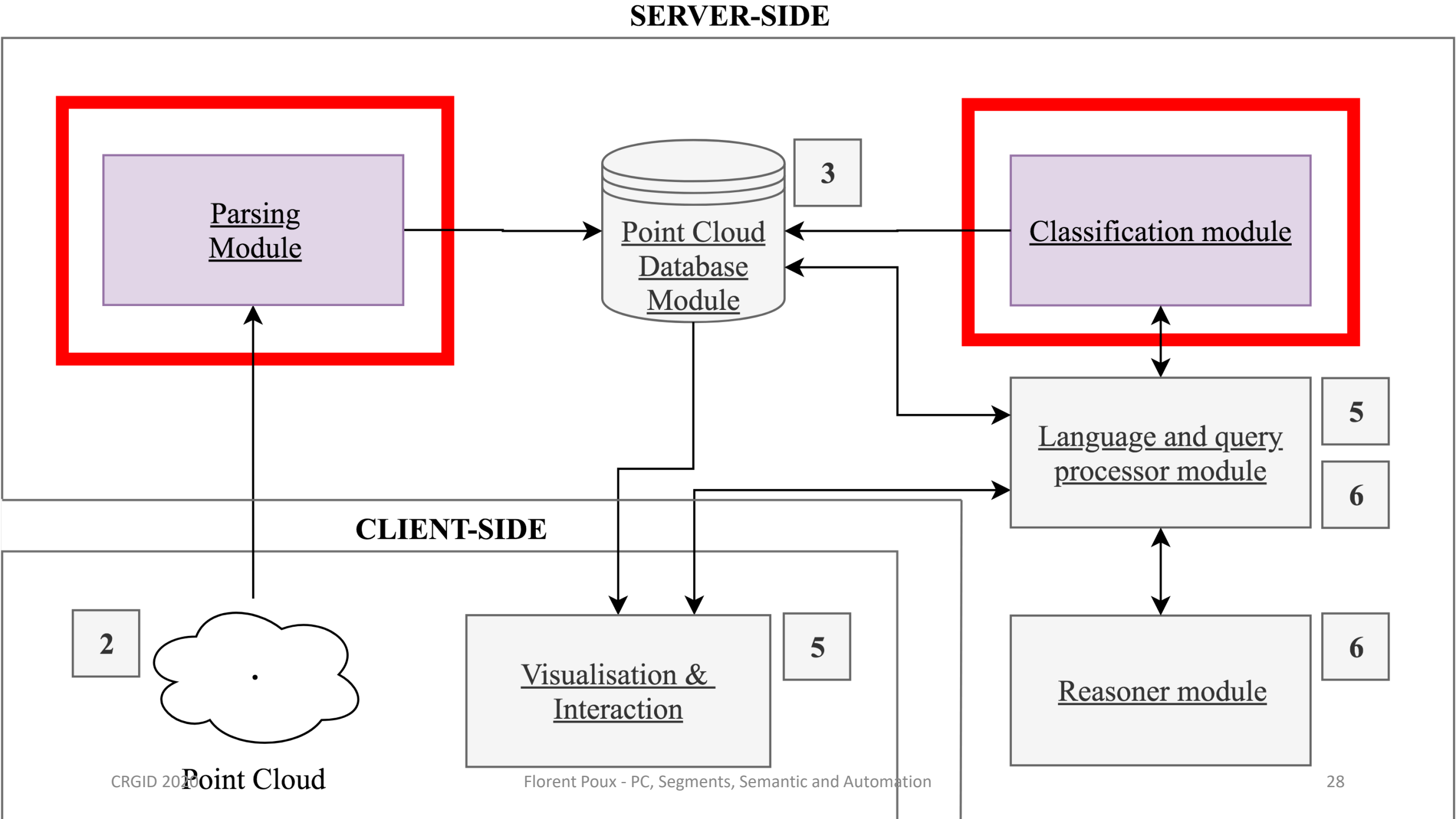
Point Cloud Specificity

Unstructured and too sparse for DBMS per-row insertion

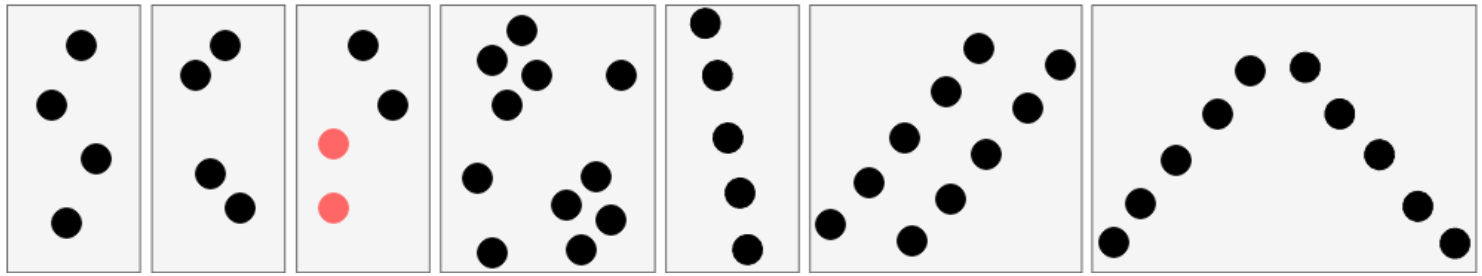





Knowledge
Point
Semantic Patch
Connected Element
Aggregated Element
Class Instance


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

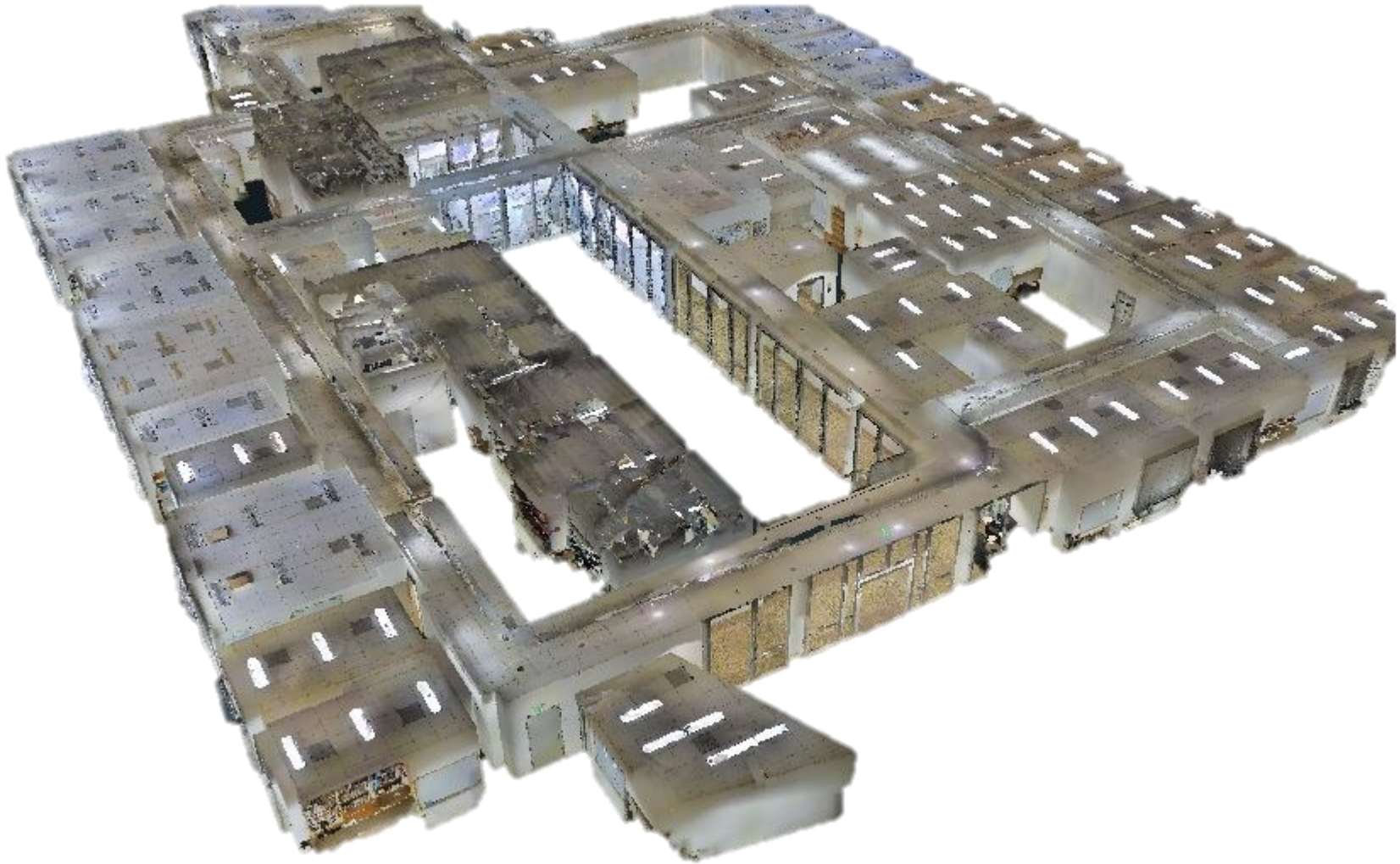
Gestalt's theory

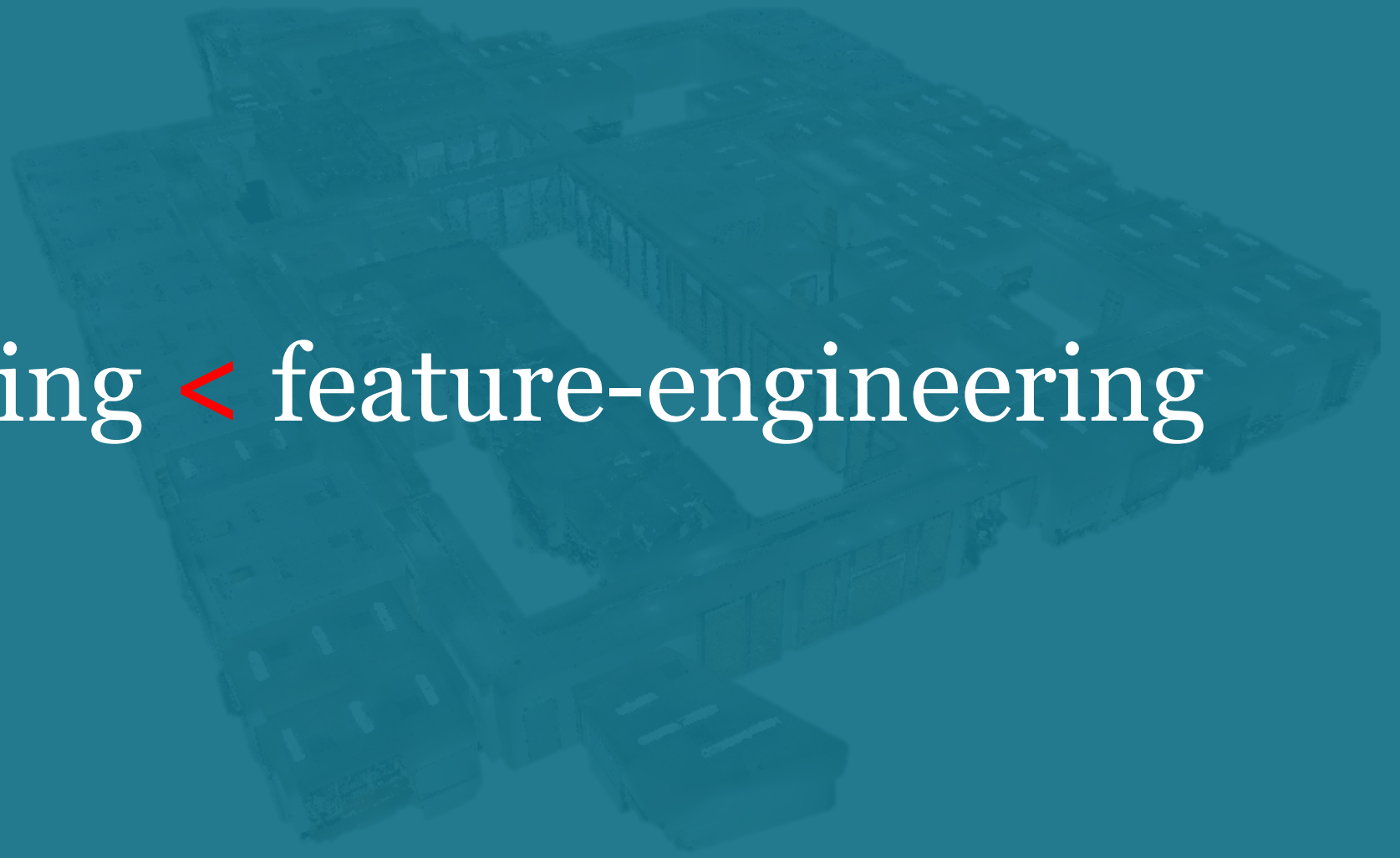


Visual patterns on points

Deep learning > feature-engineering

Point Cloud Datasets

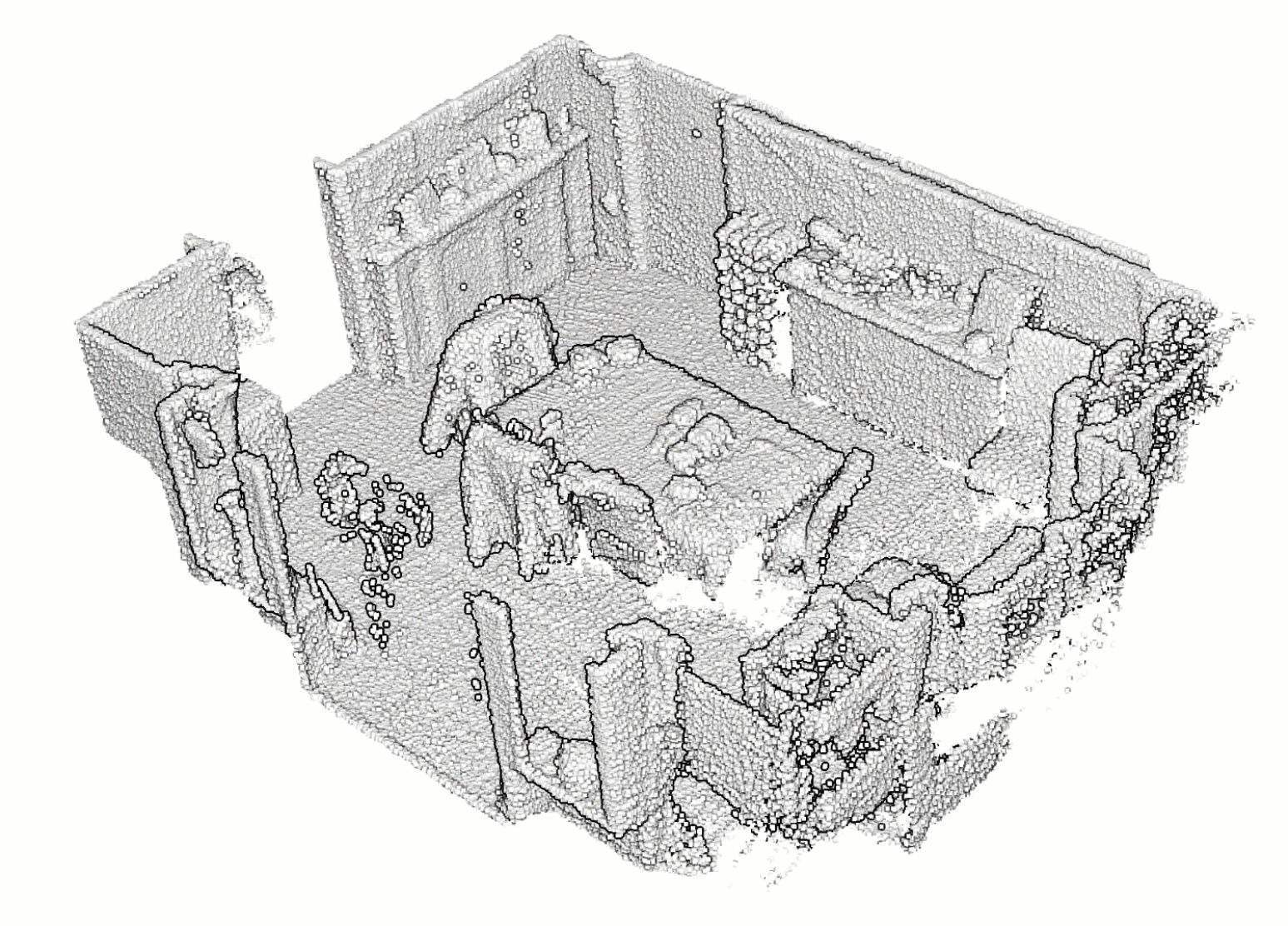


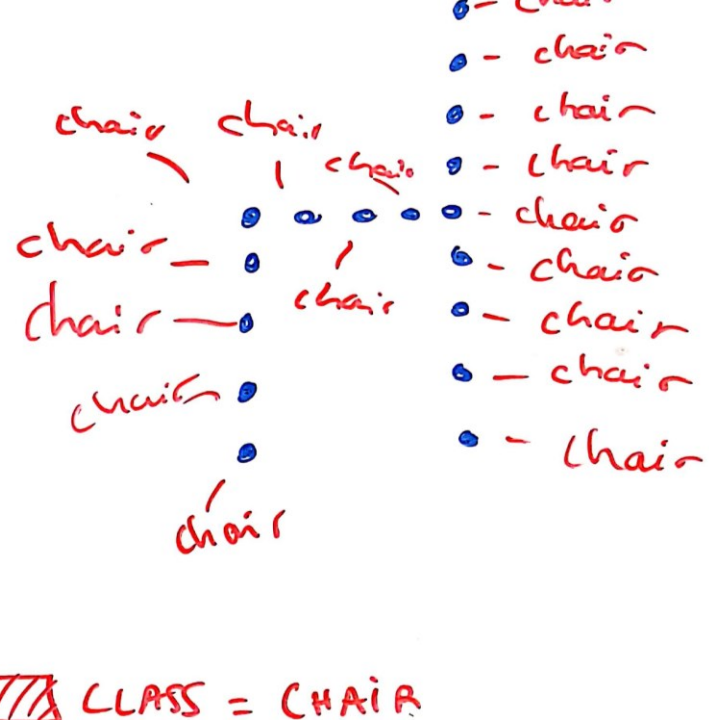


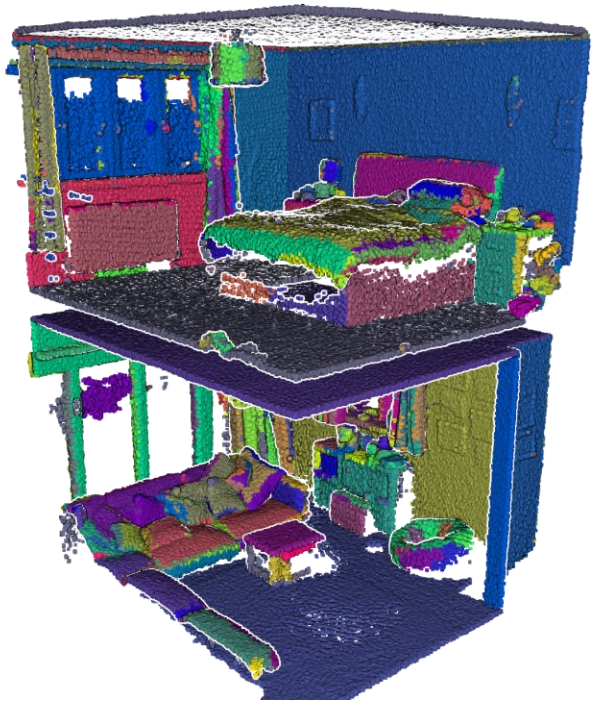
Deep learning < feature-engineering

Constitution of labelled datasets

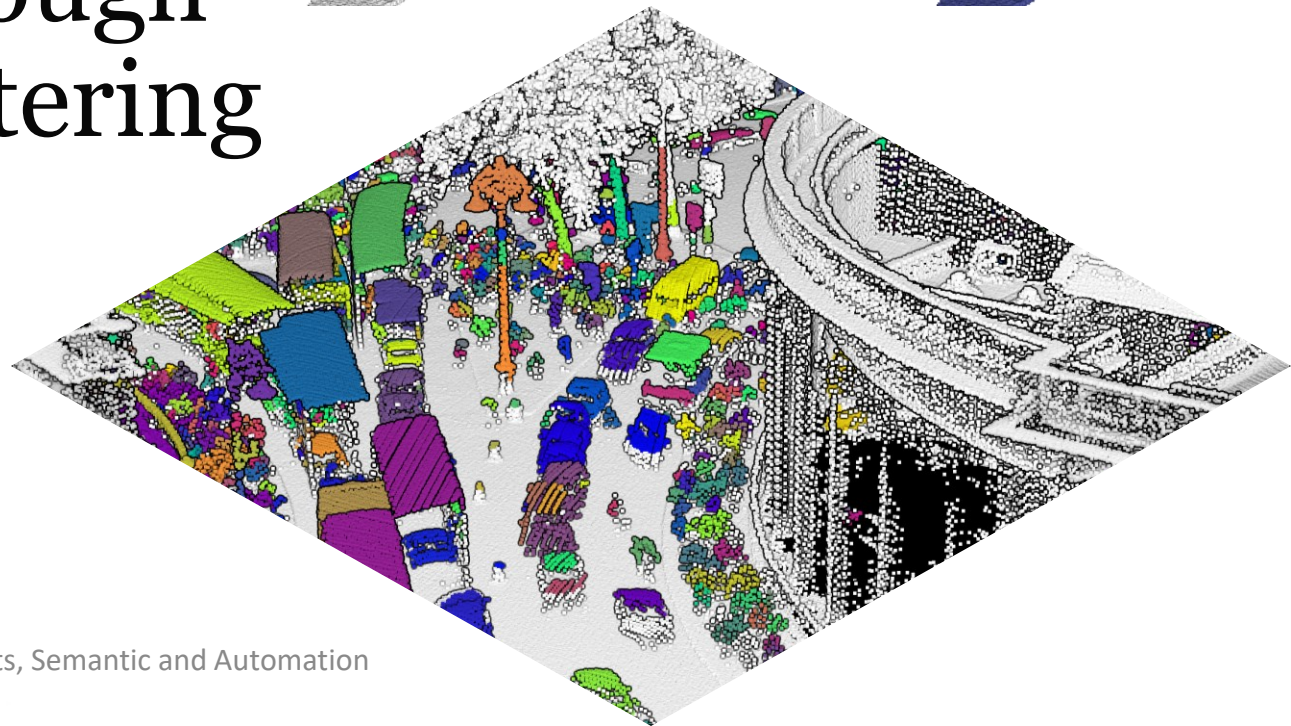
Unsupervised direction

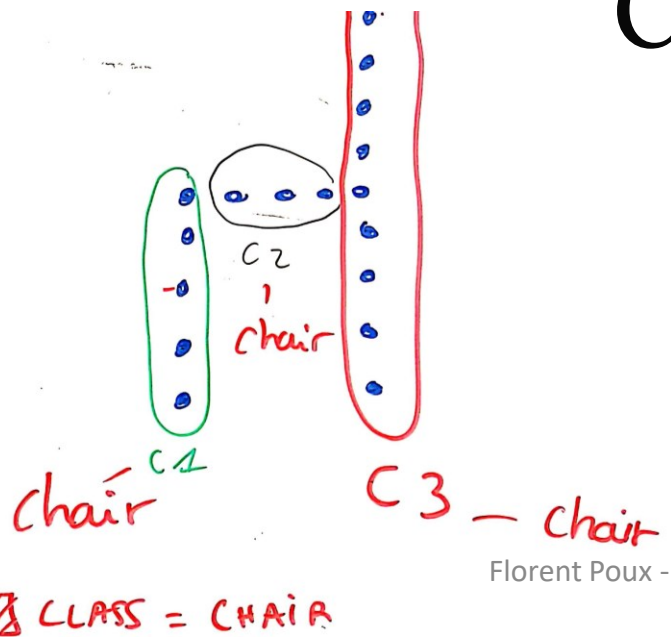




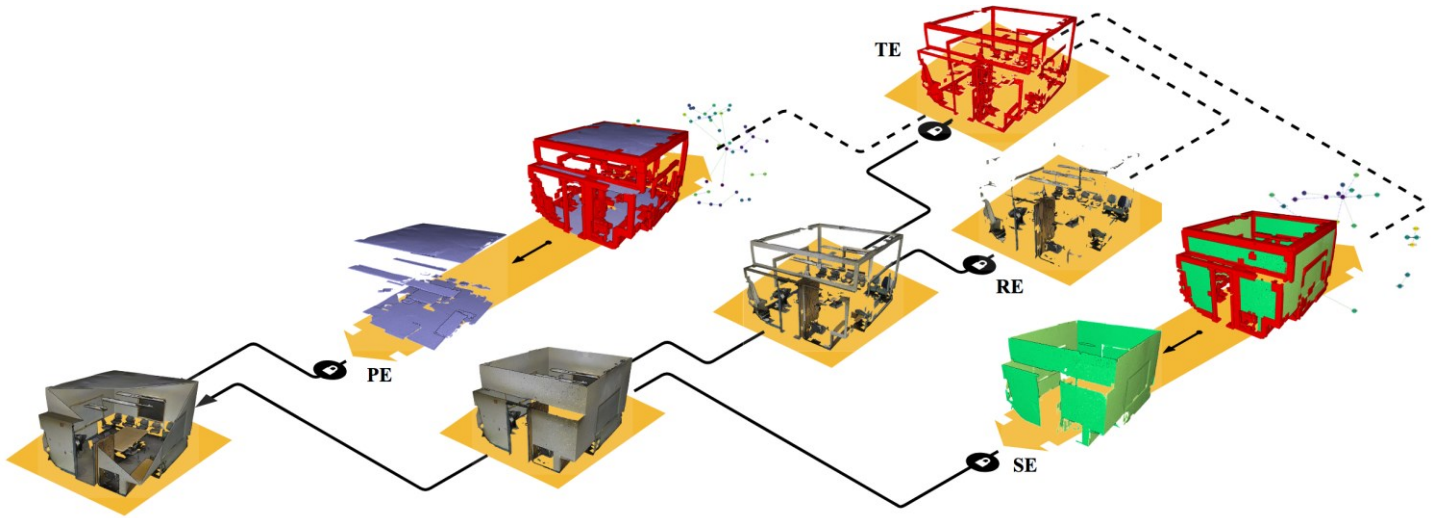


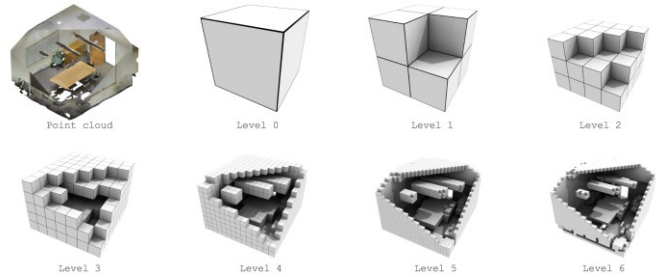
Creating through Clustering

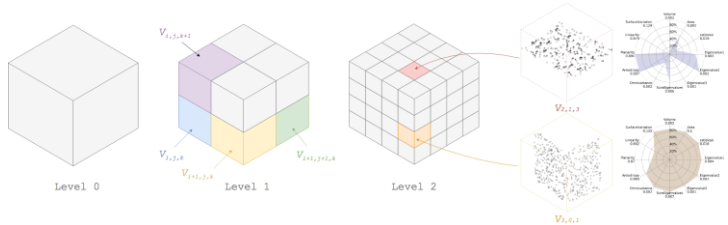




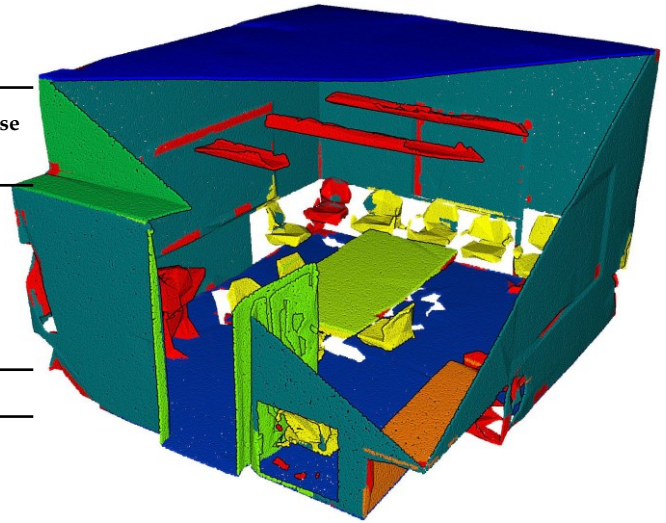

Segmentation (unsupervised)

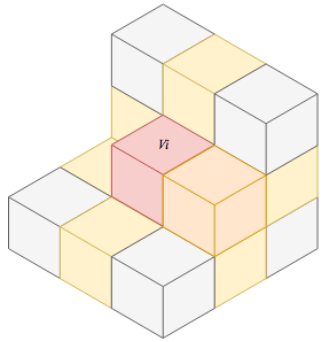


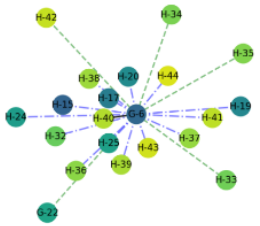




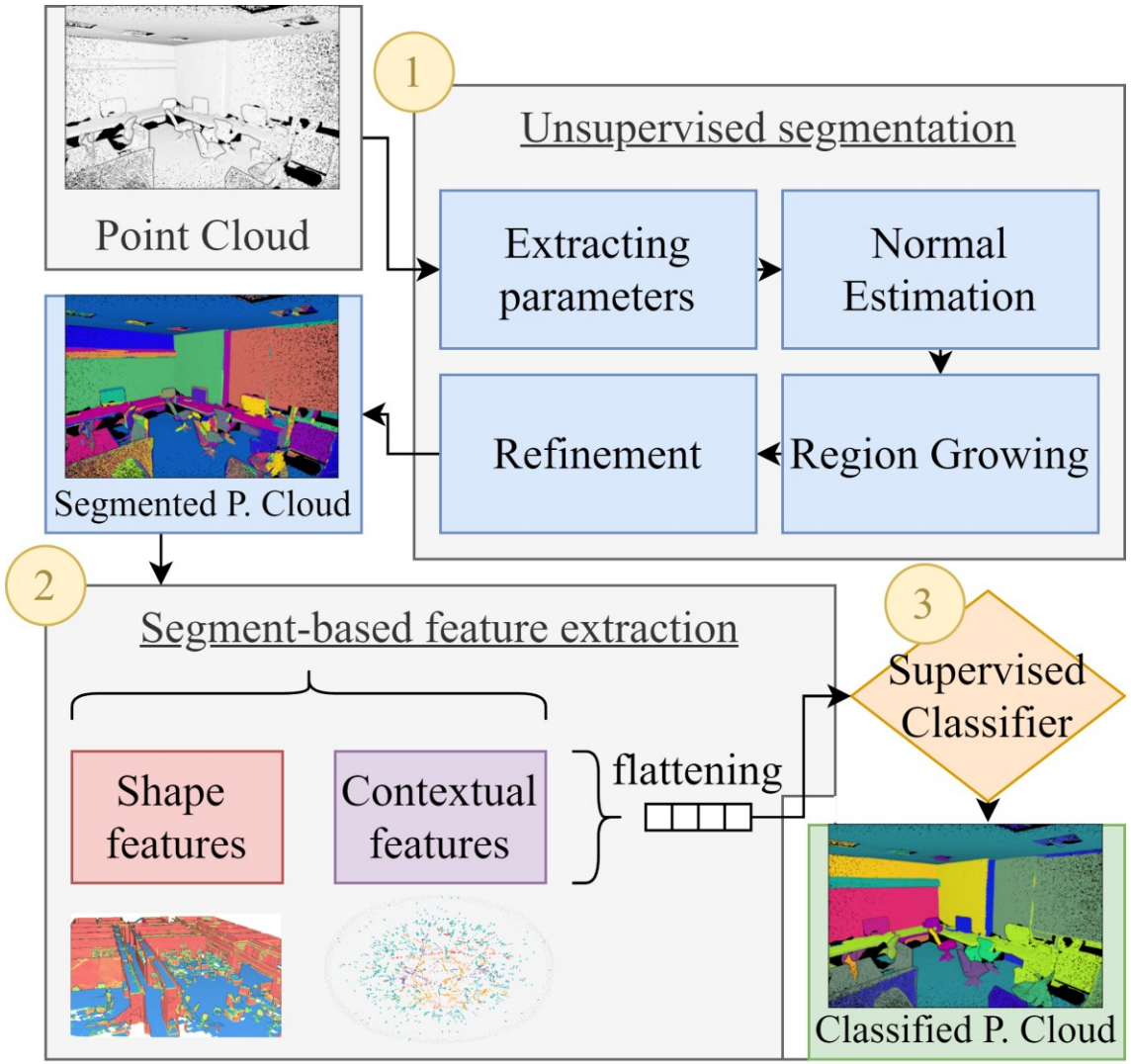
Overall Precision	Ceiling 0	Floor 1	Wall 2	Beam 3	Door 6	Table 7	Chair 8	Bookcase 10
Baseline (no colour) [16]	0.48	0.81	0.68	0.68	0.44	0.51	0.12	0.52
Baseline (full) [16]	0.72	0.89	0.73	0.67	0.54	0.46	0.16	0.55
Ours	**0.94**	**0.96**	**0.79**	0.53	0.19	**0.88**	**0.72**	0.2



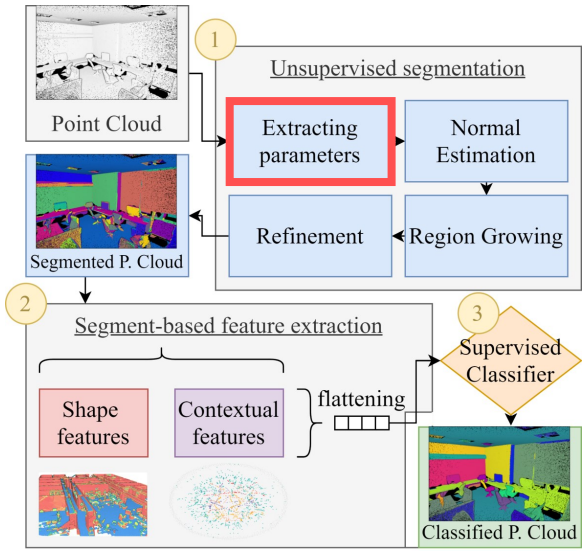


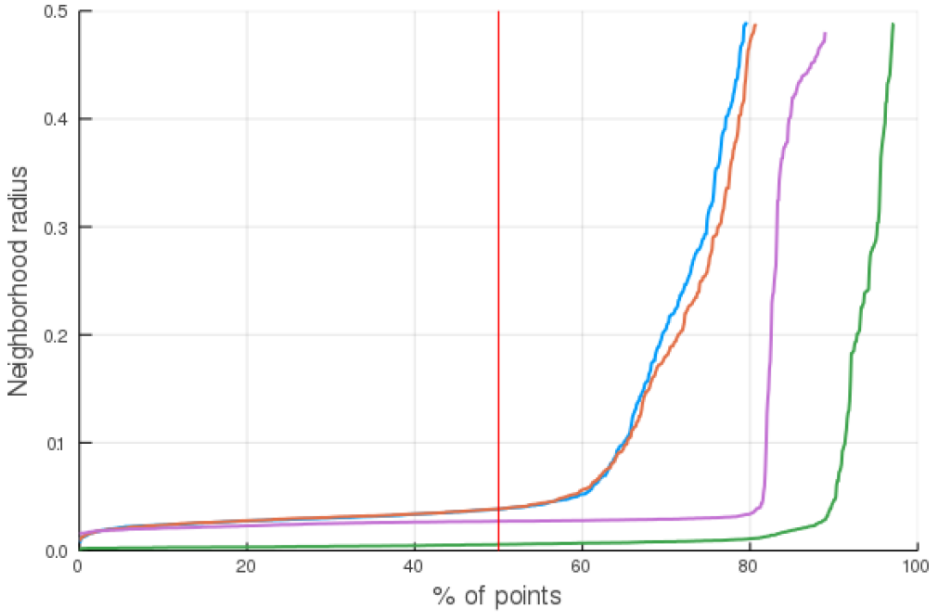


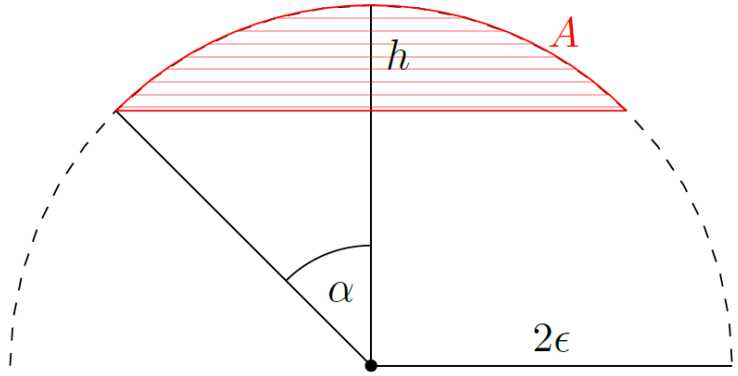
Methodology



Data analysis

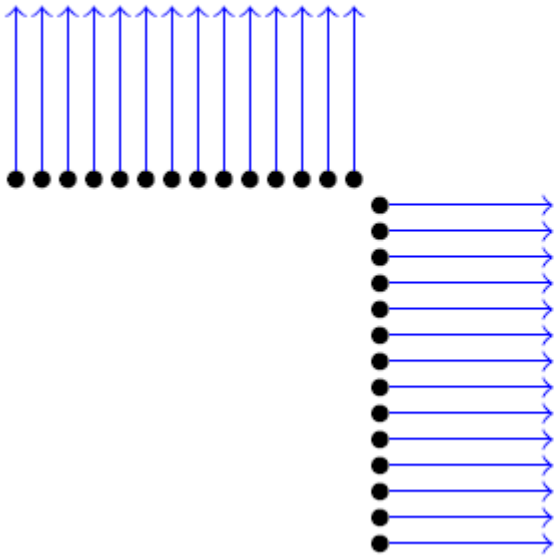


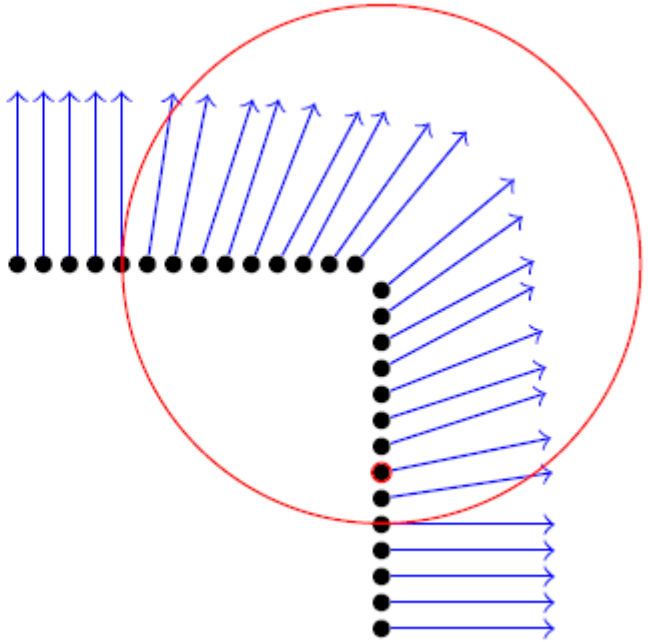


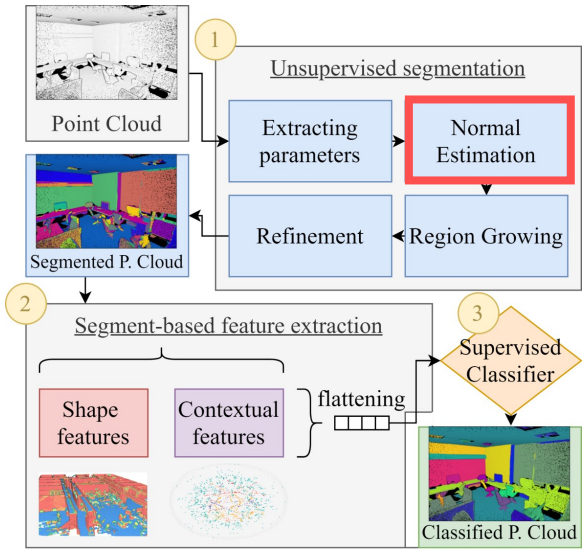


ϵ	t	$1 - n \cdot \bar{n}_0$
0.005	1.19s	0.81
0.01	2.24s	0.40
0.02	2.32s	$1.5 * 10^{-2}$
0.03	2.65s	$1.7 * 10^{-3}$
0.05	3.38s	$1.88 * 10^{-4}$
0.1	5.48s	$1.12 * 10^{-5}$

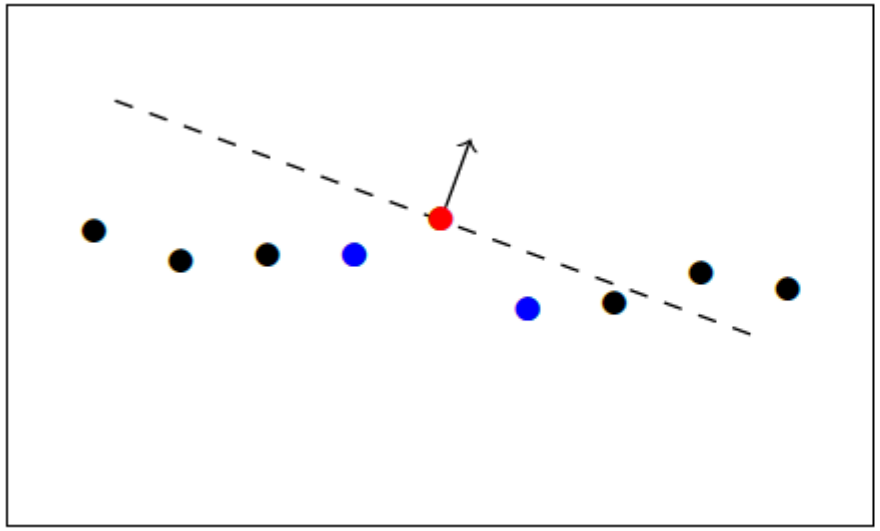
Normal estimation

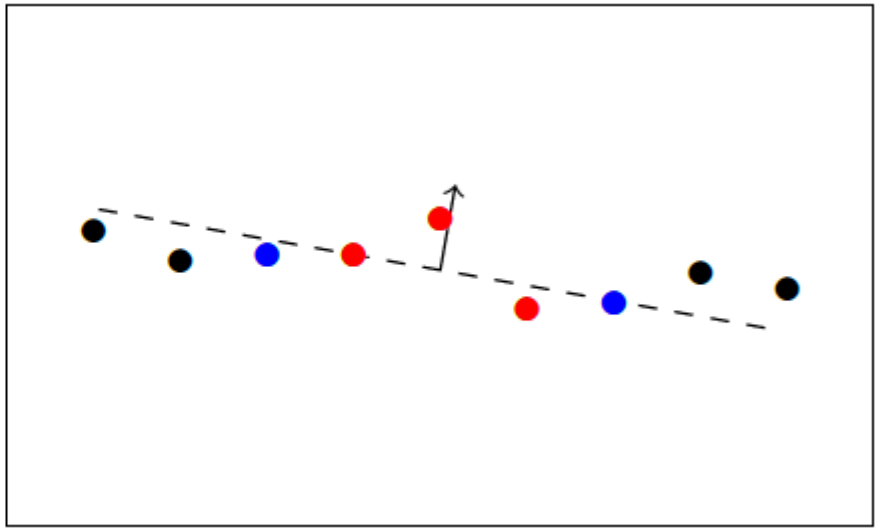


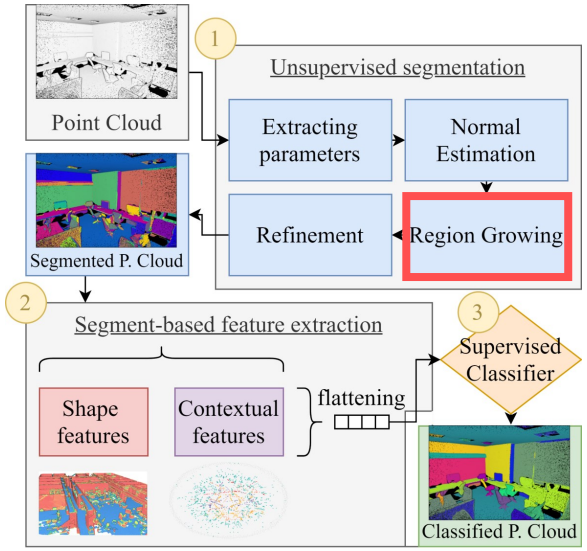




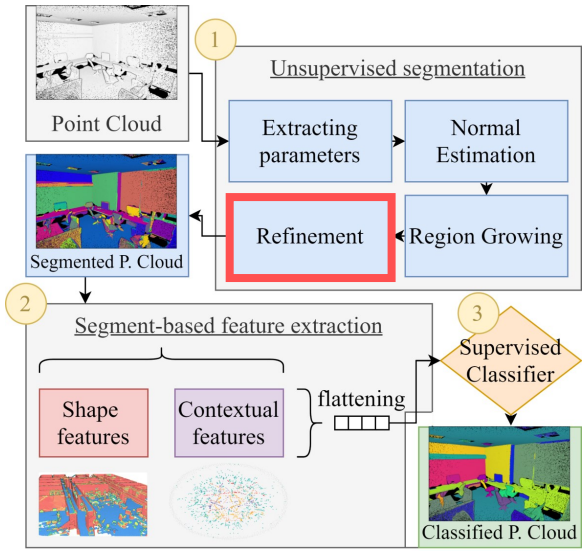
Region growing

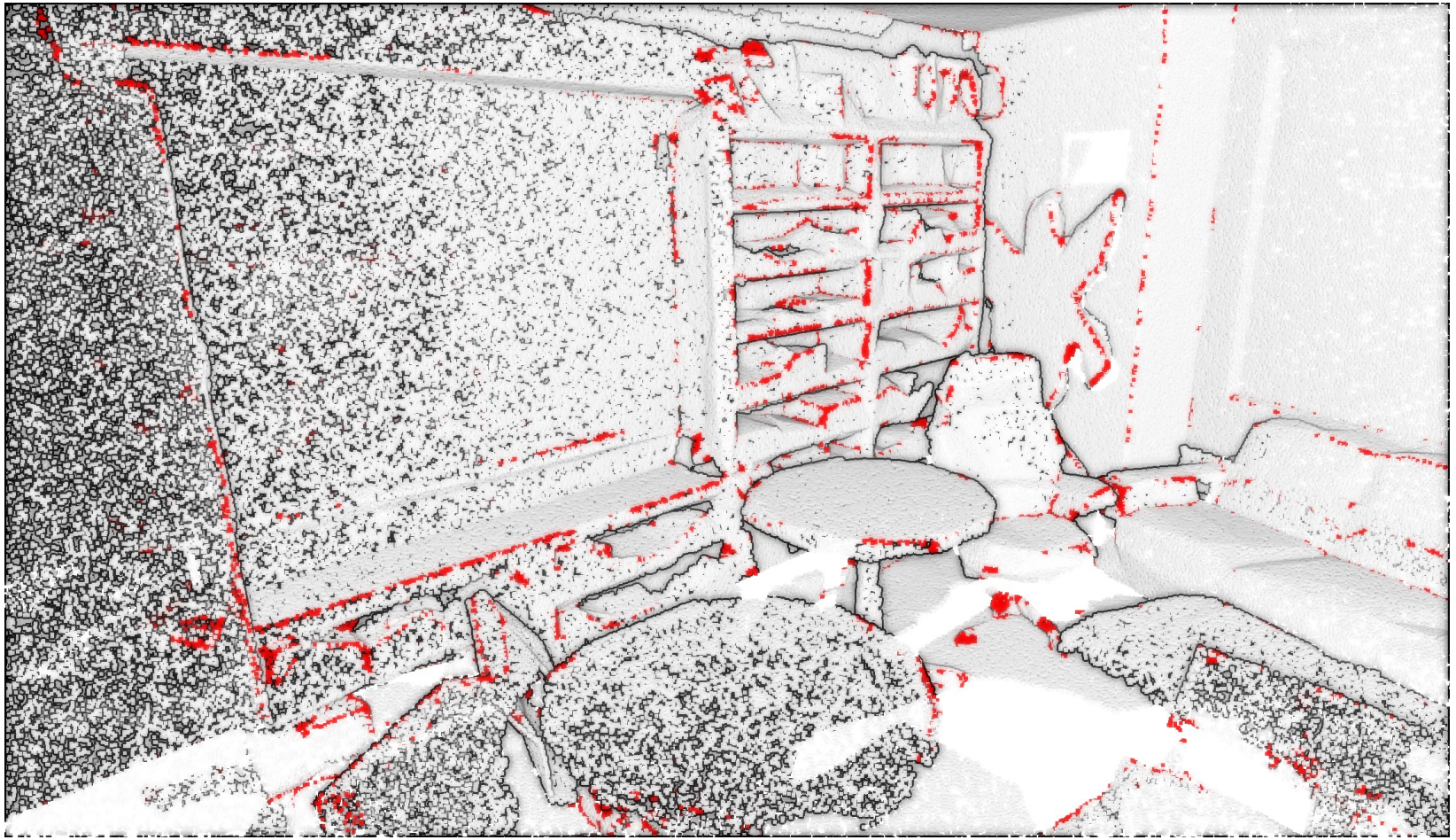




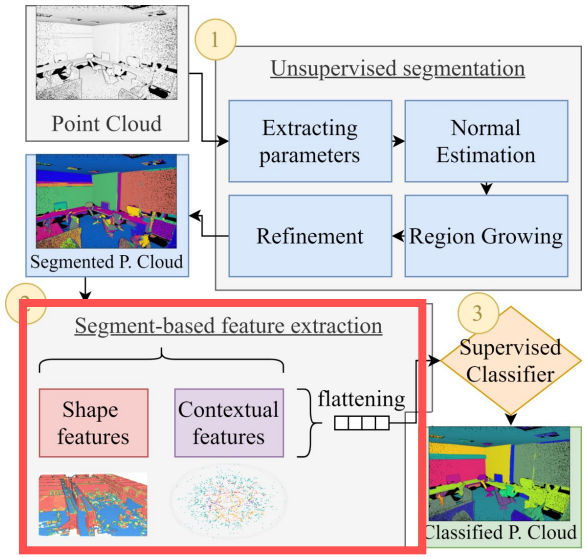


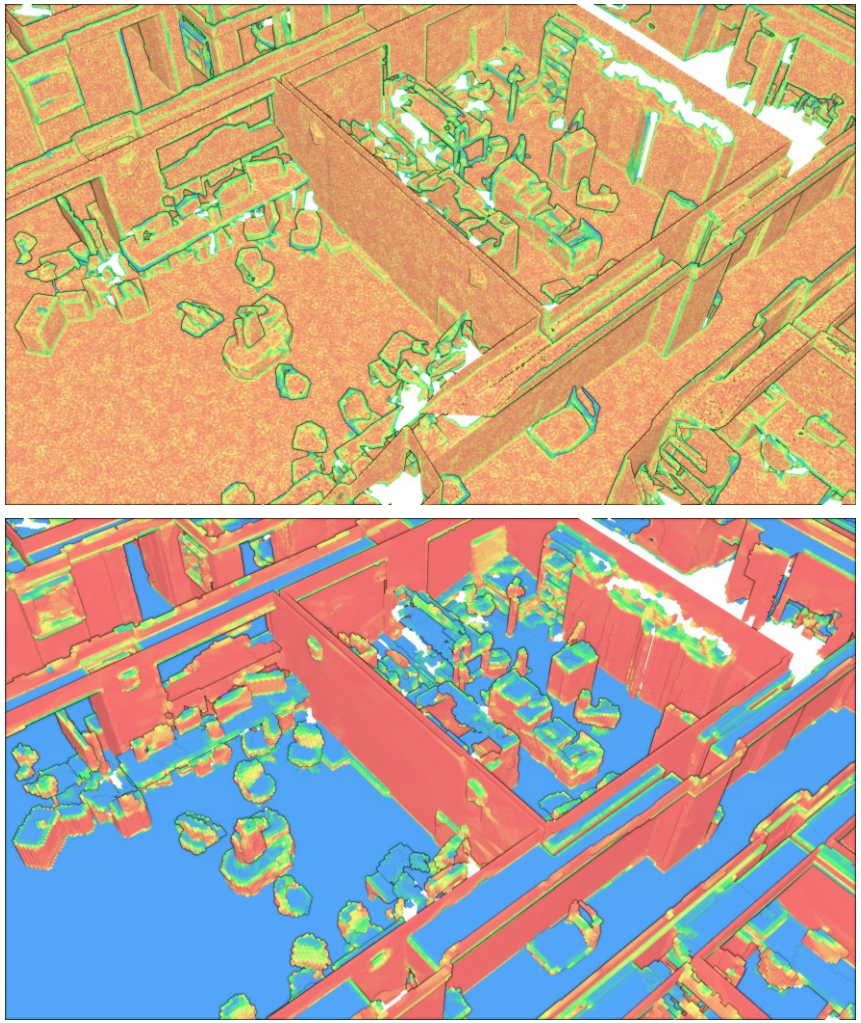
Refinement

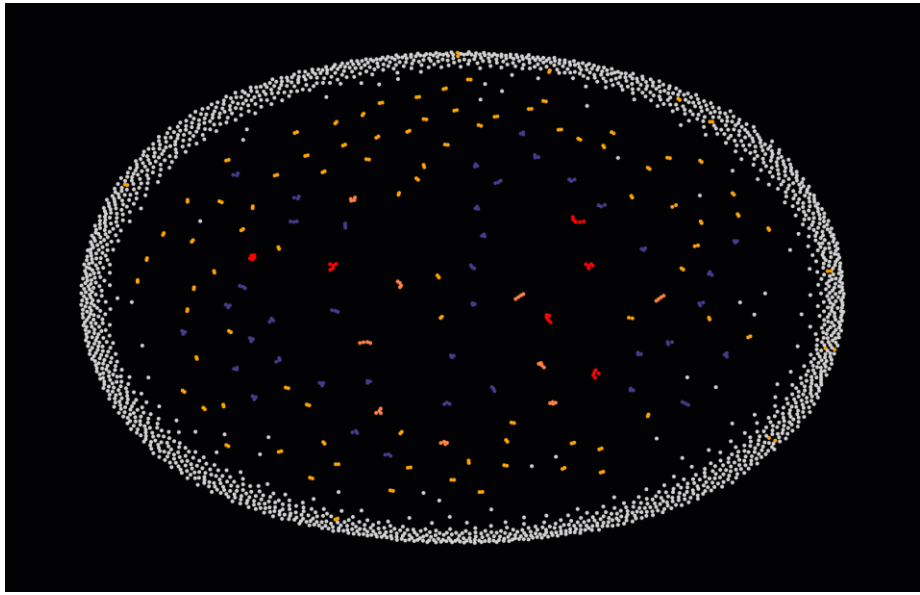

Point Cloud
1
Unsupervised segmentation
Extracting parameters
Normal Estimation
Refinement
Region Growing
Segmented P. Cloud
2
Segment-based feature extraction
3
Supervised Classifier
Shape features
Contextual features
flattening
Classified P. Cloud



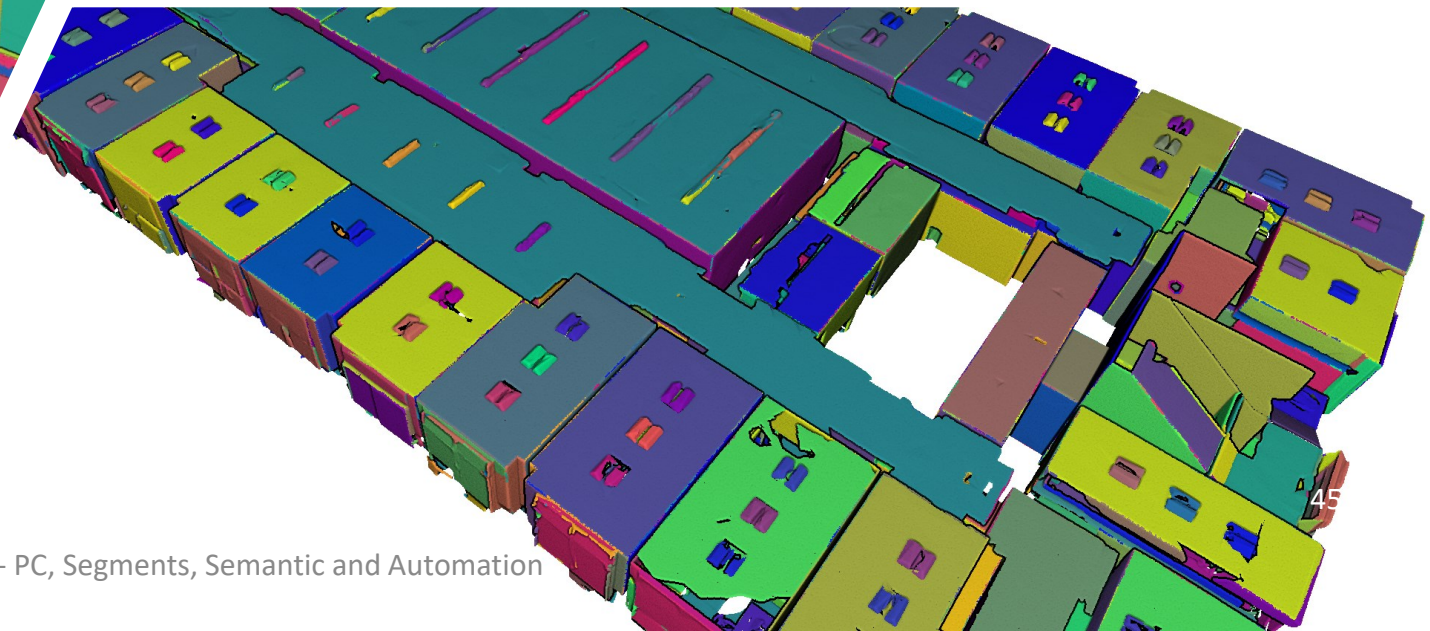
Segment-based feature extraction







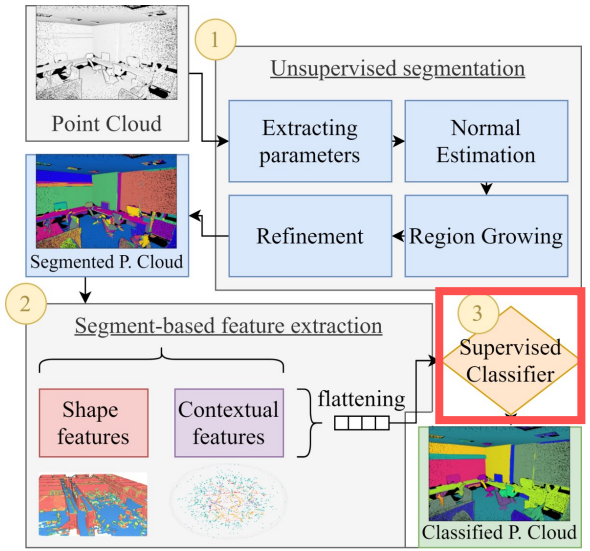
Classification

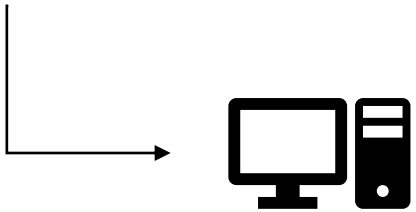


Supervised classification

PCID5_Area_1.txt | PCID5_Area_1.csv

```
"region";"size";"c_x";"c_y";"c_z";"n_x";"n_y";"n_z";"n_v";"min_x";"min_y";"min_z";"max_x";"max_y";"max_z";"t_x";"t_y";"t_z";"t_v";"b_x";"b_y";"b_z";"b_v";"class_instances";"dominant_class";"class_overlap"
1;105252;-9.575316;5.171289;2.5803957;-0.00080603594;-0.0051674023;0.9999863;1.6372062e-5;-13.029;4.366;2.533;-6.134;5.952;2.591;-0.9999878;0.0048642755;-0.00078090257;3.9600978;-0.004859984;-0.9999746;-0.0051712617;0.19752292;"(0,
2;73846;-8.200151;1.7167768;2.2110684;-0.9999941;0.0017084326;0.0029632938;1.4633276e-5;-8.219;0.498;-0.005;-8.183;3.35;4.515;-0.003405169;-0.41528076;-0.9096869;1.7162296;-0.00032354146;-0.90969163;0.41528416;0.30590907;"(2, 33) =
3;207284;-18.13789;39.021595;3.173104;-0.0029935492;0.0052707903;0.9999816;8.590412e-5;-20.529;36.811;3.111;-15.757;41.253;3.206;0.9998373;0.017808437;0.002899251;1.8795681;0.017792761;-0.9998275;0.0053232433;1.5969721;"(0, 40) =>
4;806732;-4.7358313;23.329819;2.7269266;-0.0012451629;0.001413865;0.9999982;0.00018165607;-6.0415;3.9375;2.625;-3.3935;42.8855;2.802;-0.003937032;-0.9999914;0.0014089526;121.85008;0.9999915;-0.003935272;0.0012507186;0.38948435;"(0,
5;53514;-3.8195767;37.737034;1.0725787;-0.99995154;0.008669987;0.004661228;0.0015415465;-3.9085;36.858;-0.021;-3.742;38.48;2.161;0.005078239;0.04871505;0.99879974;0.38442546;-0.008432537;-0.9987751;0.04875672;0.1548802;"(2, 77) =>
6;1425;-19.144423;35.671528;0.61222804;0.013771733;-0.070434324;-0.9974213;9.114115e-5;-19.416;35.462;0.574;-18.939;35.862;0.641;0.9490313;-0.3132078;0.03522121;0.013663678;-0.314881;-0.94706905;0.06253097;0.009783583;"(8, 0) => 14
7;5417052;-10.095664;21.070015;0.0067797024;0.0016743005;-0.0008986343;0.99999815;0.0008971762;-20.902;-1.939;-0.112;1.81;45.973;0.155;-0.04660645;-0.9989129;-0.0008196259;163.88496;0.9989119;-0.04660487;-0.0017143629;41.595848;"(1
8;64885;-9.599919;16.103174;0.5506317;-0.0049851714;-0.006380162;0.9999672;0.00014718481;-11.091;14.808;0.517;-7.987;17.478;0.661;-0.99349487;-0.1137352;-0.00567858;0.7365124;0.11376786;-0.9934905;-0.0057716705;0.44258046;"(13, 323
9;80608;-7.712195;9.3241005;1.3495656;-0.0051039457;0.99994963;0.00863042;5.8591366e-5;-9.501;9.293;0.007;-6.096;9.353;2.574;-0.9811324;-0.006675422;0.19322166;0.8954167;-0.1932695;0.007481426;-0.9811171;0.4994856;"(2, 91) => 80242
10;99766;-12.296879;0.7069866;3.092452;-0.00089496933;-0.008085594;0.9999669;6.535401e-5;-13.408;-2.073;2.984;-11.255;3.365;3.15;0.018031796;-0.99980503;-0.008068144;2.5667646;0.99983704;0.01802398;0.0010405926;0.39722216;"(0, 28)
11;20762;-15.663225;14.767419;1.0821447;-0.28027517;0.95990896;0.0045273732;9.23872e-5;-16.237;14.612;0.001;-15.151;14.932;2.154;0.012622753;-0.0010304777;0.9999198;0.36639374;0.9598367;0.2803098;-0.01182788;0.0925124;"(6, 83) => 1
12;2071;-14.200738;0.16244327;1.7010247;0.04645007;-0.0038808882;0.99891305;2.5744628e-5;-14.32;-0.208;1.676;-14.025;0.613;1.726;0.1206311;-0.99265224;-0.0094659915;0.043928787;0.99161005;0.1209397;-0.045640618;0.0056981626;"(10, 3
13;136139;-0.7689931;38.292843;3.0882318;-0.000151023;-0.0007382373;0.9999997;2.7442054e-5;-3.312;36.8;3.071;1.794;39.767;3.107;0.99997145;0.007557571;0.00015659802;2.2165673;0.00755769;-0.99997103;-0.0007370748;0.7652779;"(0, 21)
14;30206;-13.137964;32.5025;1.4776487;-0.99120545;0.014692605;-0.13151395;0.001367271;-13.181;31.156;0.248;-12.877;33.627;2.139;-0.04387787;-0.97408664;0.22187842;0.49596137;-0.124845974;0.22569765;0.9661646;0.16408584;"(2, 184) =>
15;33340;-16.780153;25.404144;1.1334536;-0.99993724;0.011157464;0.0010075002;0.00010277976;-16.812;24.615;0.041;-16.734;26.221;2.198;0.0014555681;0.040223595;0.9991896;0.3704423;-0.011107899;-0.9991283;0.04023732;0.20556074;"(2, 20
16;121266;-0.62898433;27.659338;1.8487586;-0.0009511113;0.9999603;0.008872645;2.2411346e-5;-3.313;27.644;0.005;1.766;27.701;3.116;-0.9979965;-0.0015106797;0.06325226;1.9074966;0.06326316;-0.008794691;0.9979581;0.5641115;"(2, 48) =>
17;630;-6.603506;22.584764;0.23133175;0.57028615;-0.7831471;-0.24789982;7.156103e-5;-6.738;22.483;0.022;-6.435;22.739;0.517;-0.23748207;-0.44608206;0.8629096;0.022937631;-0.7863689;-0.43323362;-0.4403778;0.0030174116;"(13, 267) =>
```





Model = Random Forests

Hyperparameters = standard (no fine-tuning)

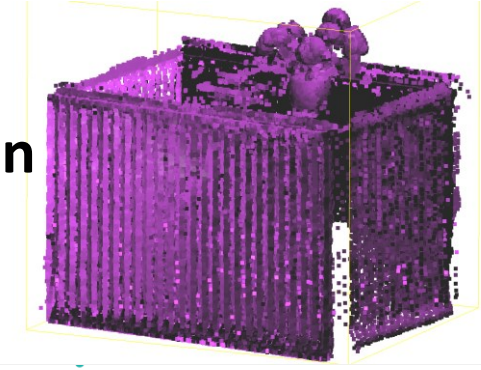
Training = 1 Area

Testing = the other 5 areas

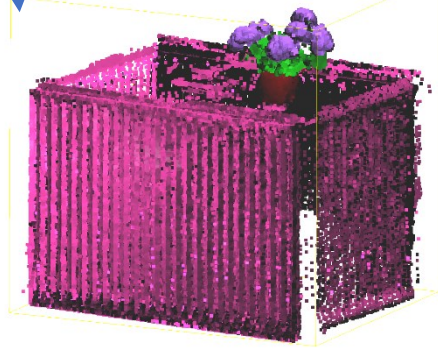
Knowledge-driven

Context / Proximity

Isolation



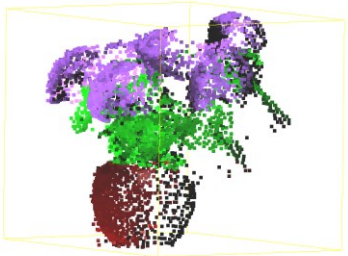
Relation « host/guest »

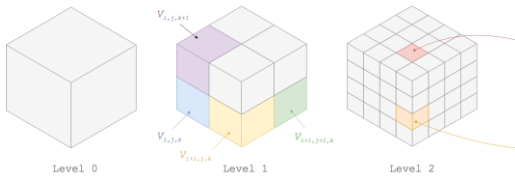


Local Features

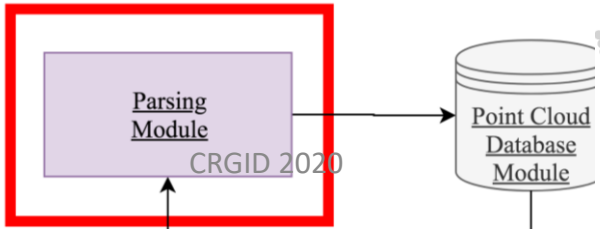
Relationships / Topology

Extract

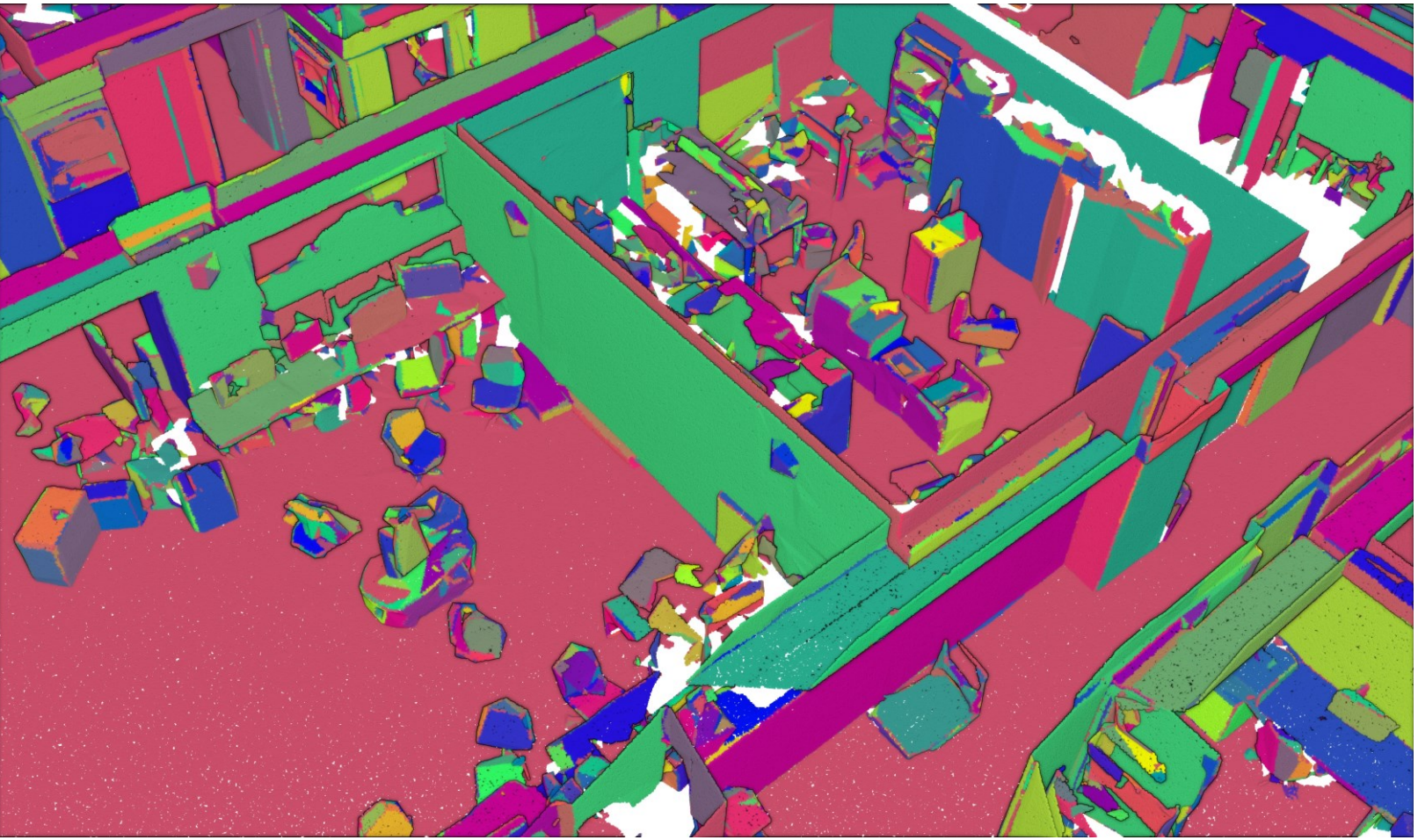




Geometries Generalizations

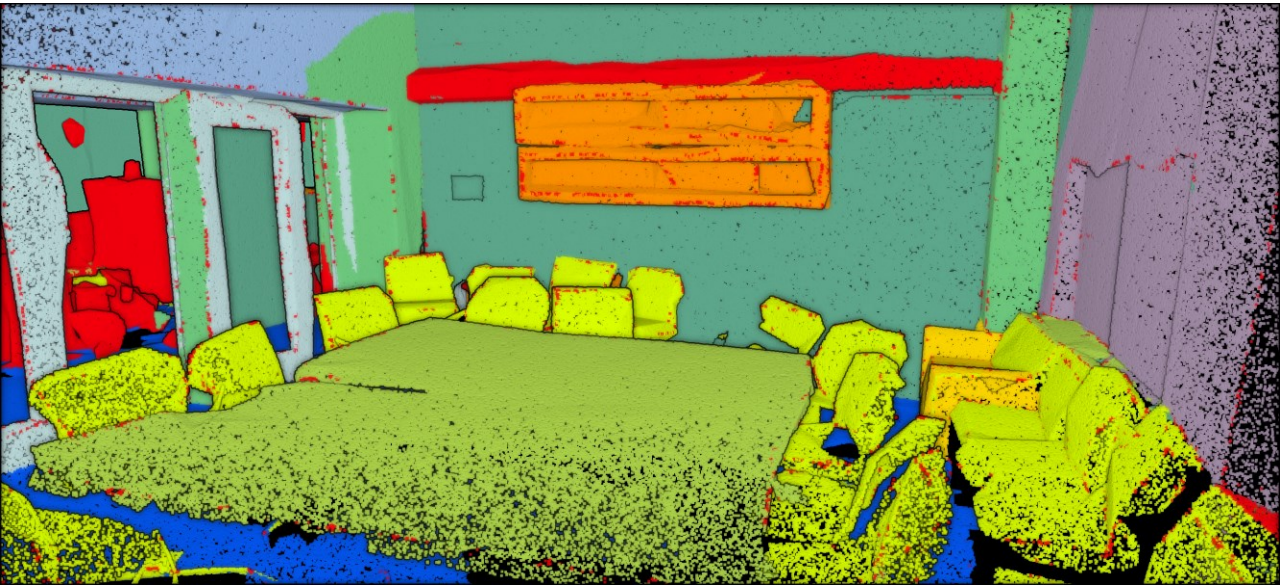


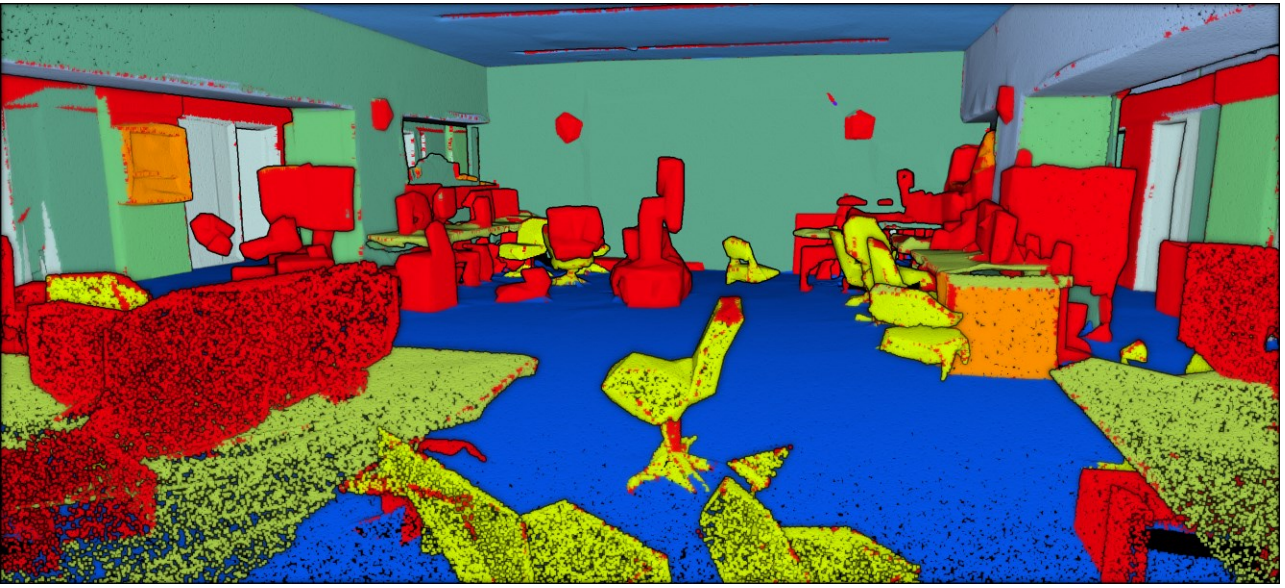
Segmentation results



Data set	Over Seg.			Under Seg.		Sharp-ness
	Med-ian	75%	Max	99%	Max	
1	11	17	3883	1	9	89.92%
2	12	20	644	1	13	90.34%
3	11	21	427	1	9	91.25%
4	9	19	896	1	15	89.86%
5	10	18	1525	1	21	86.10%
6	11	18	794	1	9	90.61%

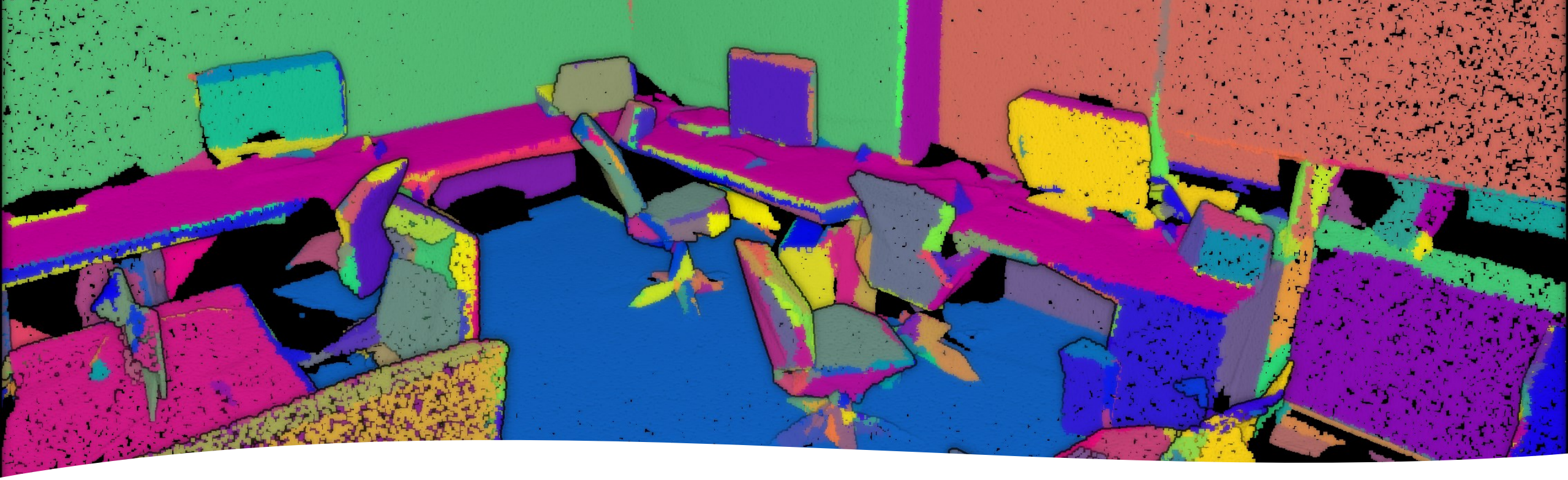
Classification results





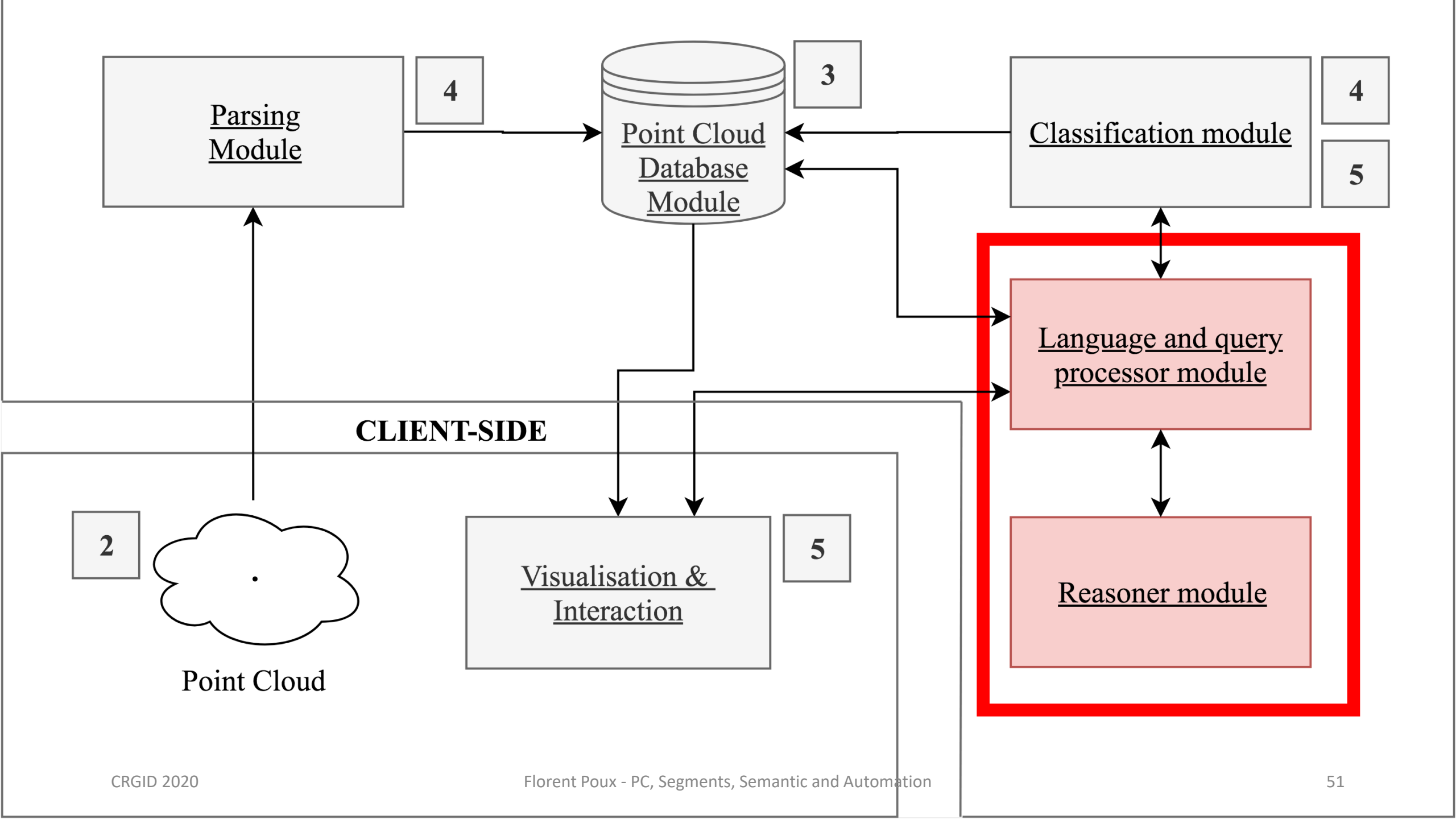
Areas	Ceil.	Floor	Wall	Win.	Door	Table	Chair	Board	Clutter
	0	1	2	5	6	7	8	11	13
A-1	98.8	98.4	86.8	80.0	73.8	84.6	83.9	33.1	83.1
A-2	97.0	89.2	89.0	97.6	67.9	87.6	97.2	33.4	67.2
A-3	98.5	99.3	87.0	72.8	79.0	88.5	93.1	30.4	78.0
A-4	95.3	98.8	89.4	82.5	79.5	86.6	89.9	16.3	71.5
A-5	97.6	99.0	89.4	69.0	83.7	85.9	81.3	4.1	71.7
A-6	98.1	98.8	86.5	77.6	76.5	88.9	90.1	19.9	80.7

Weighted F1-score = 88.1%



Key take-aways

+ Relatively simple approach (good replication)
+ Object-based classification = high scalability
+ Good performances (both in terms of accuracy and comp. d.)
+ High potential for semi-automated classification
+ Usable for a large panel of applications (registration, modelling …)
+ In-test for highly variable scenes


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 : Œuvre 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)
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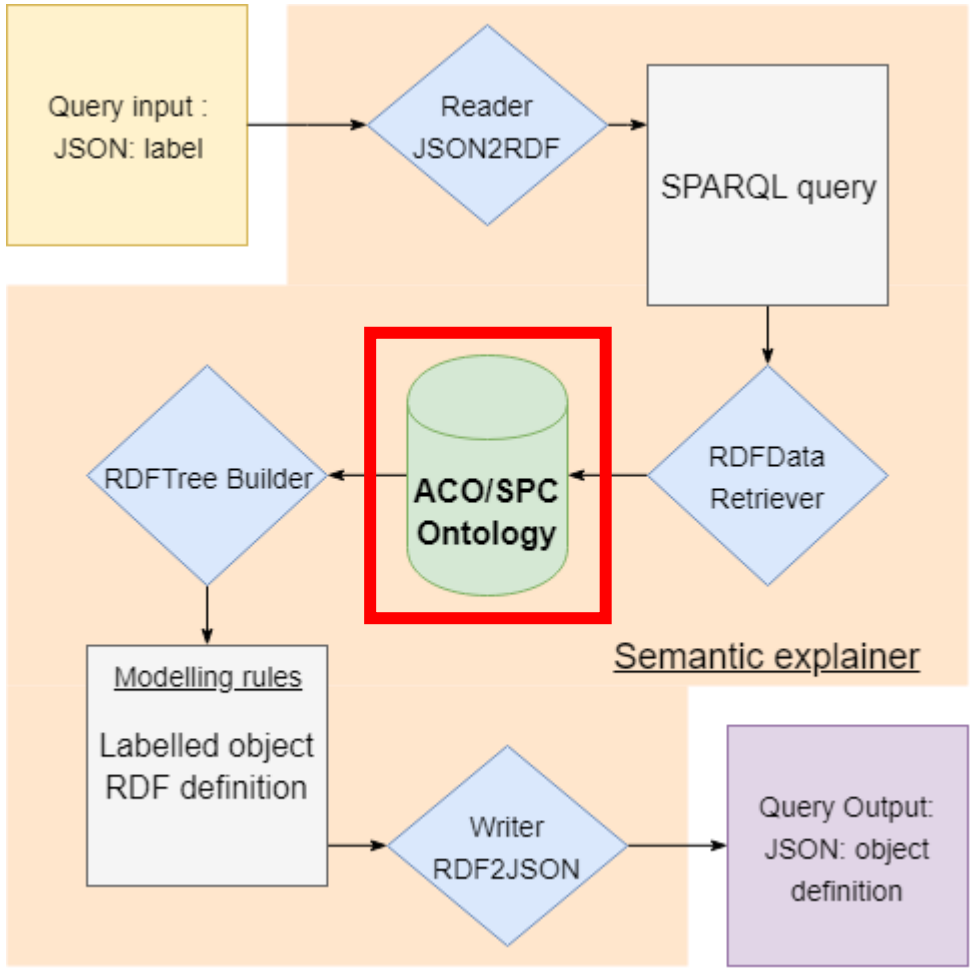
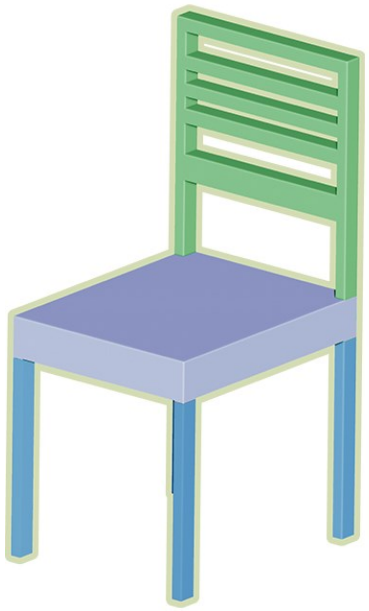
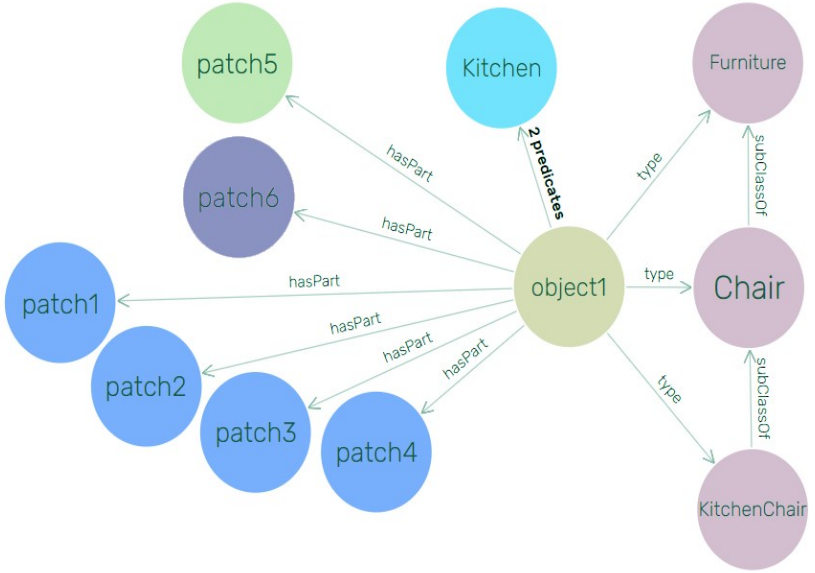
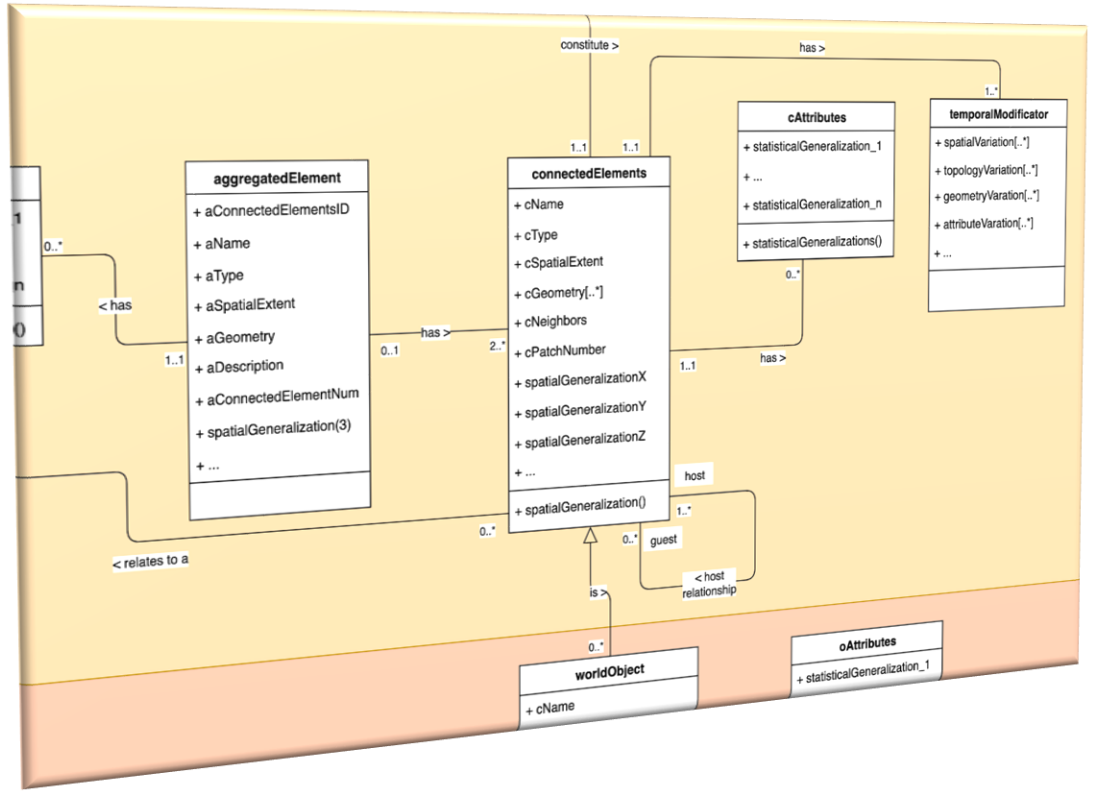

Query input :
JSON: label
Reader
JSON2RDF
SPARQL query
RDFTree Builder
ACO/SPC
Ontology
RDFData
Retriever
Semantic explainer
Modelling rules
Labelled object
RDF definition
Writer
RDF2JSON
Query Output:
JSON: object
definition




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

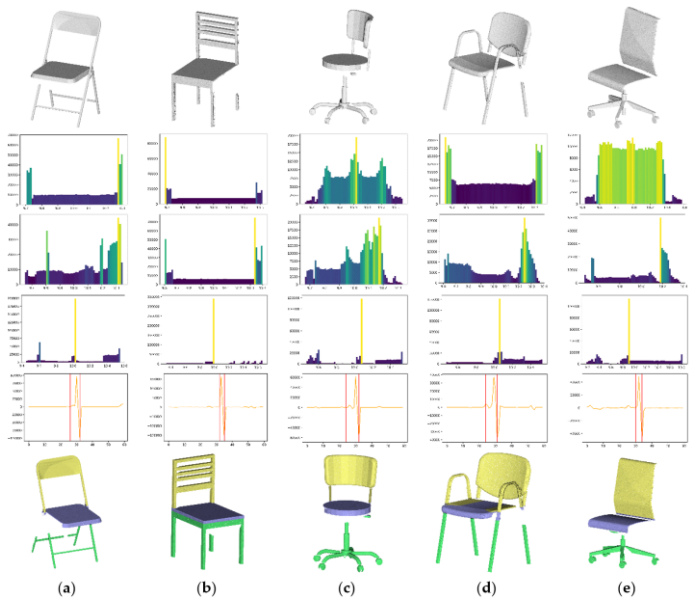


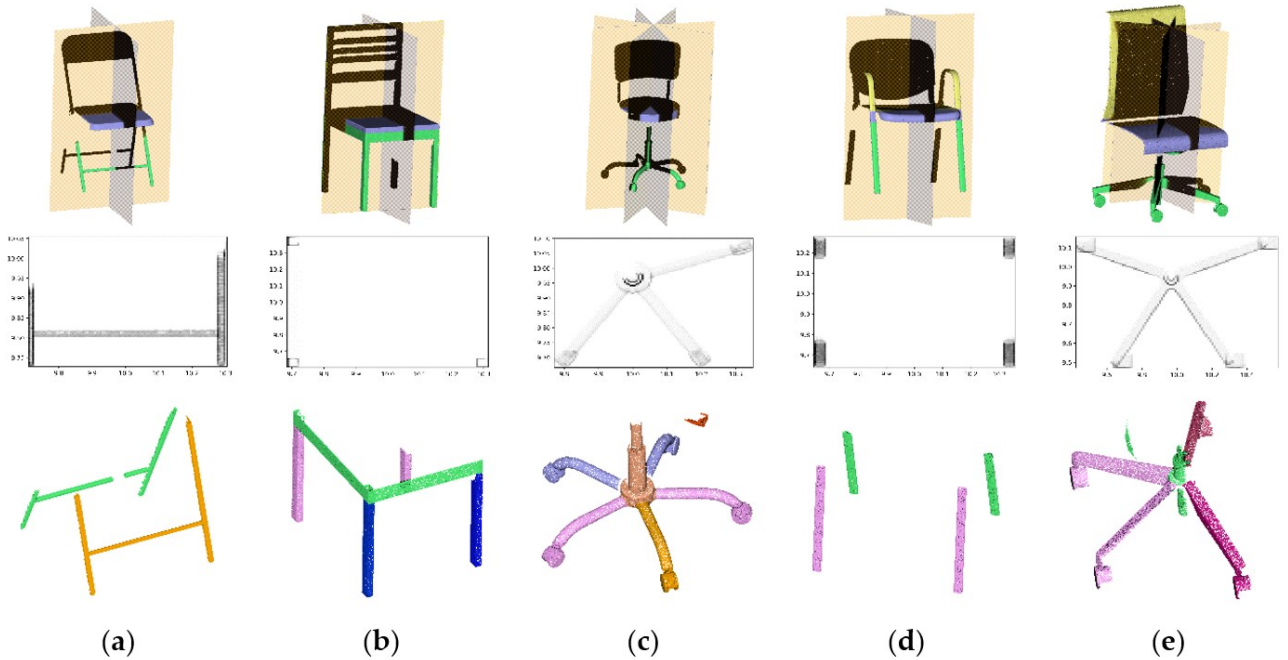
Connected Elements

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

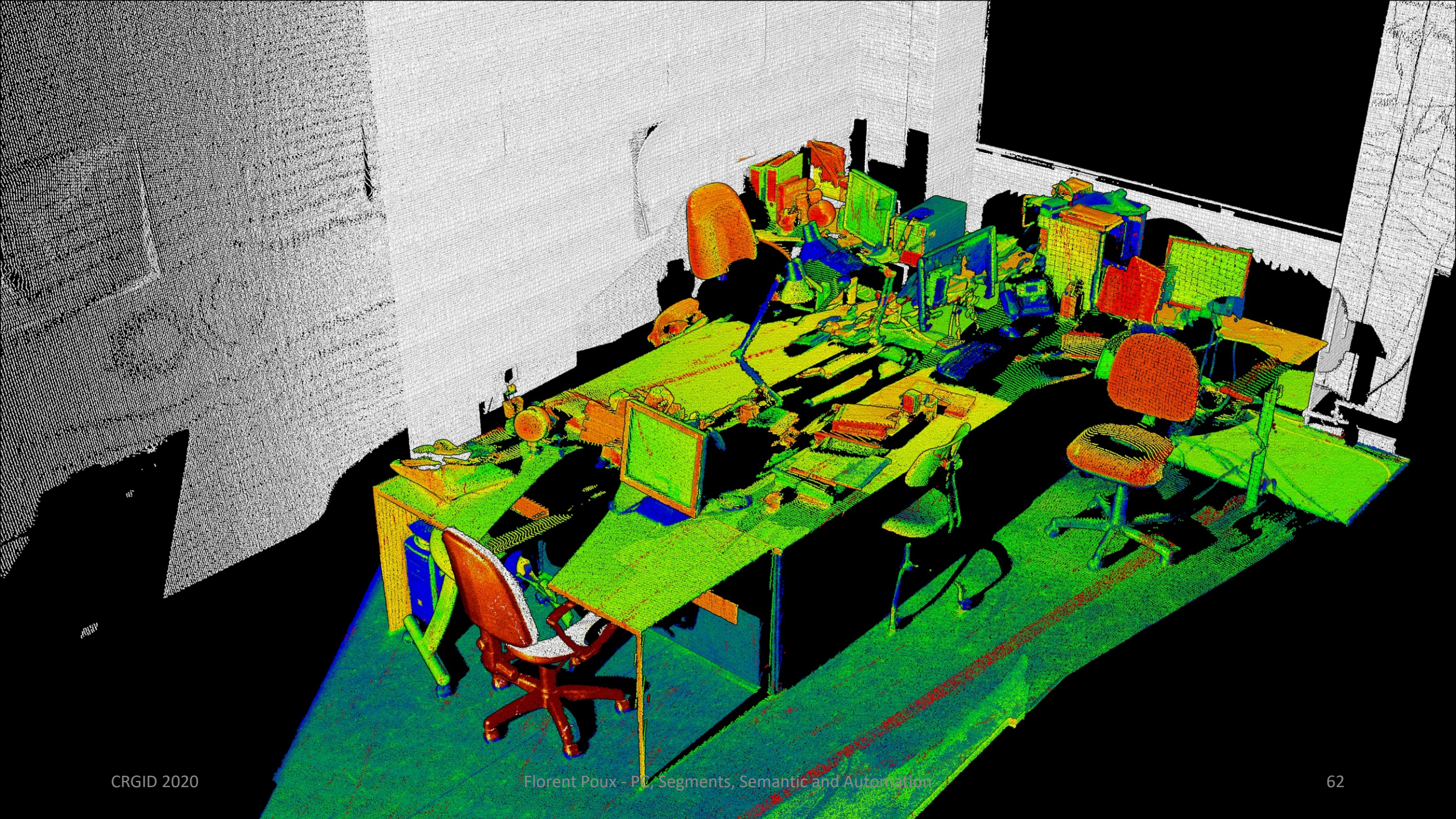
Chair = AE

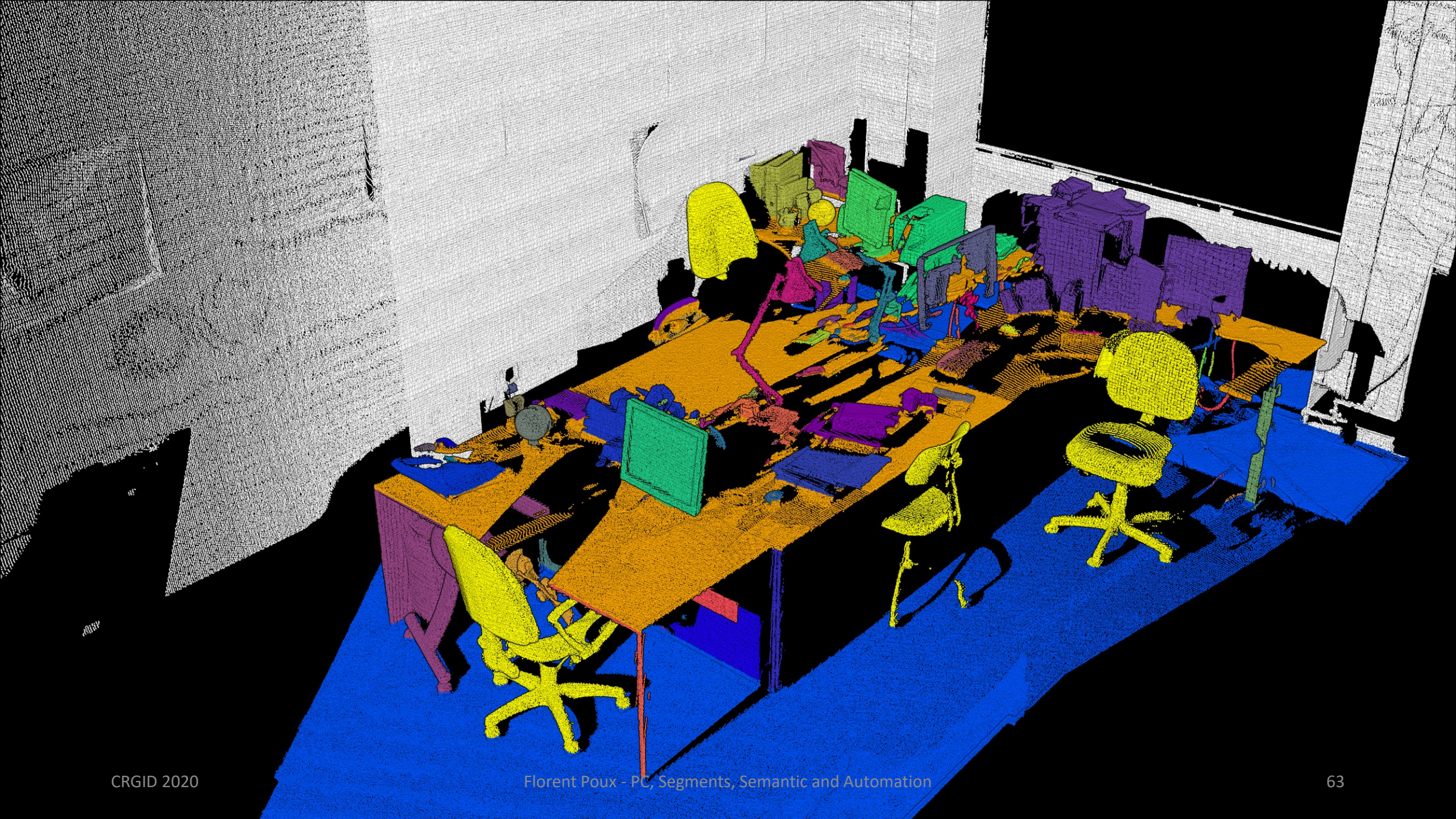
Part segmentation

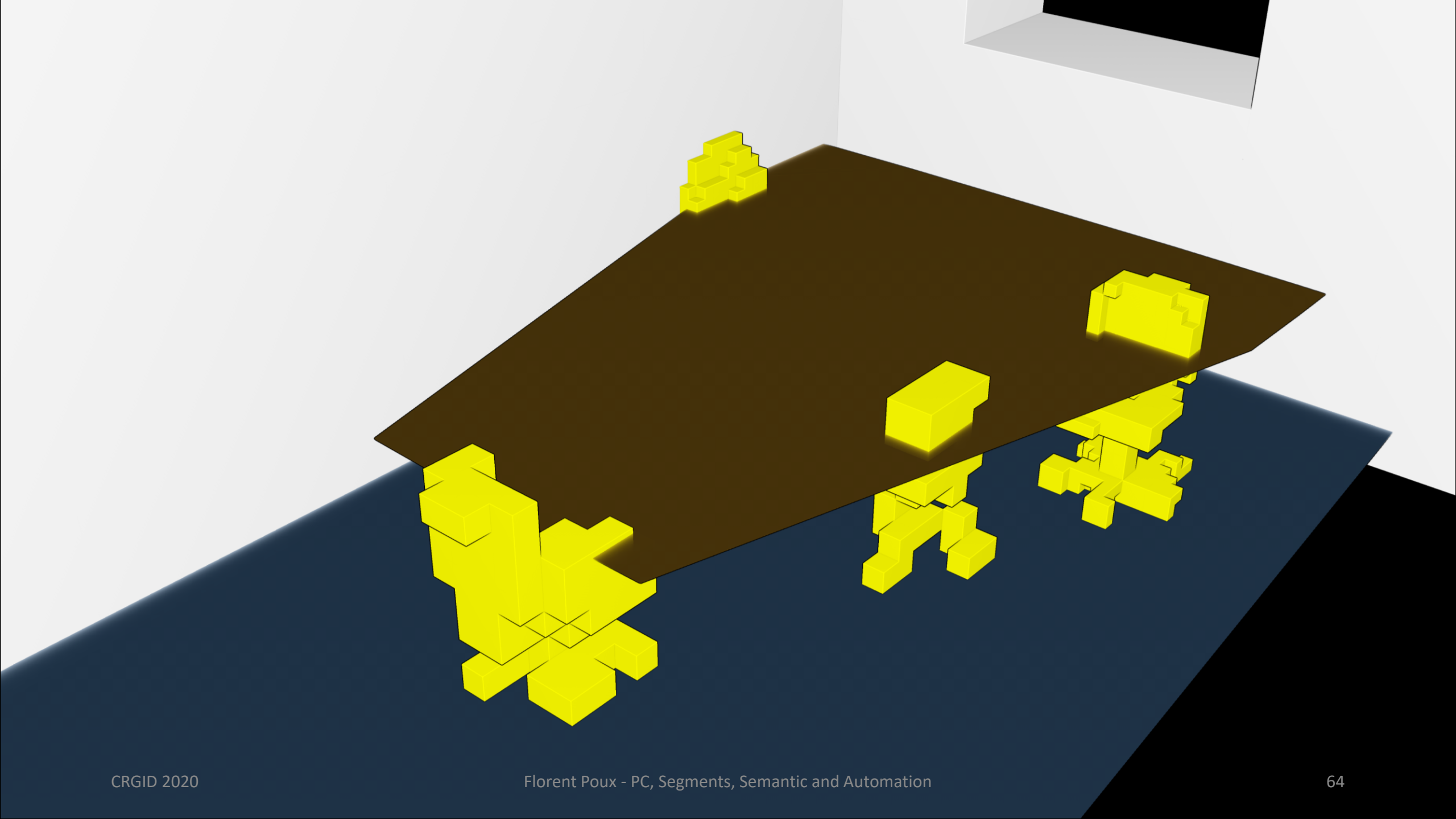

(a)
(b)
(c)
(d)
(e)

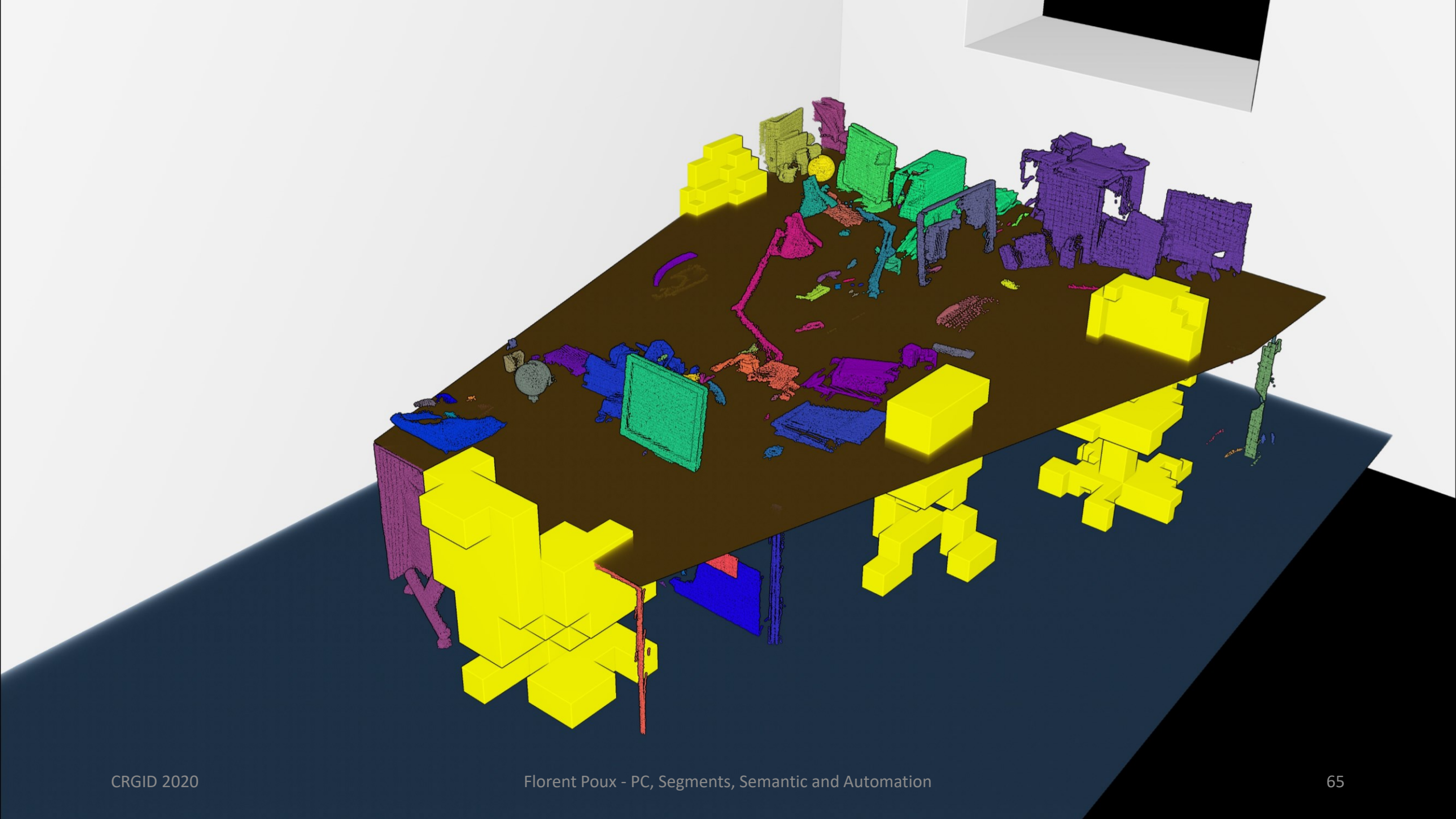

(a)
(b)
(c)
(d)
(e)

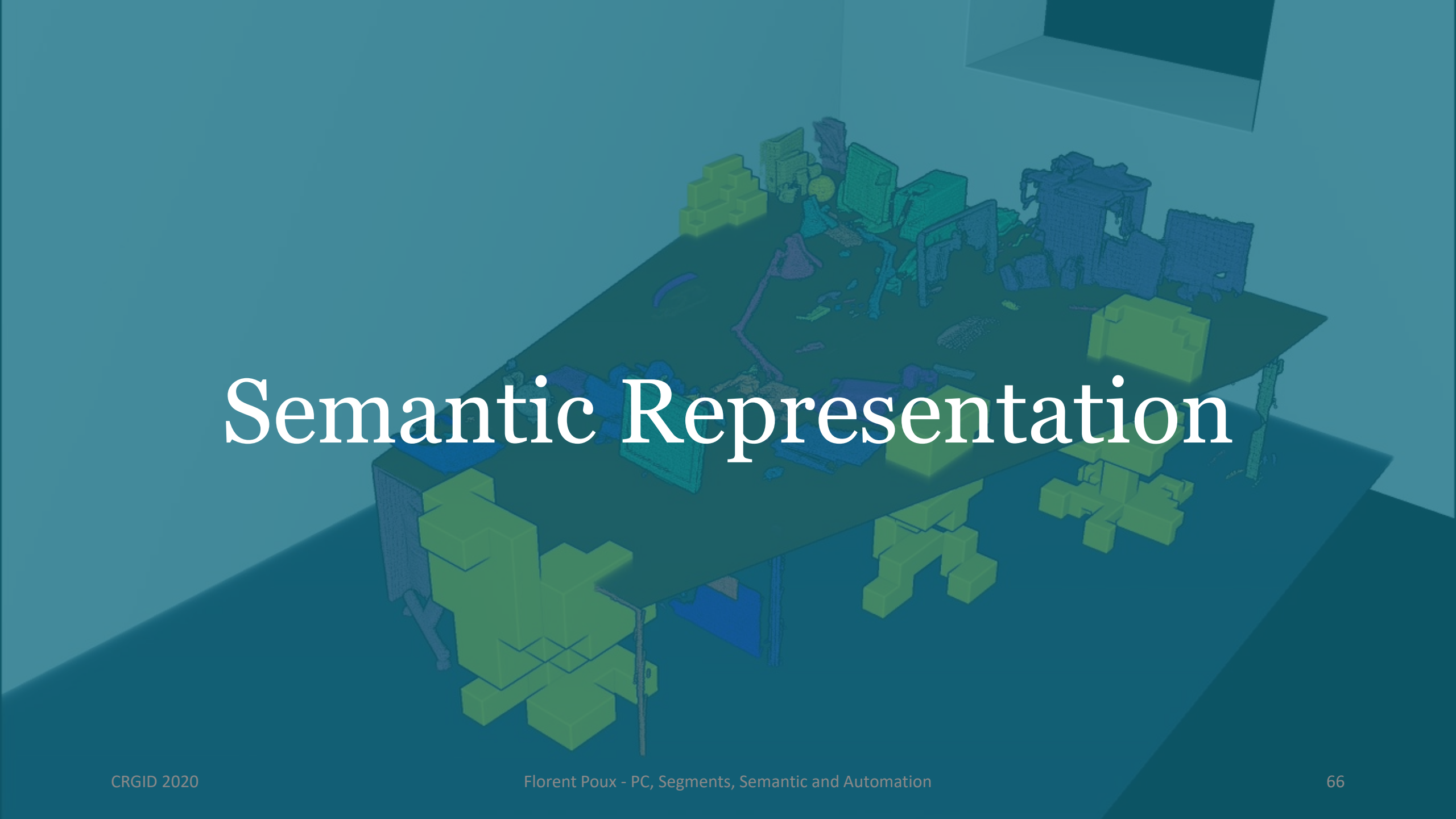
Characterization refinement





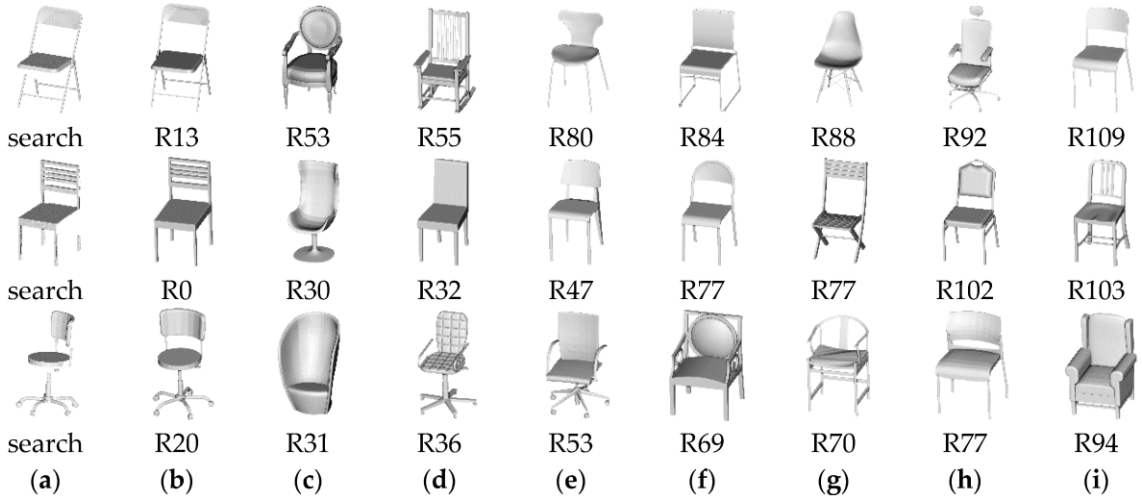


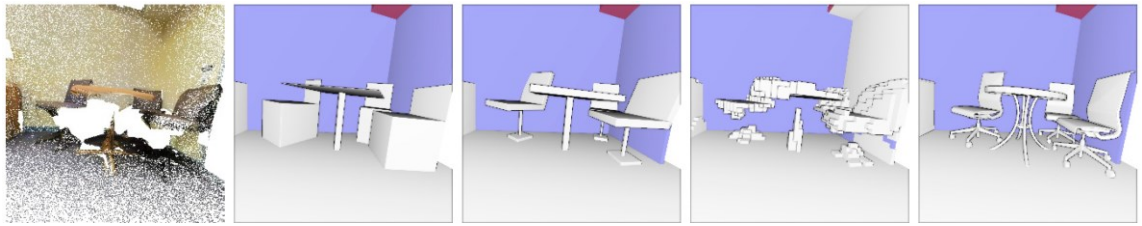


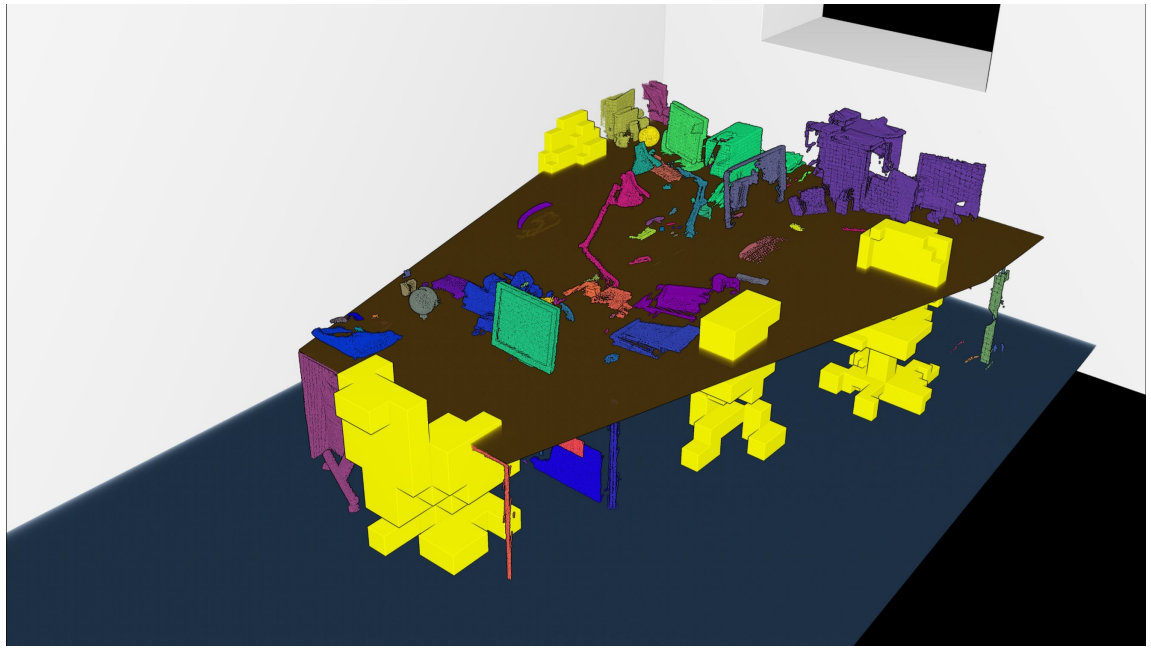


Semantic Representation

Semantic Representation



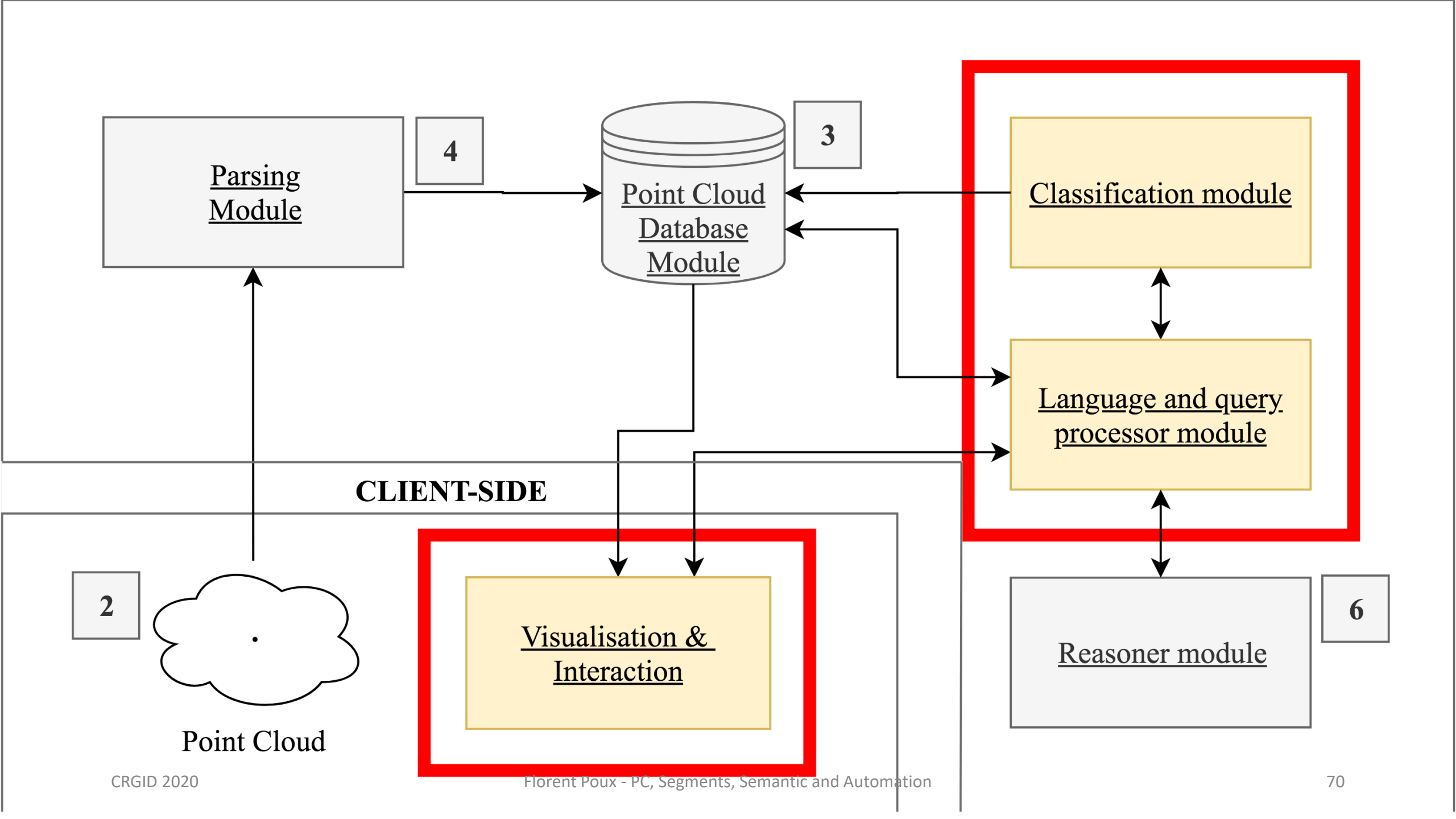


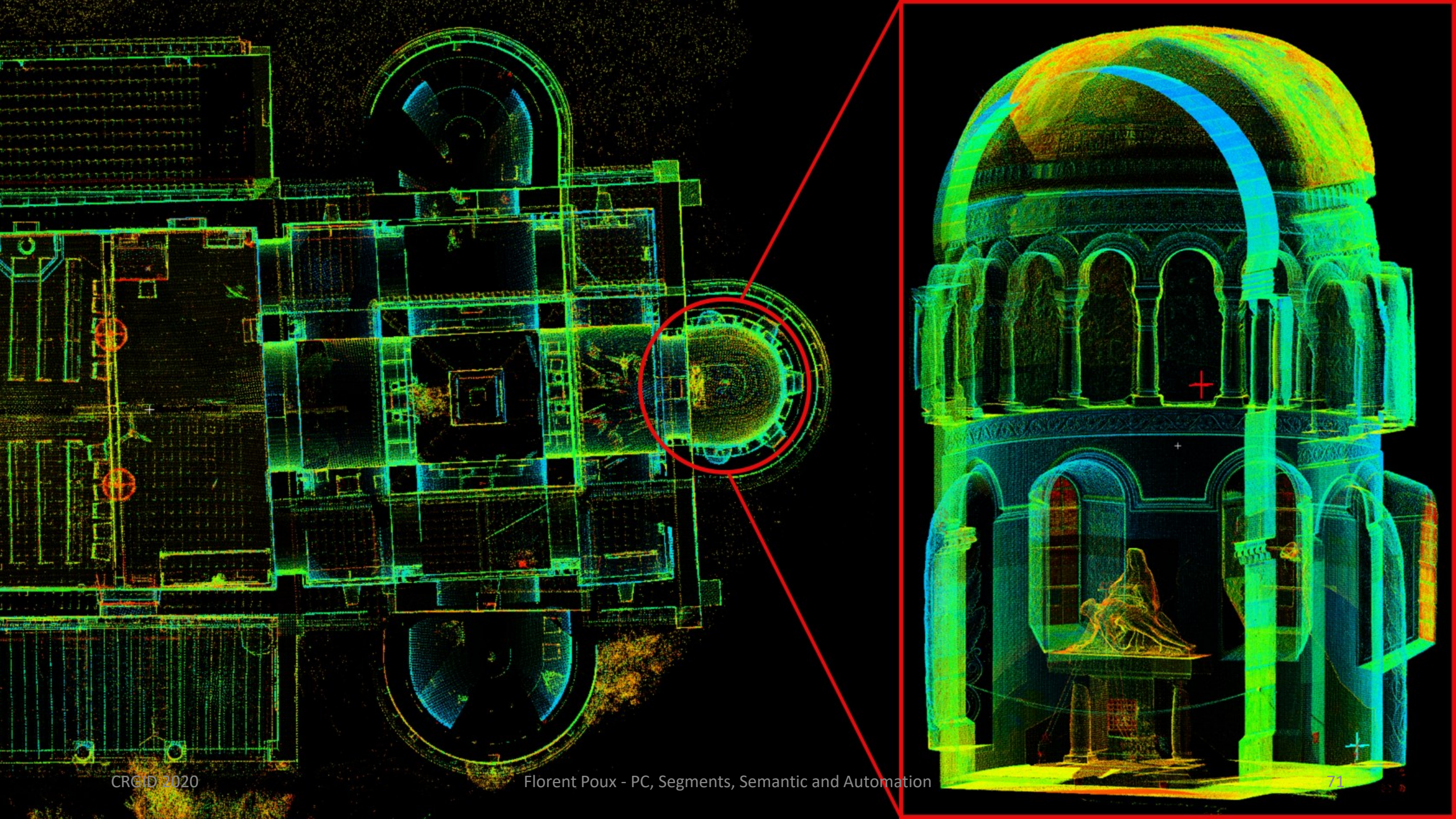


How to extract and integrate knowledge within 3D point clouds for autonomous decision-making systems?

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

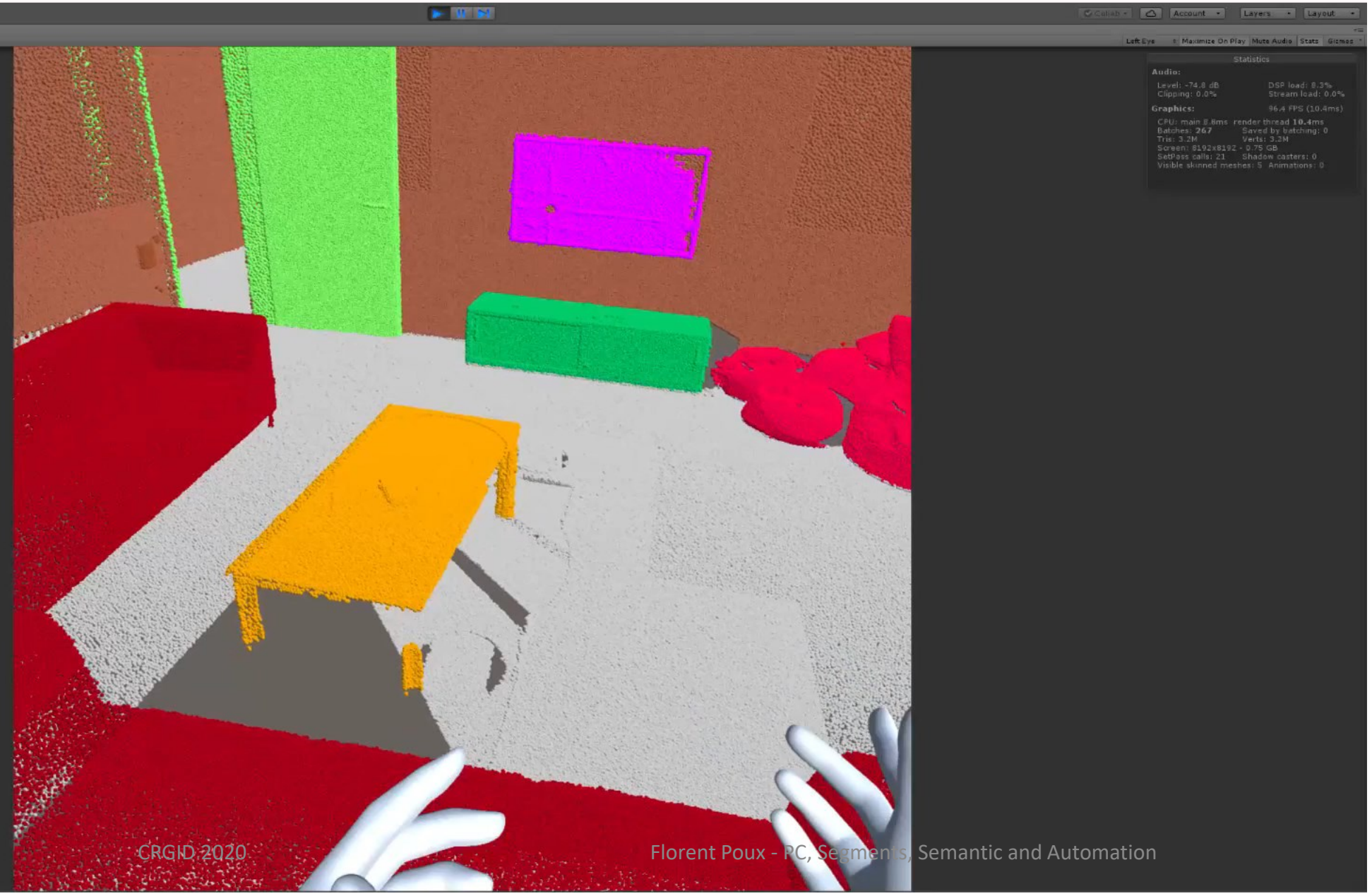

923B3351.CR2

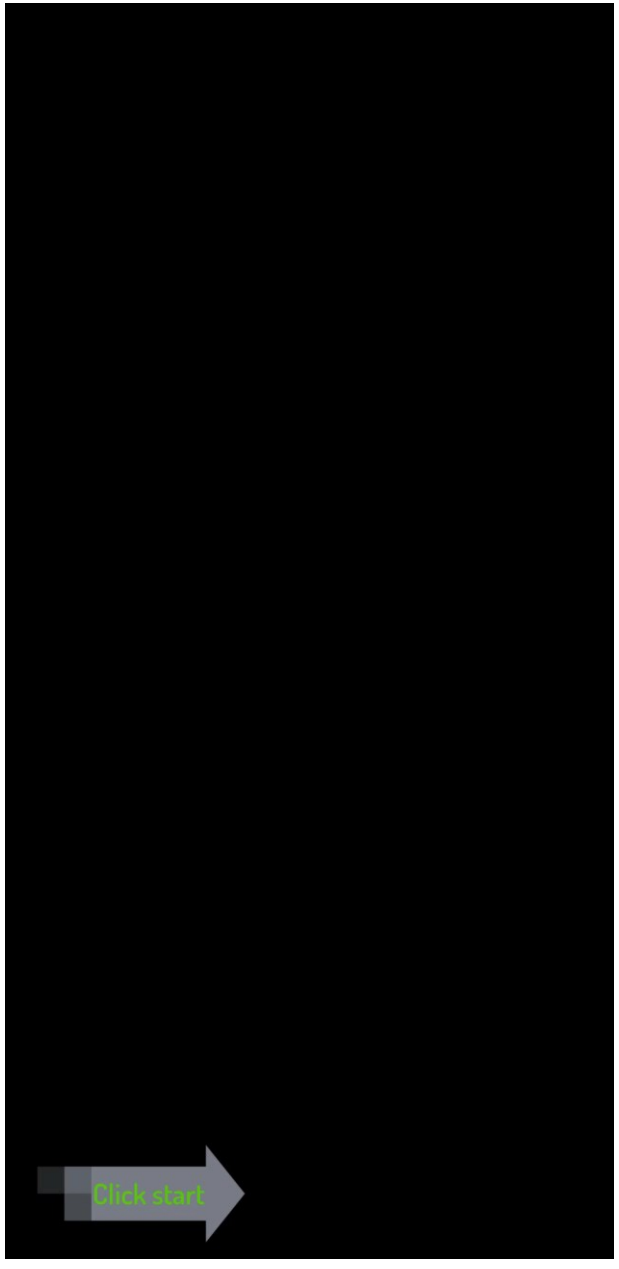

923B3352.CR2

INITIAL GOLD FAIENCE SILVER

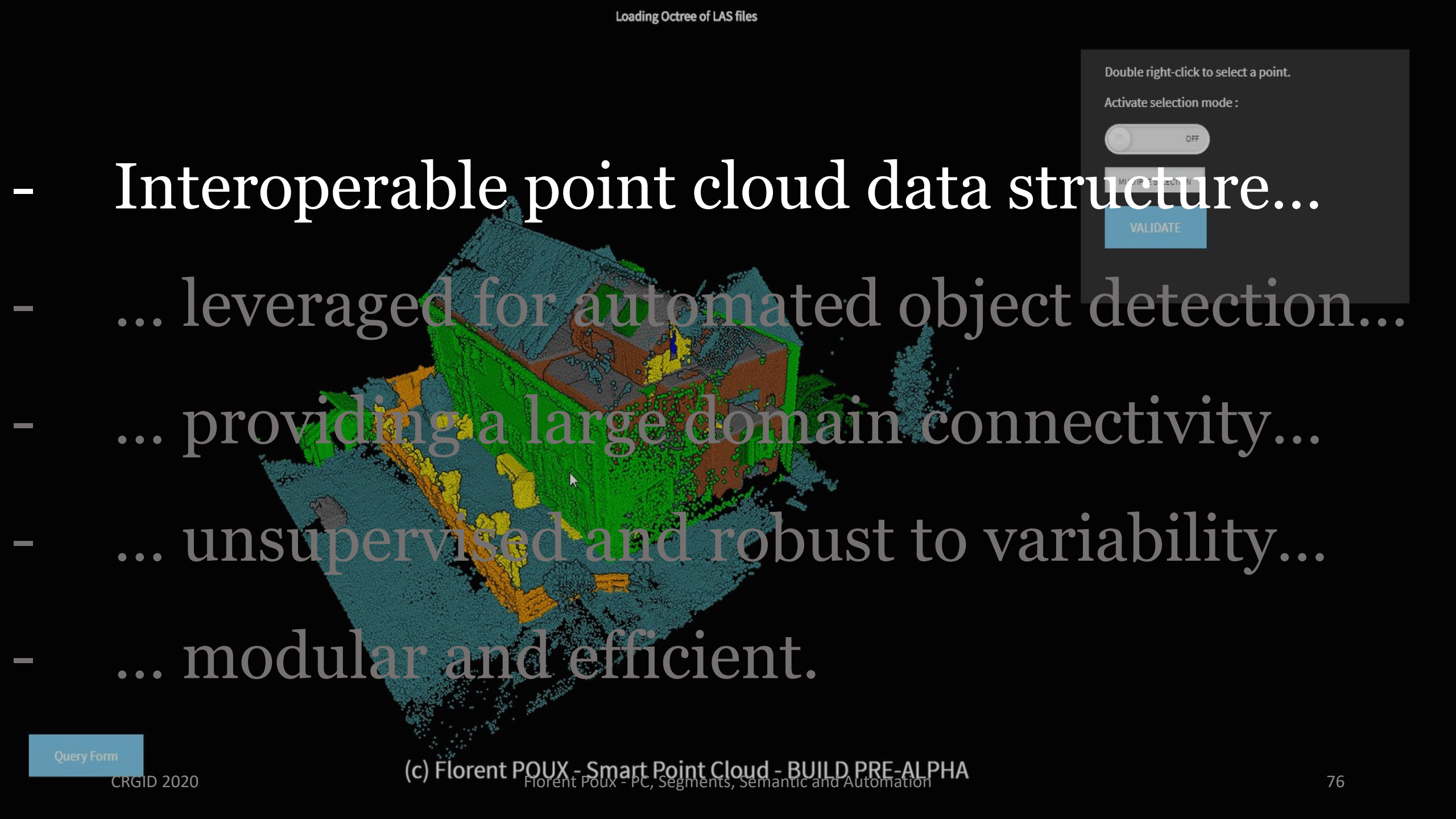
VR APPILCATION

AR APPLICATION

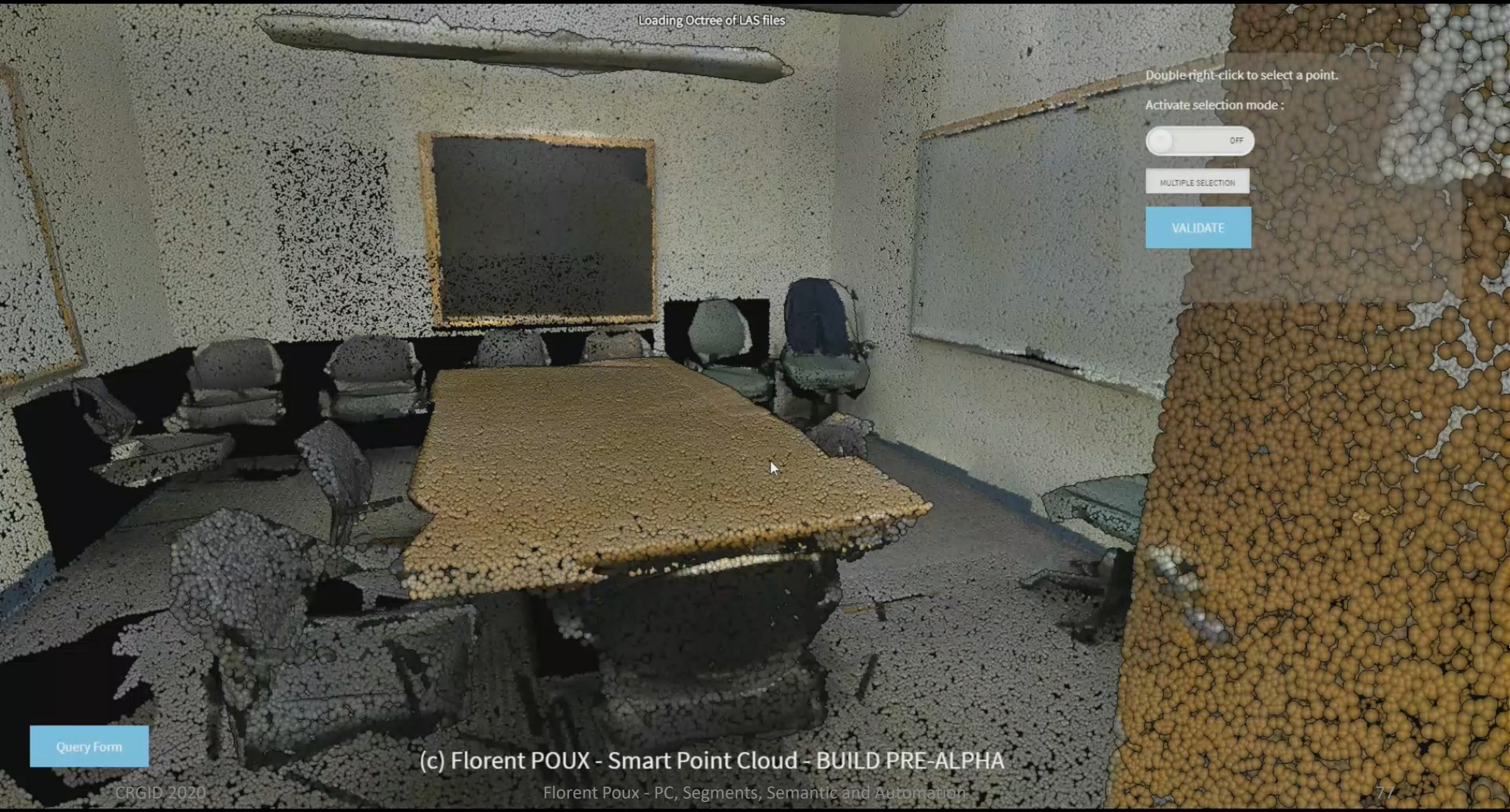




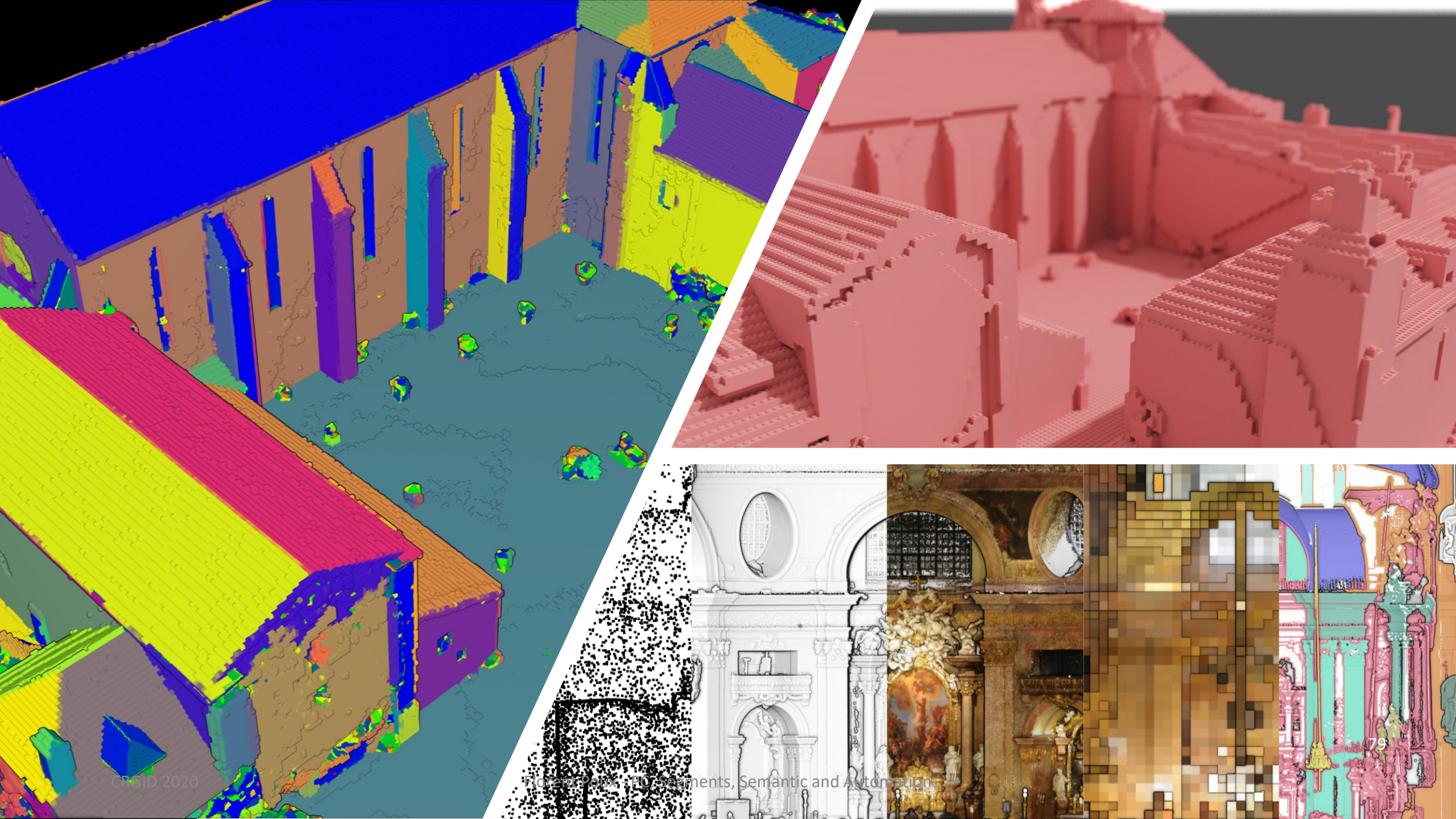
The SPC in 5 points



- 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



Projet 1

Création d’une plateforme en ligne pour les professionnels

Statut: Ouvert à la BETA

Projet 2

Création d'une plateforme d'entraînement pour la communauté (gratuit)

Statut: Recherche de financement (sponsors, projets, autre)

Projet 3

Formation en ligne 3D Geodata pour les sociétés, entrepreneurs et étudiants.

Statut ouvert:
learngeodata.eu

Segmentor 3D en pre-order



fpoux@uliege.be – learngeodata.eu


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


LIÈGE université
Sciences

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