Smart Point Clouds for information modelling: application in Cultural Heritage

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Geomatics Unit, University of Liège

Introduction

About Geomatics Unit

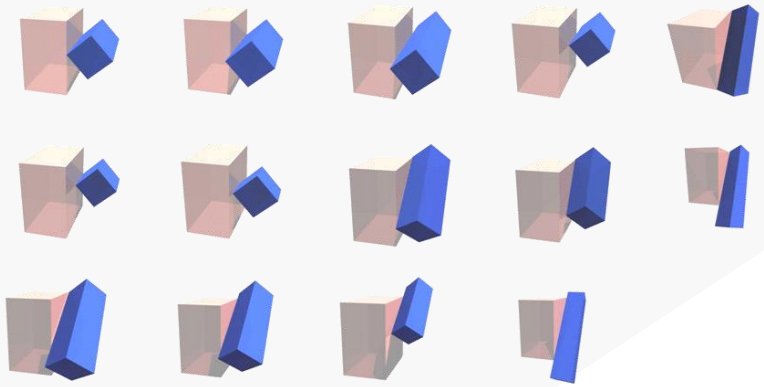
Teaching

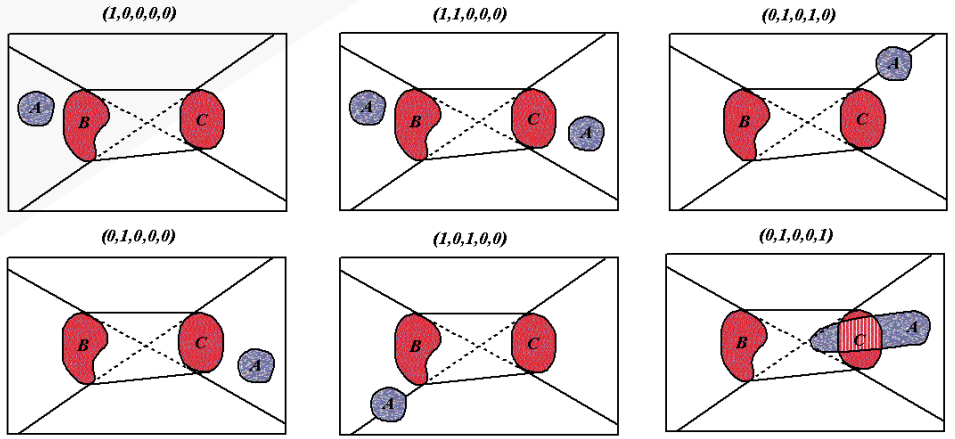
- GIS – Mapping
- Surveying – Laserscanning
- Geodesy – GNSS
- Remote Sensing - Photogrammetry

About Geomatics Unit

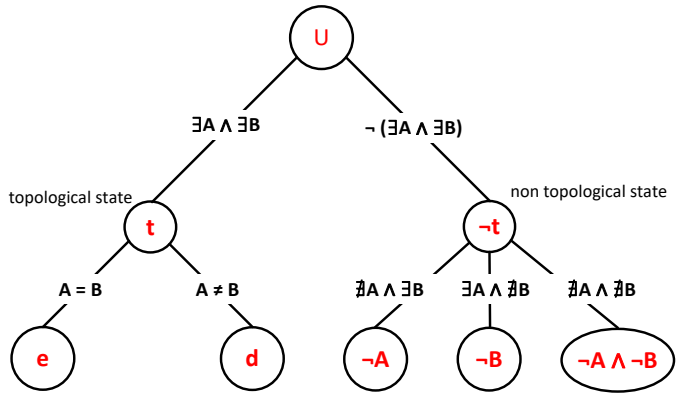
RB's Research Group

- SI Theory





- 3D GIS



- 3D Reality Capture / 3D Data processing

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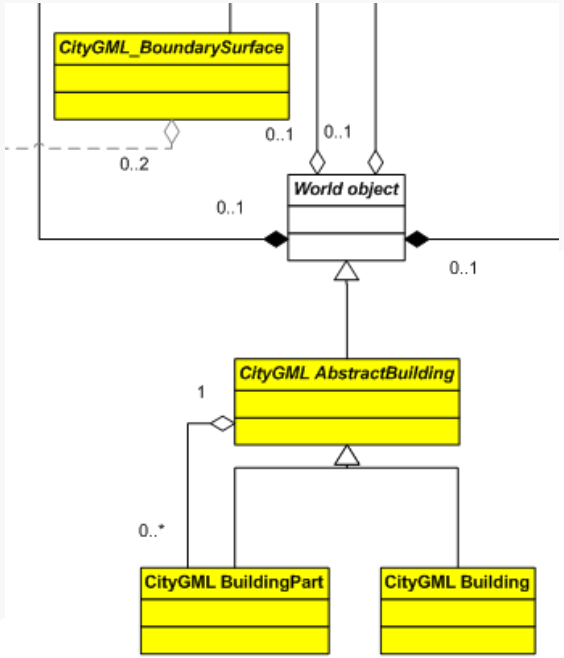

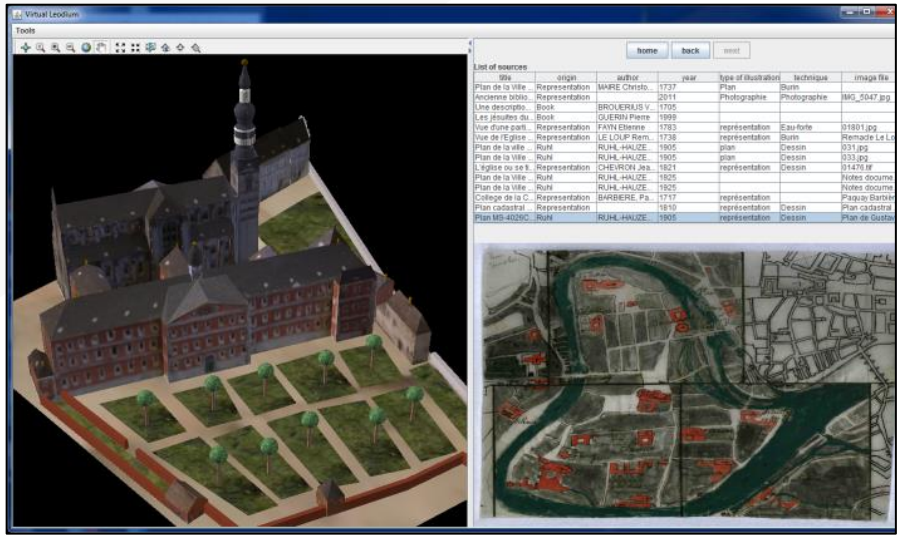

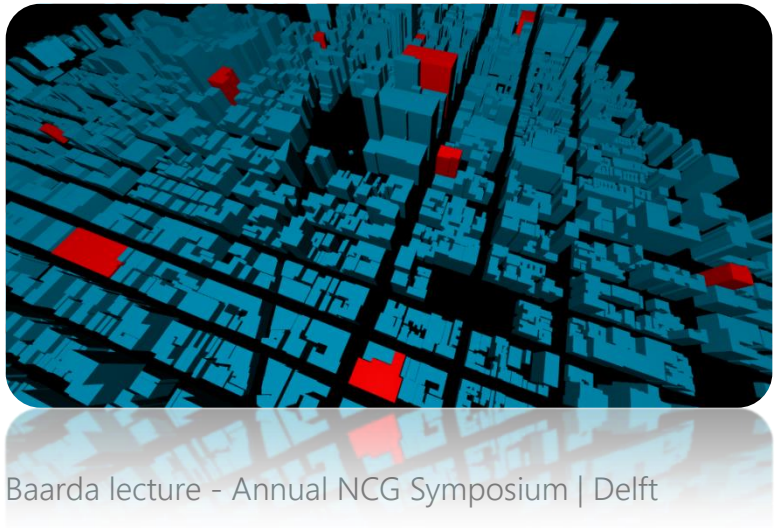

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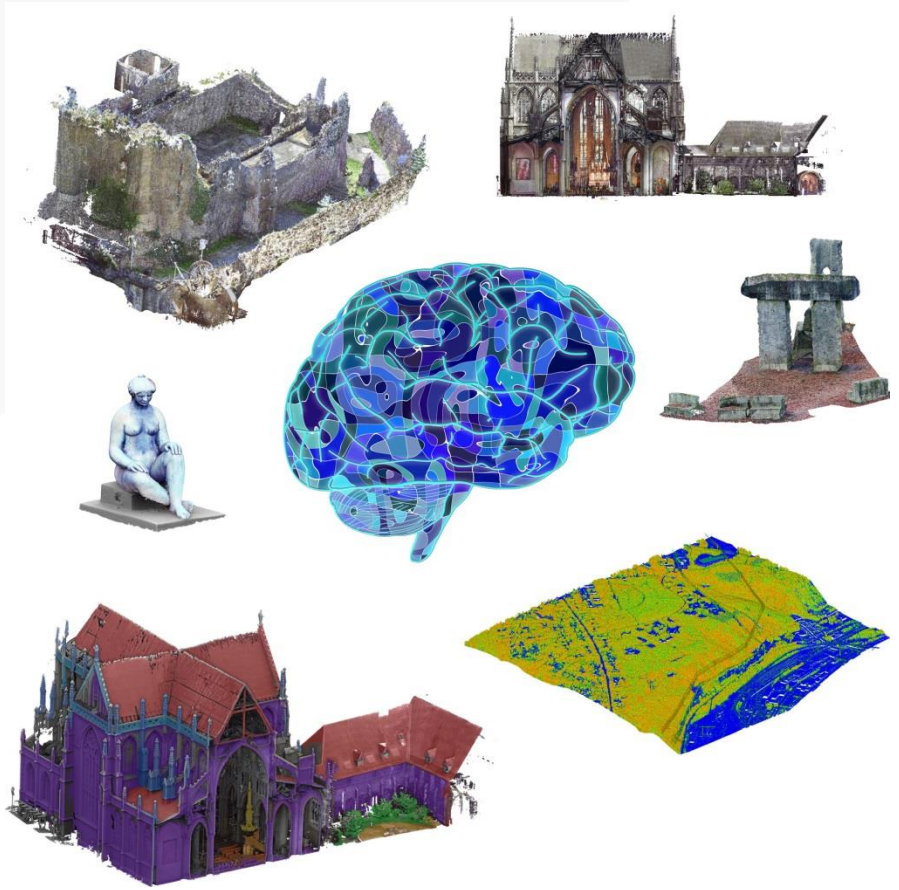


Digital (Built) Cultural Heritage

For Tourism : Video / VR and AR

https://youtu.be/71vbCPE2w1o

Digital (Built) Cultural Heritage

For fun … multi-scale experience … Creating new space

https://youtu.be/QNRoYLWBjw8

Digital (Built) Cultural Heritage

CH information system : CH researches, CH building management … dealing with all the complexity of CH information

https://youtu.be/bWHC0kwEtx8

CH Information system R&D issues

- How to manage multiple needs?
- How to deal with multiple data sources?
- Which data models should be used?
- Do they encompass the whole CH information complexity?
- Etc.

?

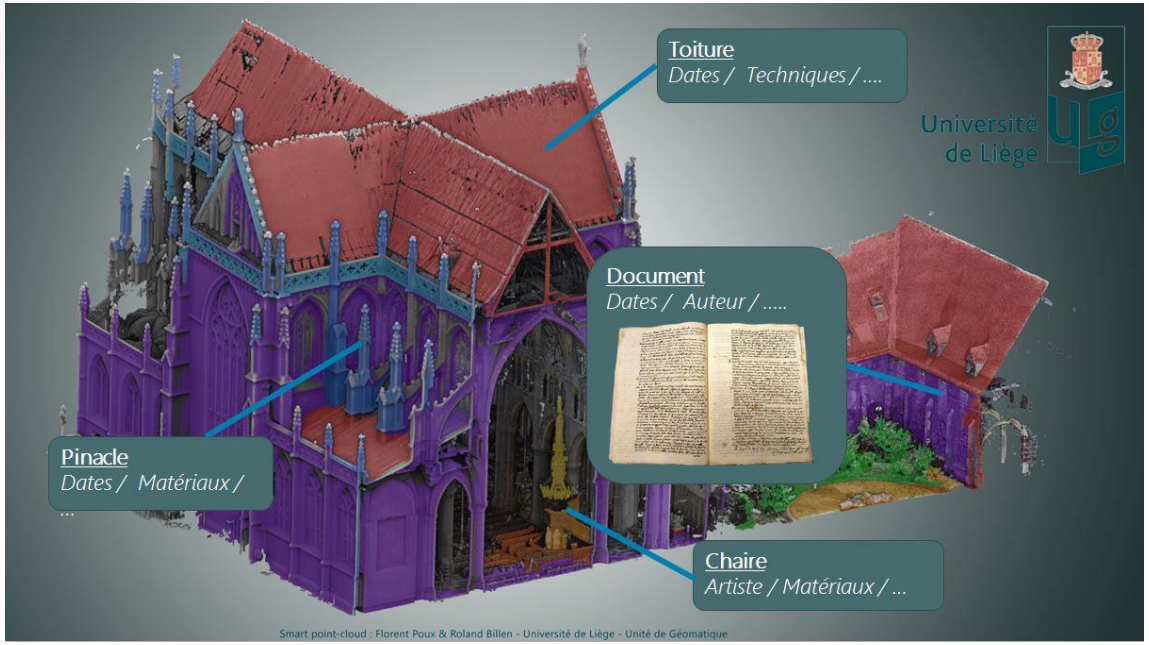
?

?

Our researches in Digital (Built) Cultural Heritage

- SI Theory
- 3D GIS
- 3D Reality Capture / 3D Data processing

Smart Point Cloud



Our researches in Digital (Built) Cultural Heritage

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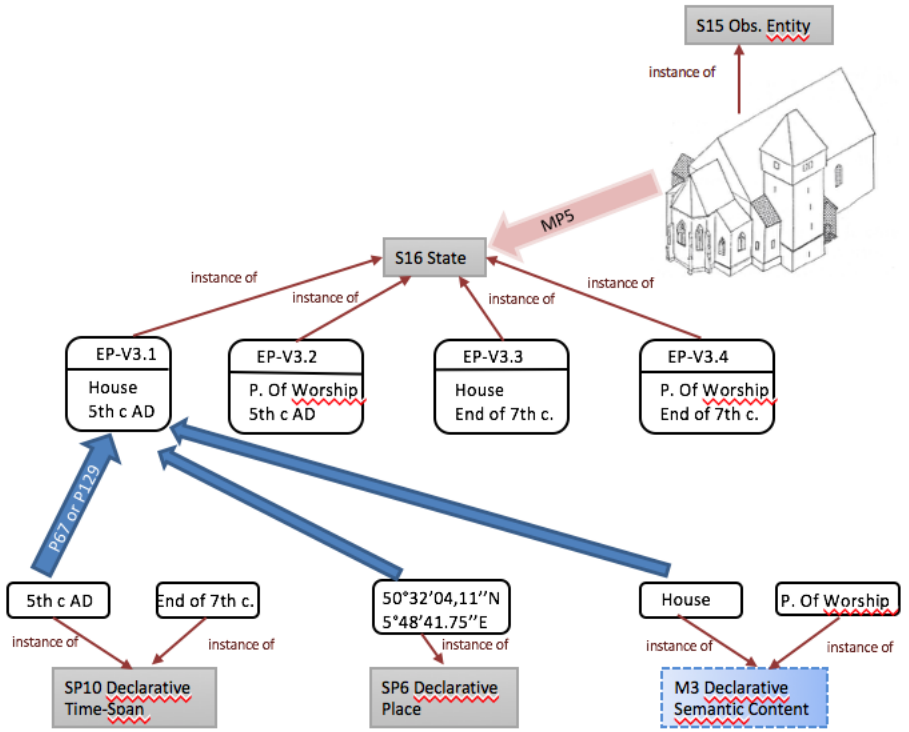
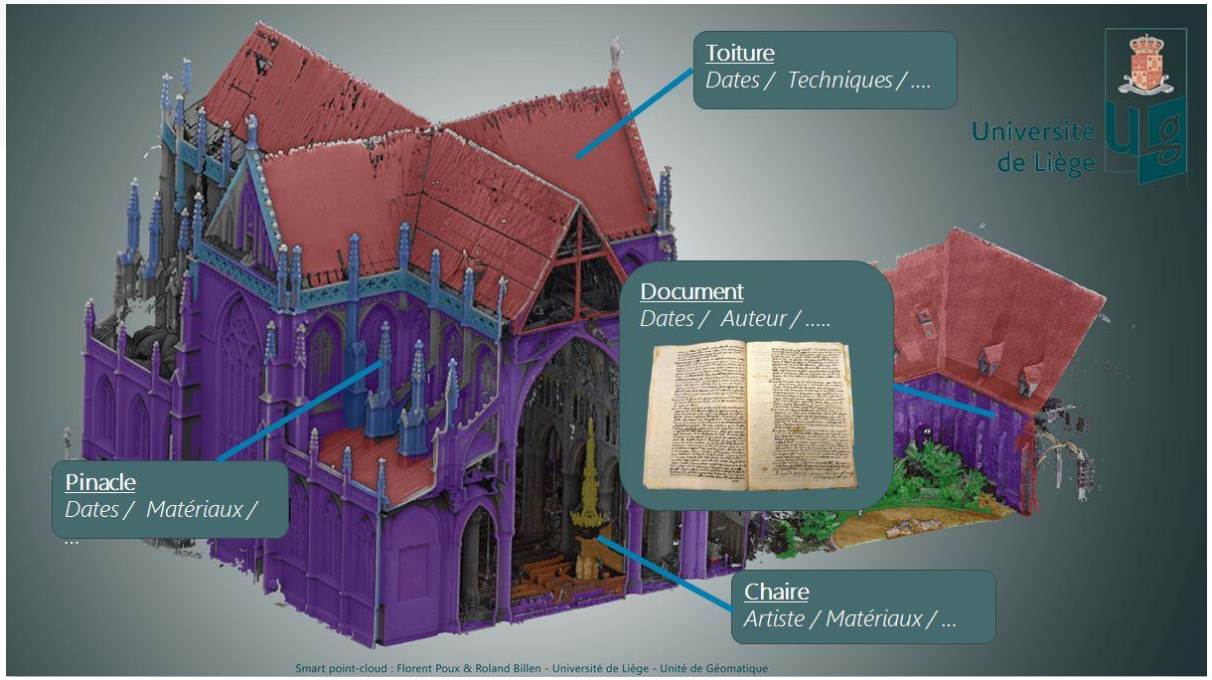
Multiple Interpretation Data Model

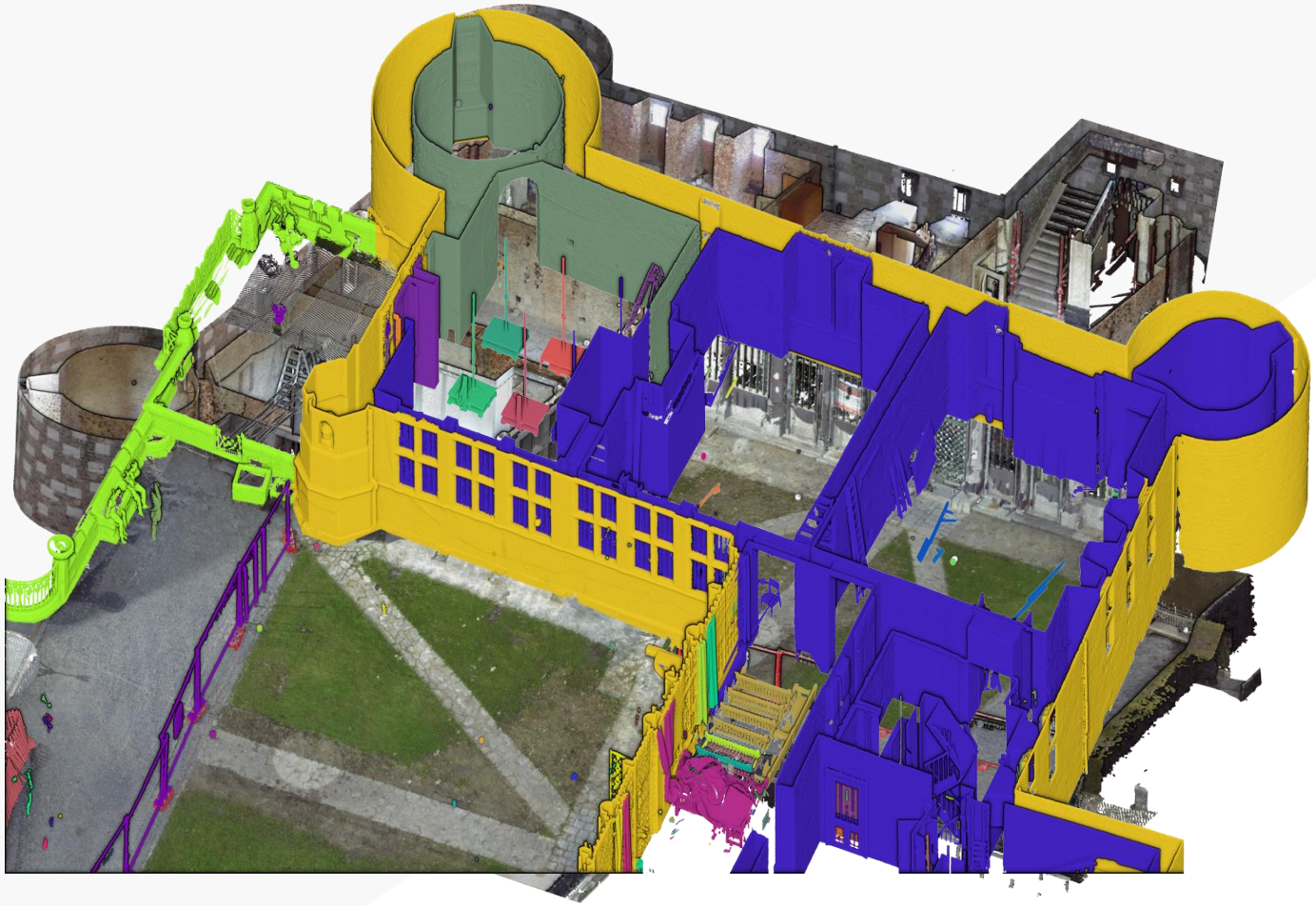


Smart Point Cloud

A direct path from 3D Perception to Cognitive Decision

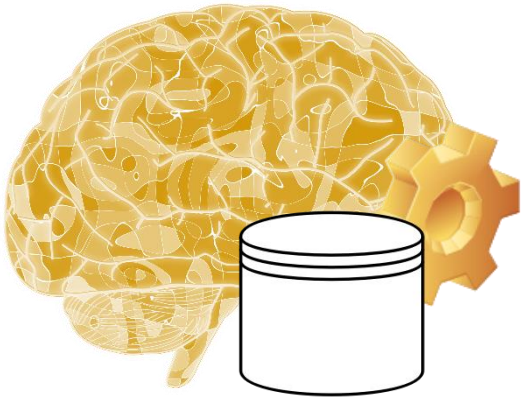


Semantics & Knowledge Integration



TODAY

WHAT WE WANT



KNOWLEDGE

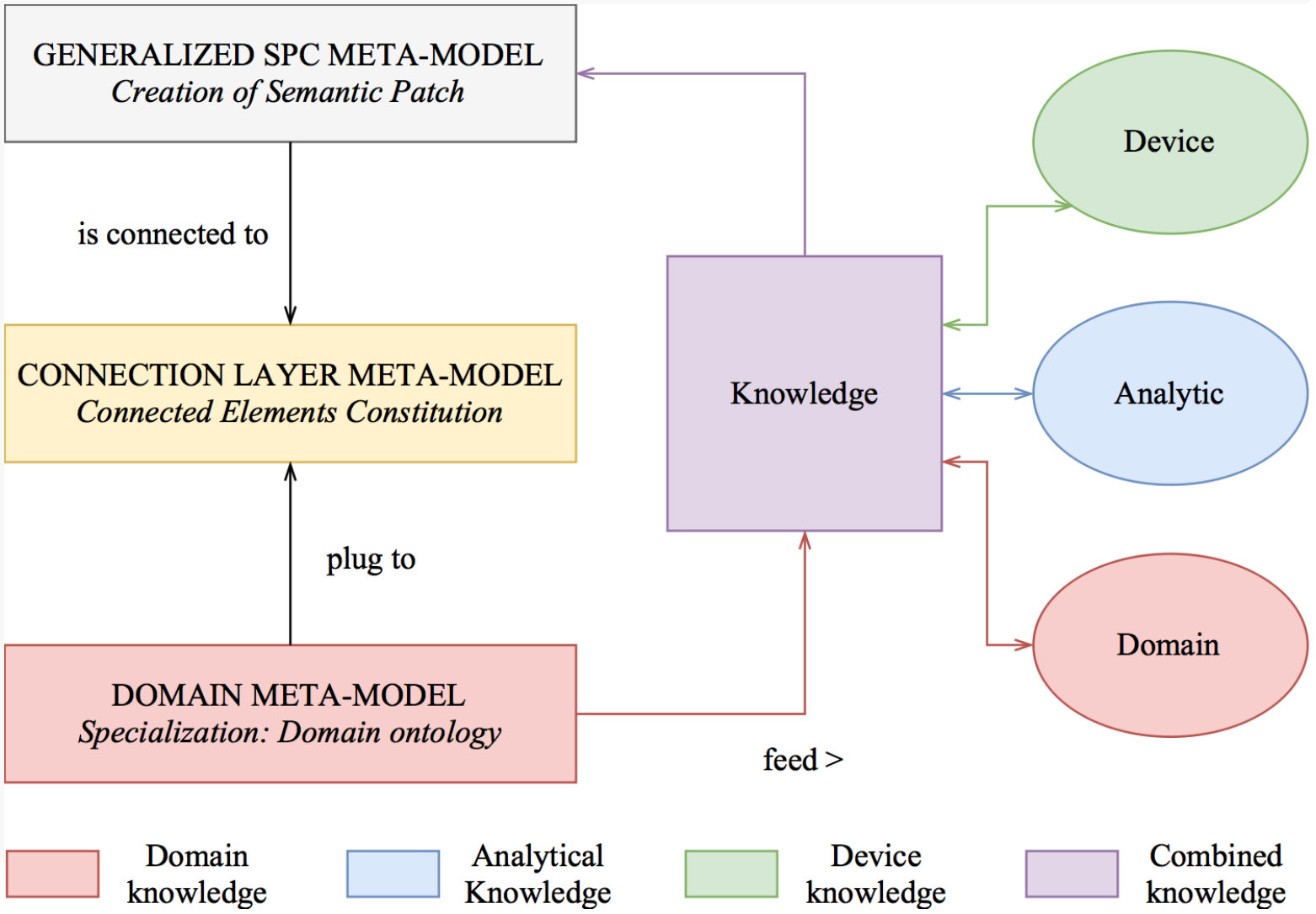
DELIVERY PRODUCTION (Floor plan, Mesh, ...) SIMULATION, ...

LIÈGE université

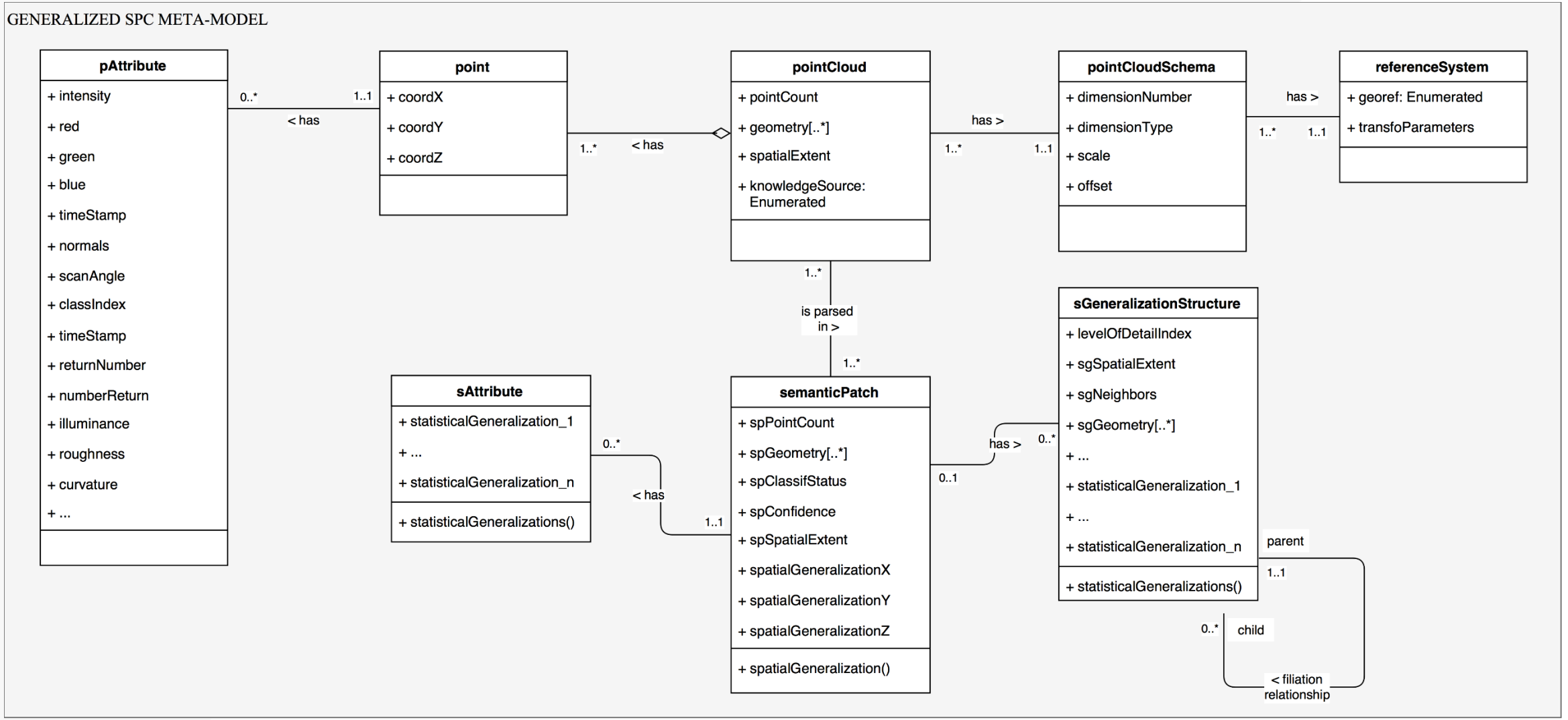
Smart Point Clouds for information modelling: application in Cultural Heritage | 2 Nov. 2017 | Baarda lecture - Annual NCG Symposium | Delft

14

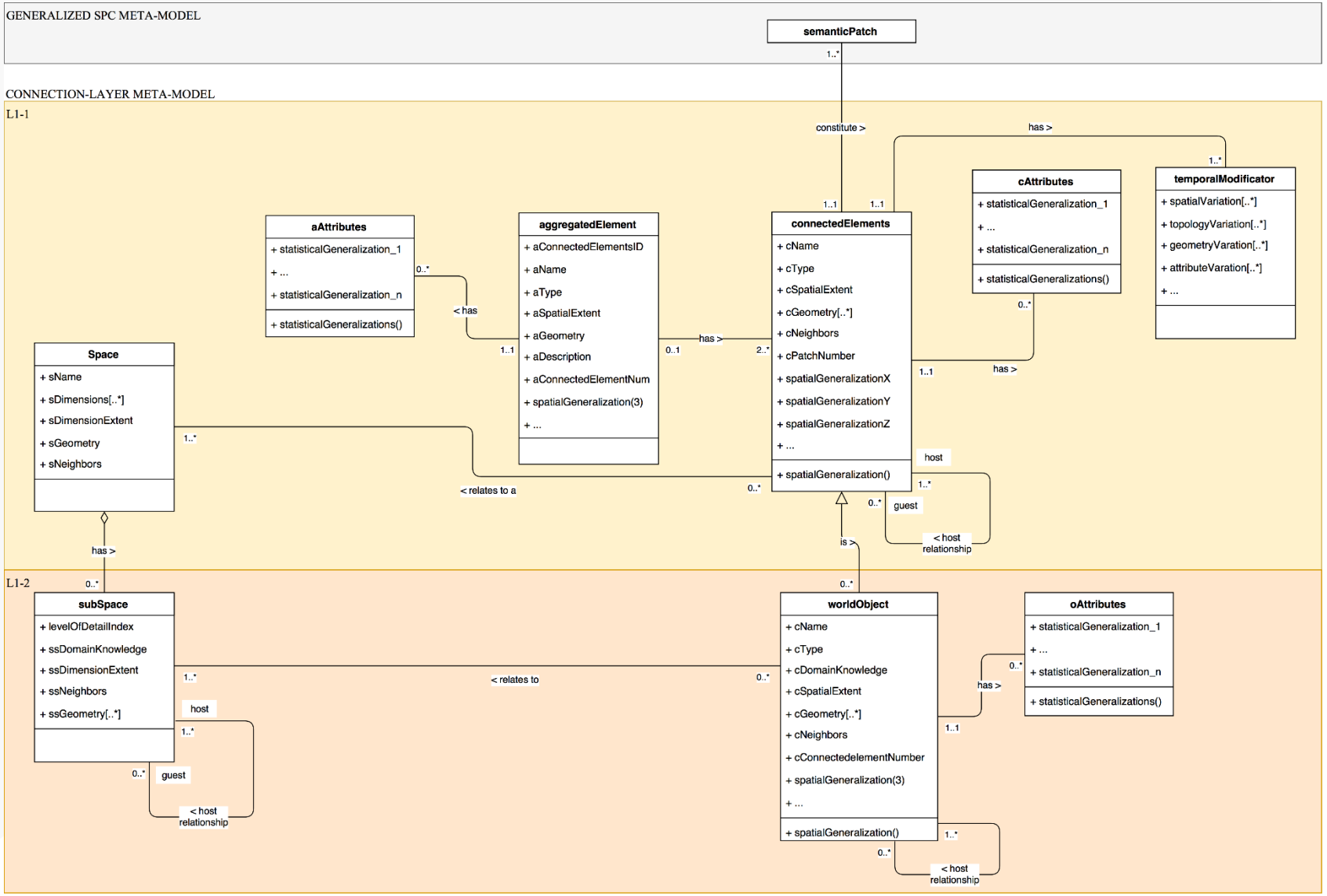
Conceptual SPC Model Overview

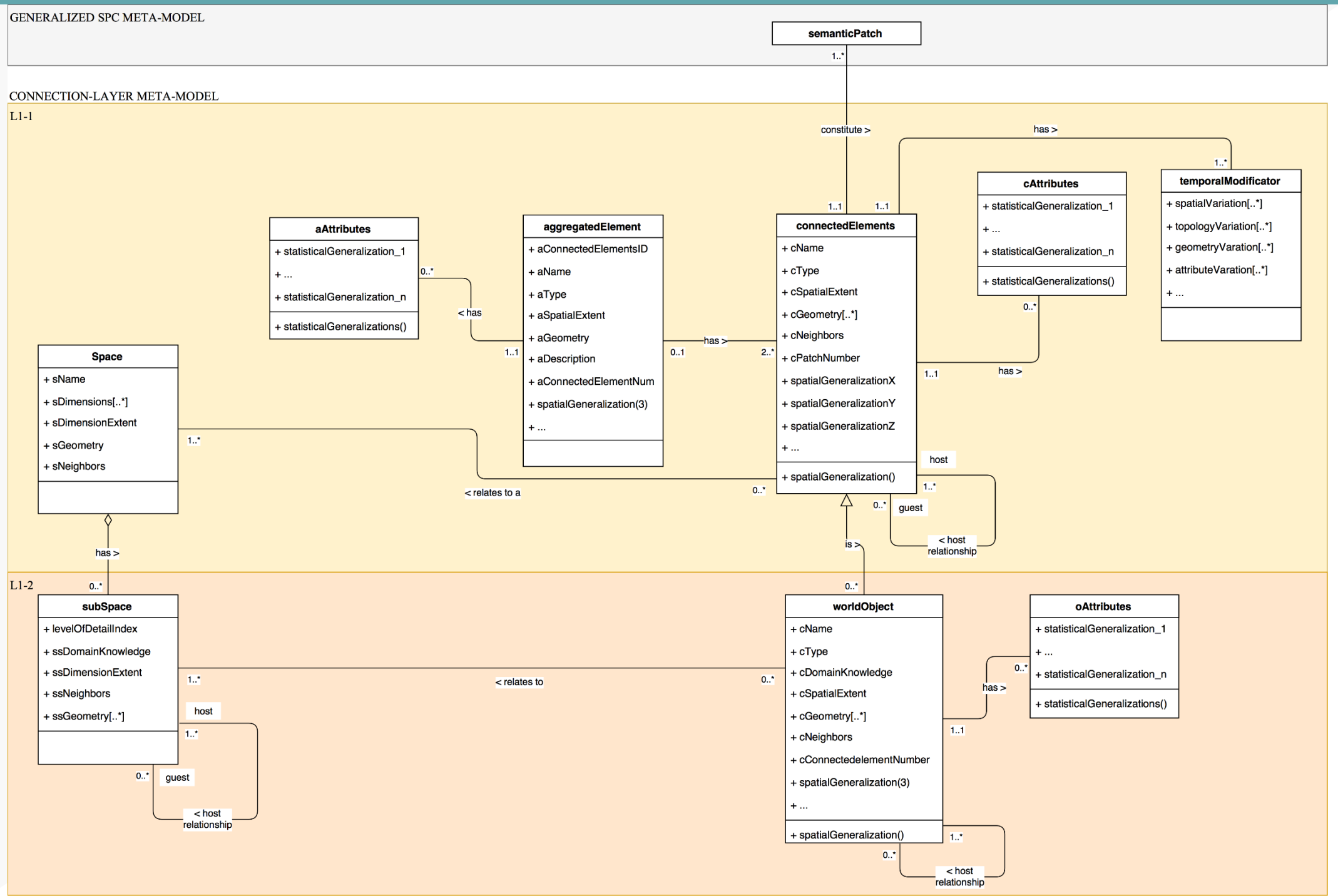


Level-0 SPC Meta-Model



Level-1: SPC CL Meta-Model




GENERALIZED SPC META-MODEL
semanticPatch
1..*
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has >
CONNECTION-LAYER META-MODEL
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+ statisticalGeneralization_1
+ ...
+ statisticalGeneralization_n
+ statisticalGeneralizations()
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+ aConnectedElementsID
+ aName
+ aType
+ aSpatialExtent
+ aGeometry
+ aDescription
+ aConnectedElementNum
+ spatialGeneralization(3)
+ ...
0..1
has >
2..*
connectedElements
+ cName
+ cType
+ cSpatialExtent
+ cGeometry[..*]
+ cNeighbors
+ cPatchNumber
+ spatialGeneralizationX
+ spatialGeneralizationY
+ spatialGeneralizationZ
+ ...
+ spatialGeneralization()
1..1
1..1
cAttributes
+ statisticalGeneralization_1
+ ...
+ statisticalGeneralization_n
+ statisticalGeneralizations()
0..*
has >
1..1
temporalModificator
+ spatialVariation[..*]
+ topologyVariation[..*]
+ geometryVaration[..*]
+ attributeVaration[..*]
+ ...
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+ sName
+ sDimensions[..*]
+ sDimensionExtent
+ sGeometry
+ sNeighbors
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0..*
host
1..*
0..*
guest
< host relationship
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is >
L1-2
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0..*
subSpace
+ levelOfDetailIndex
+ ssDomainKnowledge
+ ssDimensionExtent
+ ssNeighbors
+ ssGeometry[..*]
1..*
< relates to
0..*
worldObject
+ cName
+ cType
+ cDomainKnowledge
+ cSpatialExtent
+ cGeometry[..*]
+ cNeighbors
+ cConnectedelementNumber
+ spatialGeneralization(3)
+ ...
+ spatialGeneralization()
host
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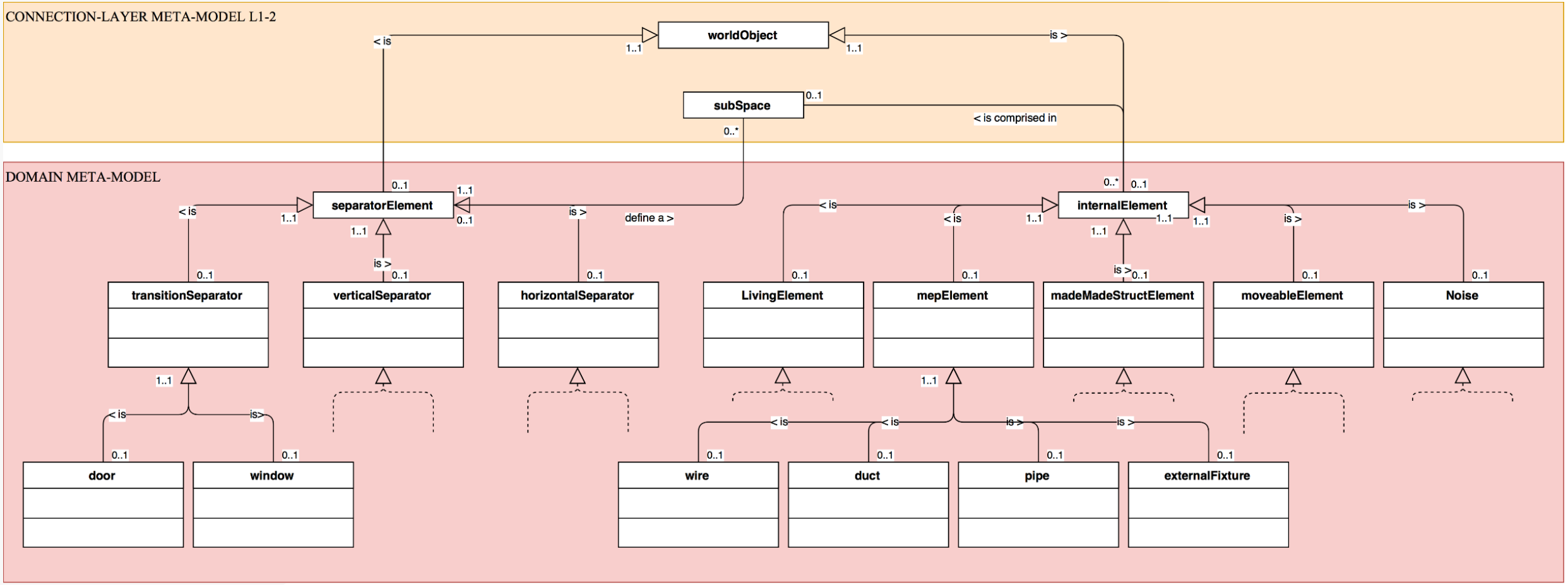
has >
1..1
oAttributes
+ statisticalGeneralization_1
+ ...
+ statisticalGeneralization_n
+ statisticalGeneralizations()
1..*
0..*
< host relationship

Level-2 SPC Domain Adaptation



SPC application to CH

Device knowledge

TLS DATA

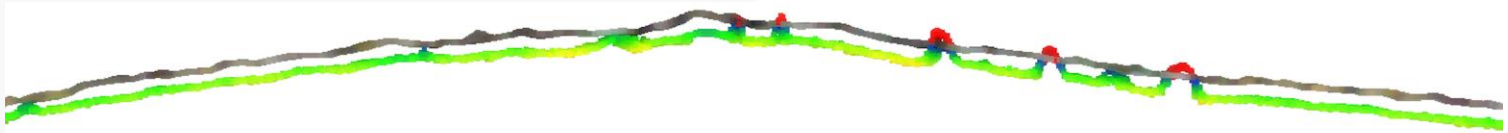
DENSE-IMAGE MATCHING DATA

Fusion / NURBS

Colour point cloud

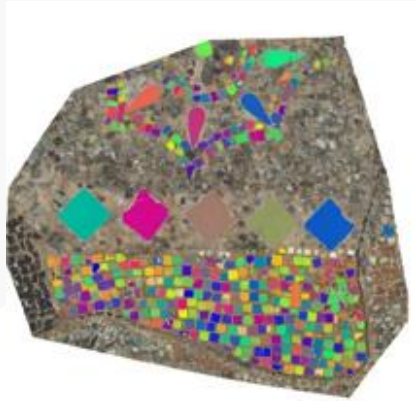
Device knowledge

- Amplitude of the spatial error between TLS and NURBS
- TLS signal is influenced by the material, the error issued from the material reflectance can be used as a semantic information to help tat he classification process.



Analytical knowledge

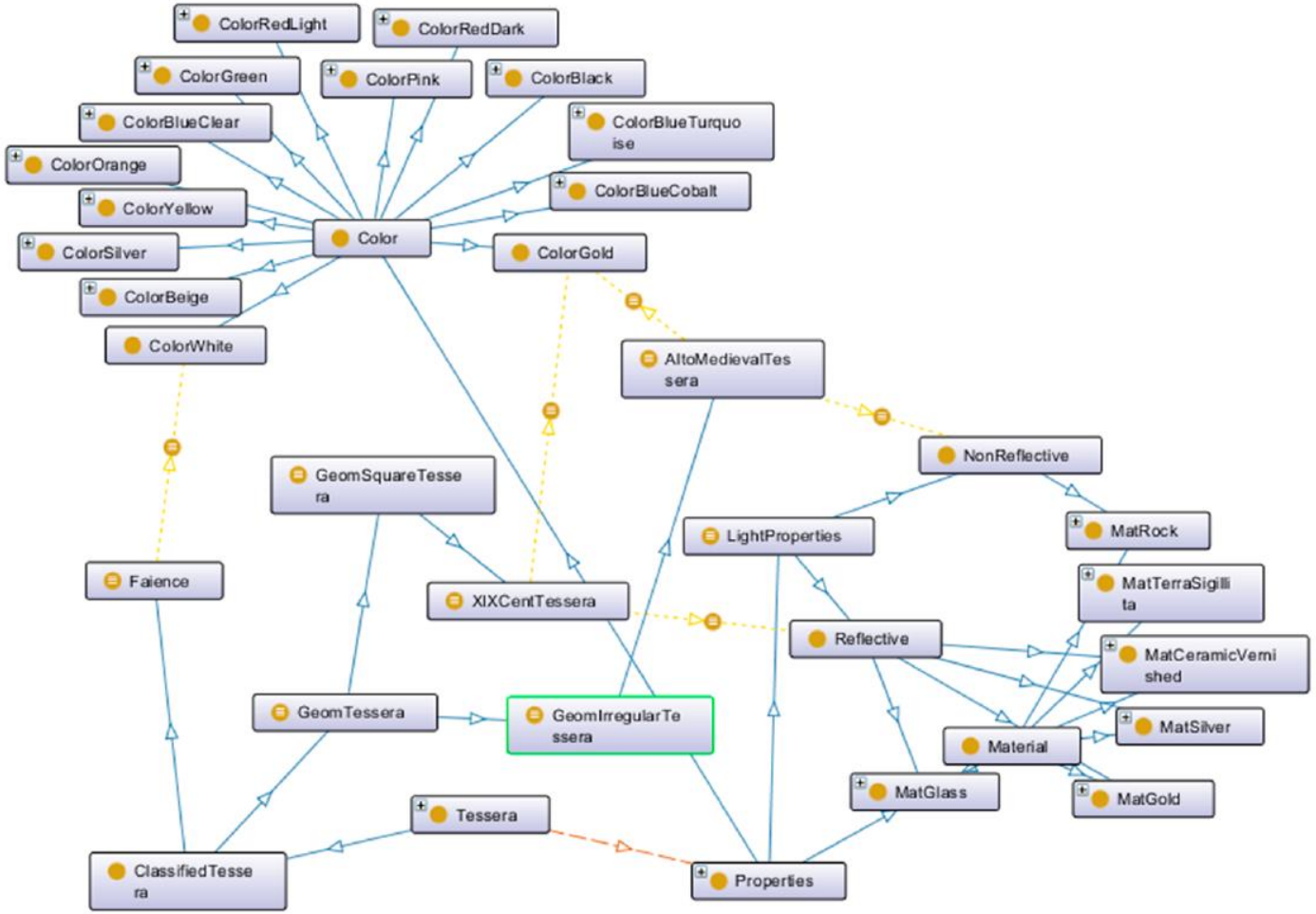
Colour point cloud



Segmented point cloud

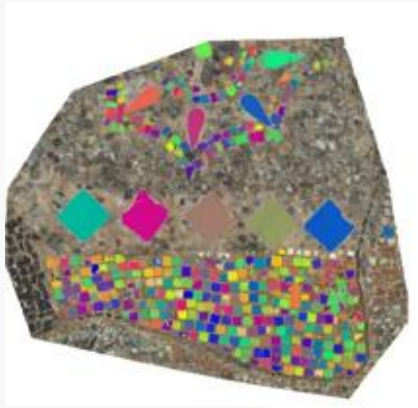
Type	Point Features	Range	Explanation
Sensor desc.	X, Y, Z	Bounding-box	Limits the study of points to the zone of interest
	R, G, B [1]	Material Colour	Limited to the colour range that domain knowledge specifies
	I		Clear noise and weight low intensity values for signal representativity
Shape desc.	RANSAC [2]	-	Used to provide estimator of planarity
Local desc.	Nx, Ny, Nz [3]	[−1, 1]	Normalized normal to provide insight on point and object orientation
	Density [4]	-	Used to provide insights on noise level and point grouping into one object
	Curvature	[0, 1]	Used to provide insight for edge extraction and break lines
	KB [5] Distance map		Amplitude of the spatial error between the raw measurements and the final dataset
Structure desc. [6]	Voxels	-	Used to infer initial spatial connectivity

Domain knowledge



Domain knowledge

Colour point cloud



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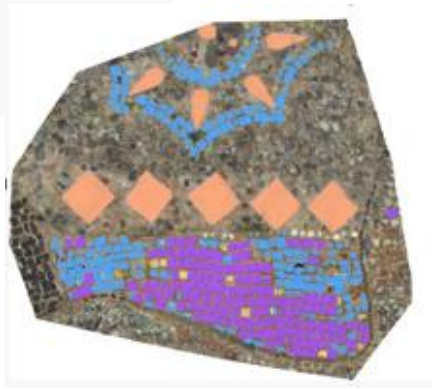


Classified point cloud

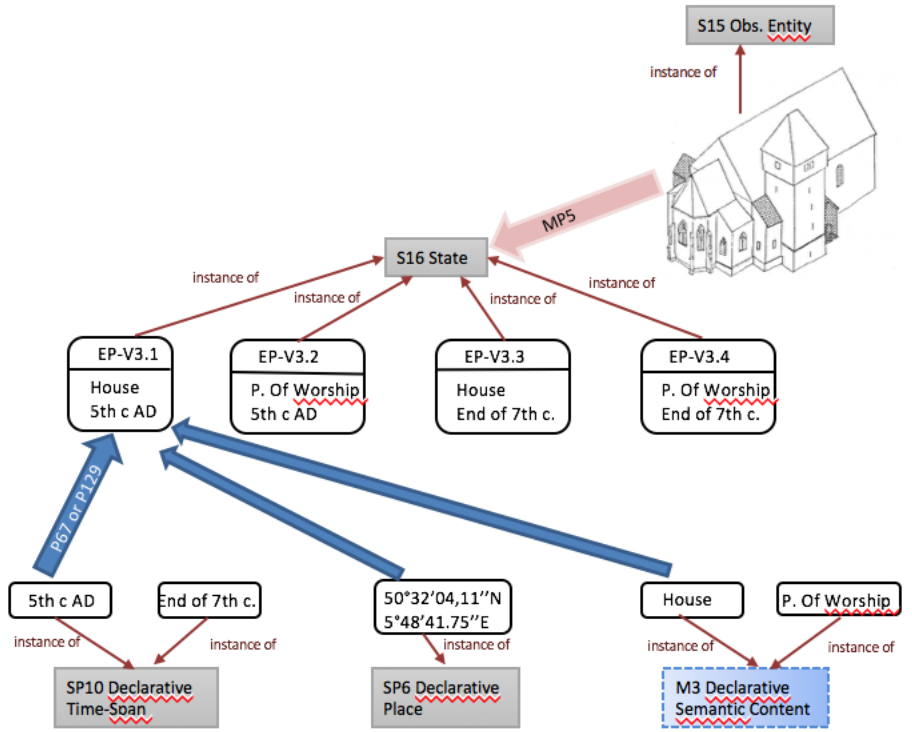
Sample	Available knowledge			
	Surface (in cm²)	Approx. Geometry	Reflectance (at 1.55 µm)	Date
Gold	~ 1 cm²	~ square	H. Reflective	XIX
Gold	< 1 cm²	irregular	~ Mat	<
Faience	~ 20 cm²	tear, diamond	Reflective	XIX
Silver	~ 1 cm²	~ square	H. Reflective	XIX
C. glass	~ 1 cm²	irregular	~ Reflective	<
C. glass	~ 1 cm²	irregular	~ Absorbent	<
C. glass	~ 1 cm²	irregular	Reflective	<
C. glass	~ 1 cm²	irregular	Reflective	<
C. glass	~ 1 cm²	irregular	~ Mat	<

Reasoning

Language	RDF Triple Store	Effect
SPARQL	PREFIX rdf:<http://www.w3.org/1999/02/22-rdf-syntax-ns#> PREFIX npt: <http://www.geo.ulg.ac.be/nyspoux/> SELECT ?ind WHERE { ?ind rdf:type npt:AltoMedievalTessera } ORDER BY ?ind	Return all alto-medieval tesserae (regarding initial data input)
SQL	SELECT name, area FROM worldObject WHERE ST_3DIntersects(geomWo::geometry, polygonZ::geometry);	Return all tesserae which are comprised in the region defined by a selection polygon and gives their area
SPARQL & SQL	SELECT geomWo FROM worldObject WHERE ST_3DIntersects(geomWo::geometry, polygon2Z::geometry) AND area > 0,0001; PREFIX rdf: <http://www.w3.org/1999/02/22-rdf-syntax-ns#> PREFIX npt: <http://www.geo.ulg.ac.be/nyspoux/> SELECT ?ind WHERE { ?ind rdf:type npt: XIXCentTessera } ORDER BY ?ind	Return all renovated tesserae in the region 2 where the area is superior to 1 cm^2

Semantic integration by user / training platform

Multiple Interpretation Data Model



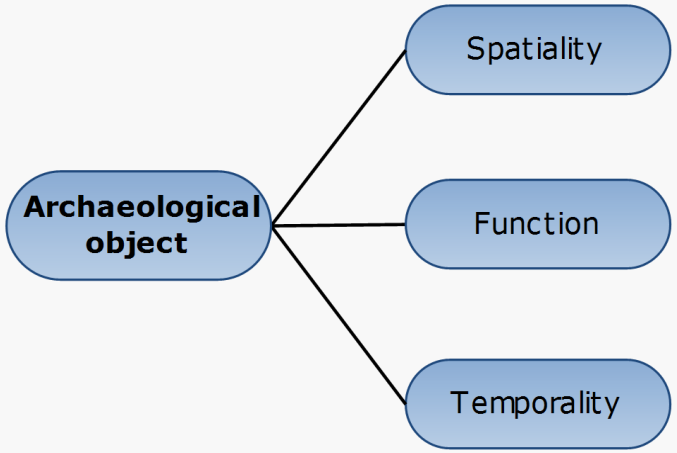
CIDOC-CRM MDIM extension

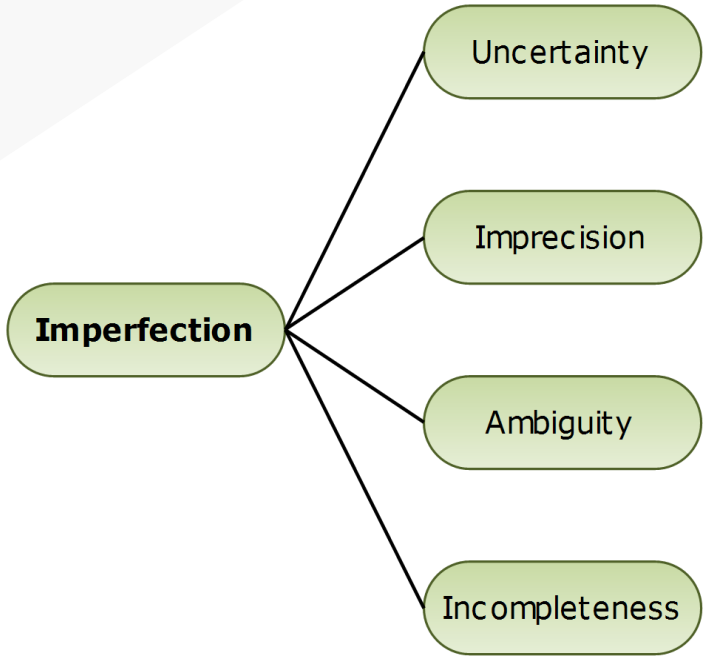
What is the MIDM?

Multiple Interpretation Data Model
We aimed at developing a model handling …

- Complex nature of CH information and its inherent imperfection
- Events
- Multiple interpretation

Peculiarities of archaeological Data





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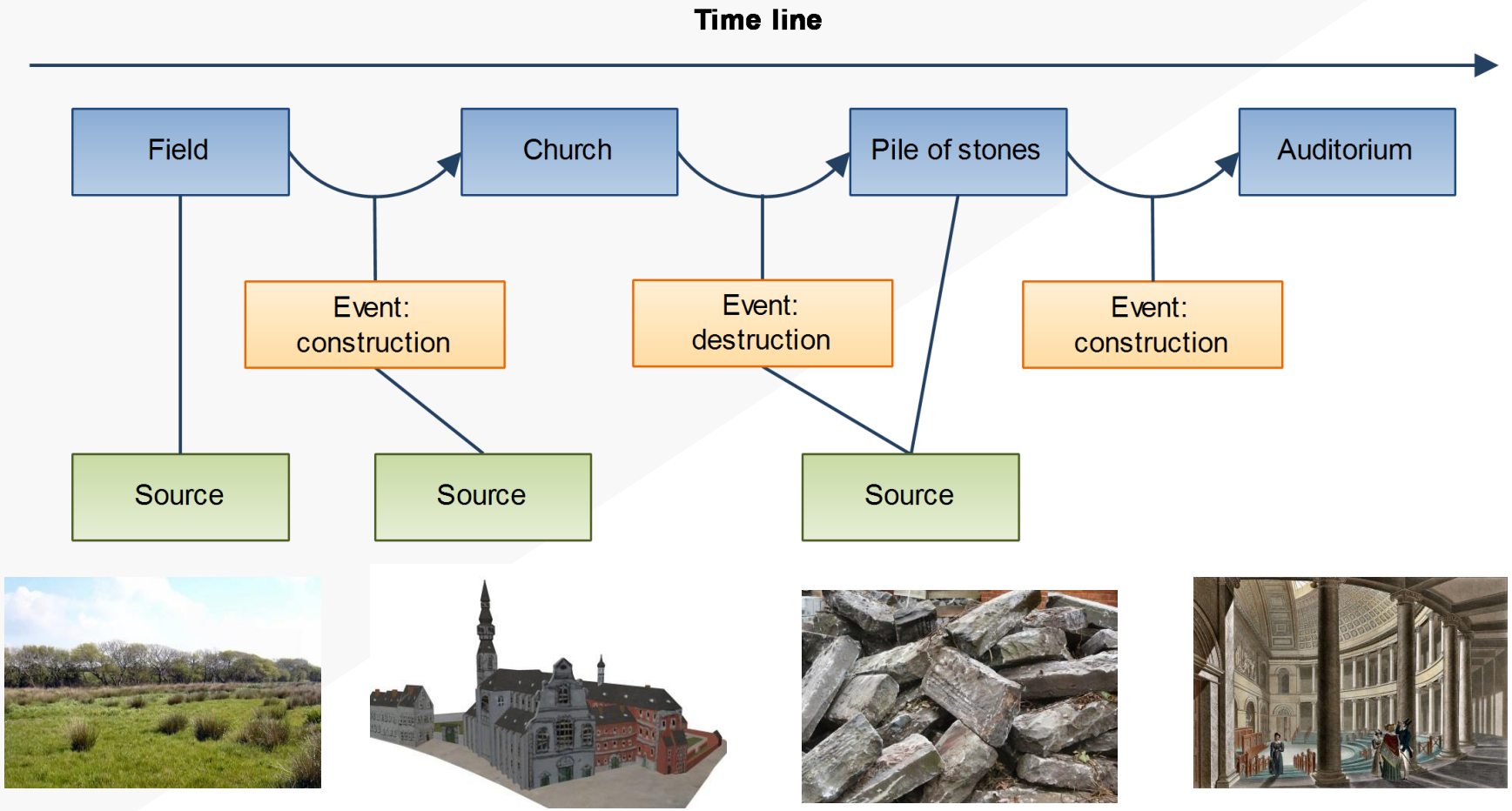

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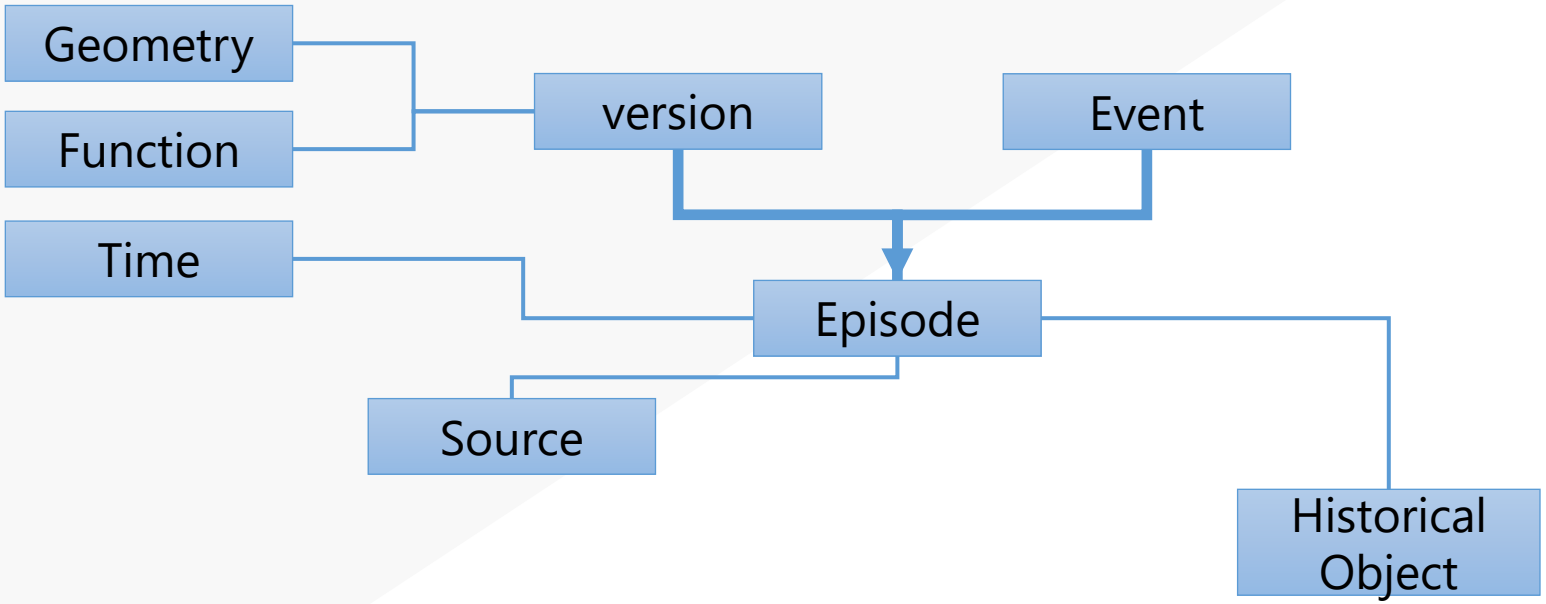
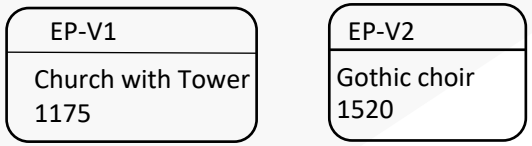


MIDM - Example

- Record of two Episodes (version) about the Church of Theux



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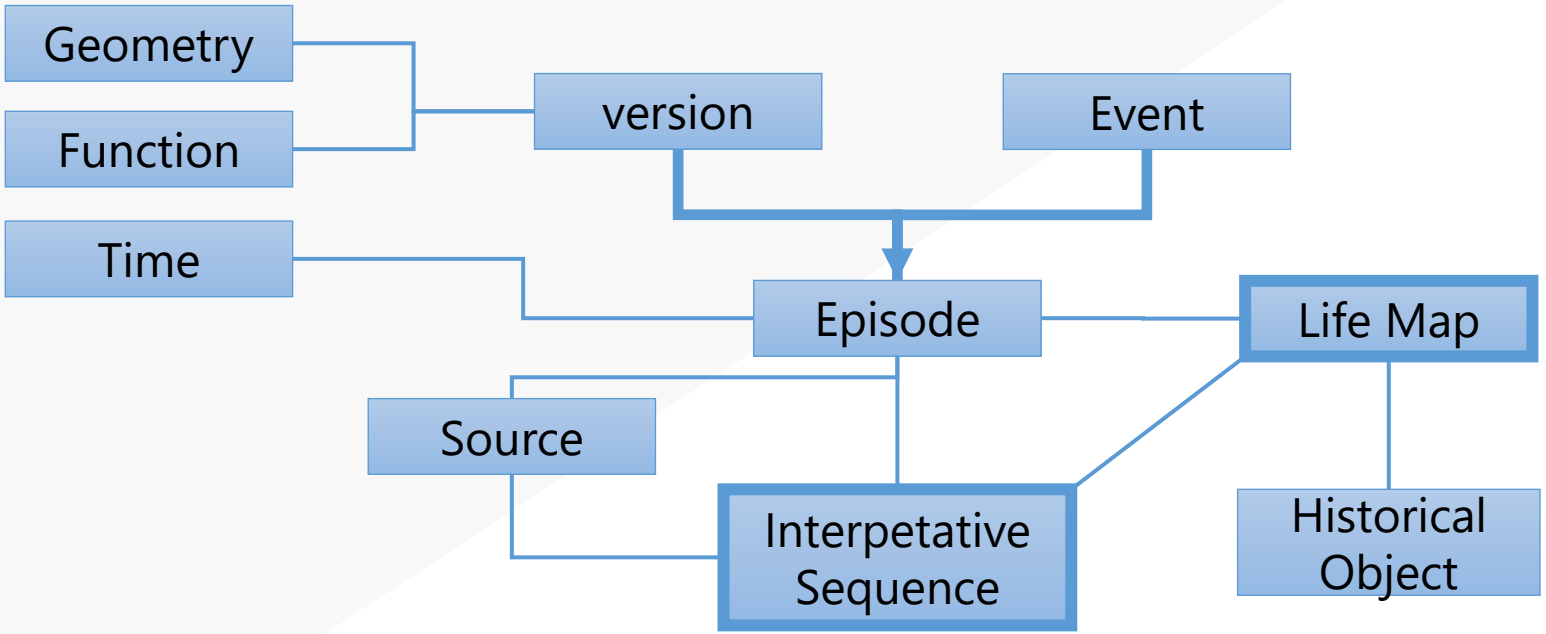
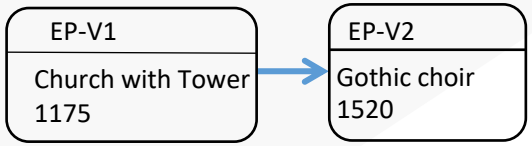


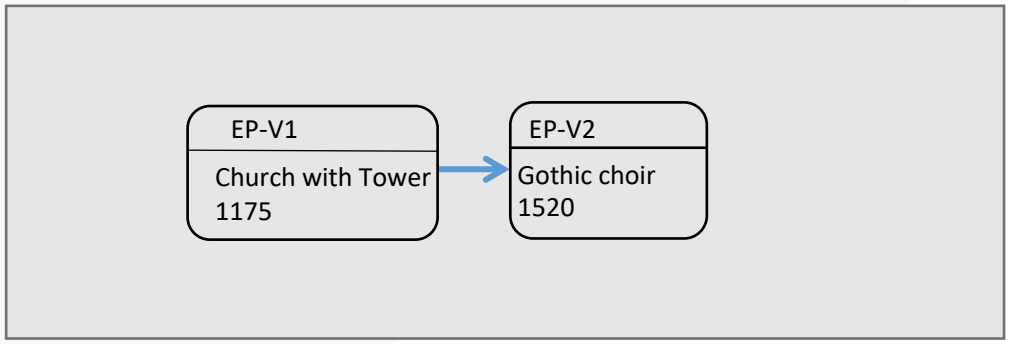
MIDM - Example

Record of one Interpretative Sequence by author 1



MIDM - Example

Life Map of the Church of Theux



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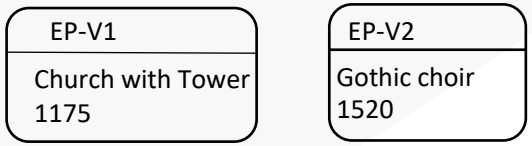
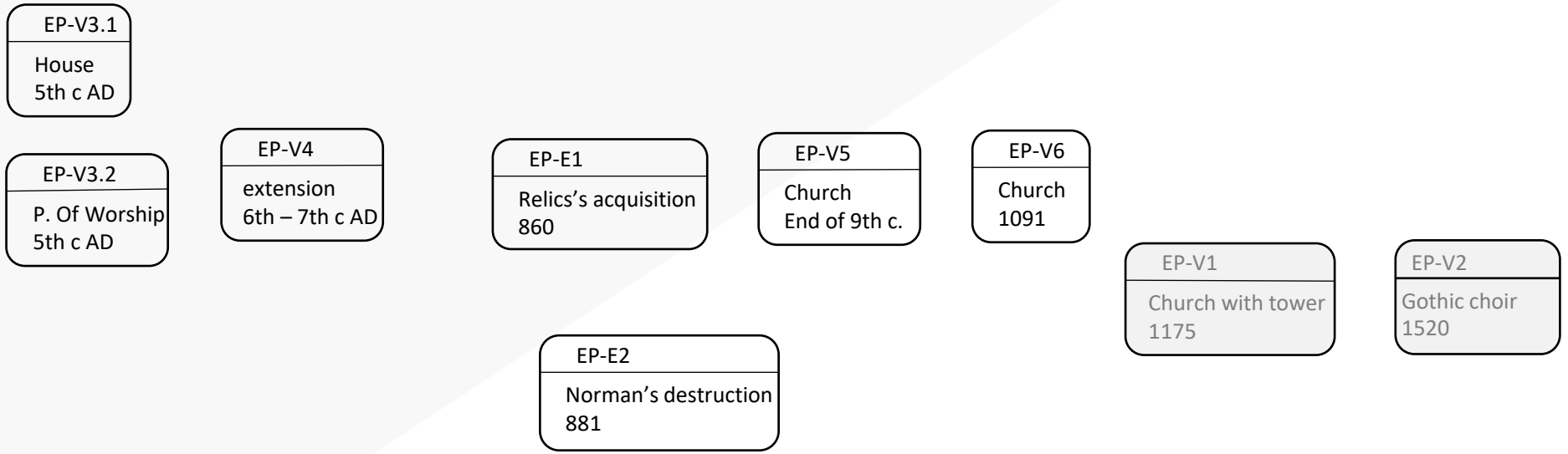


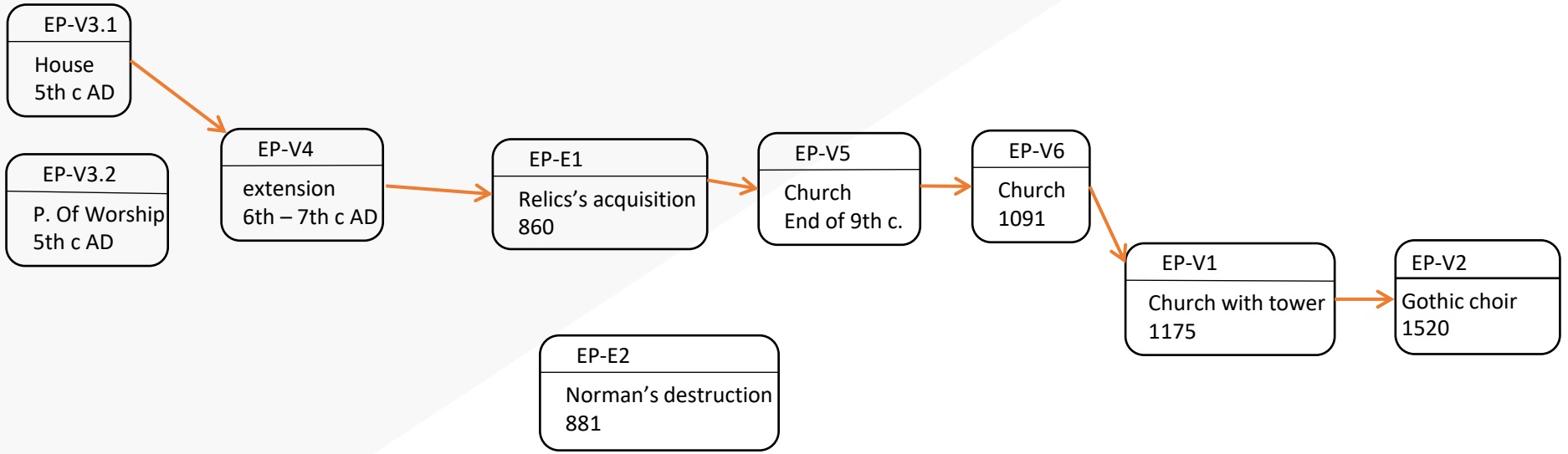
MIDM - Example

Record of new Episodes (version and event) about the Church of Theux



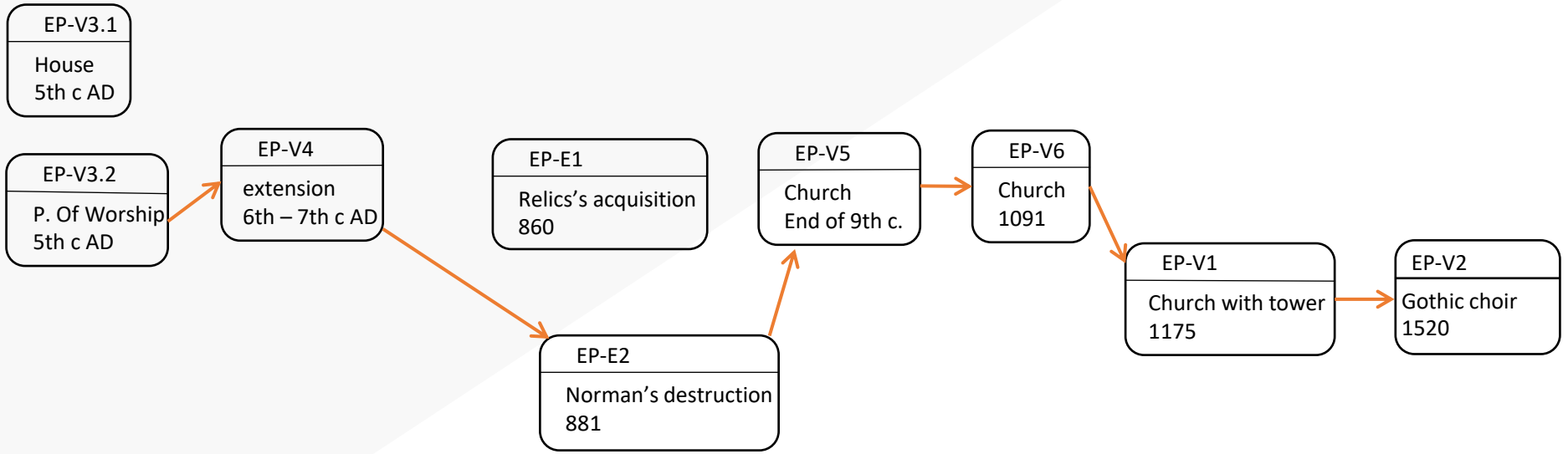
MIDM - Example

Record of one Interpretative Sequence by author 2



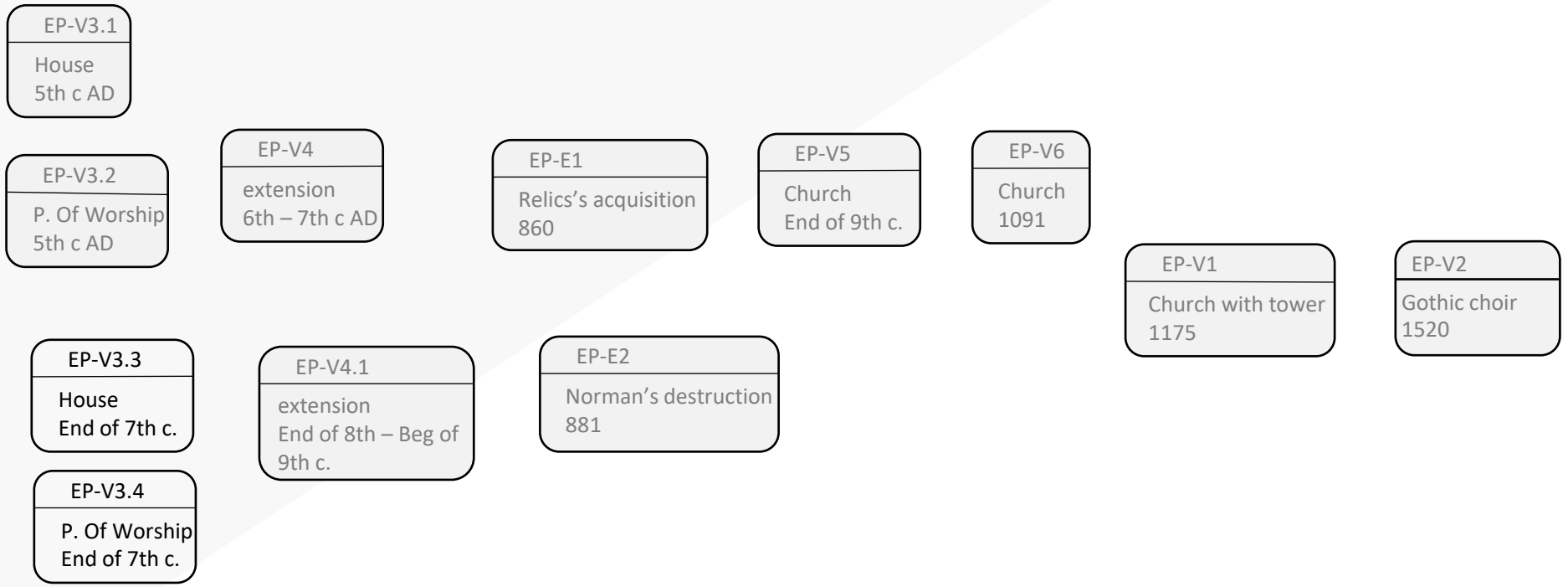
MIDM - Example

Record of a second Interpretative Sequence by author 2



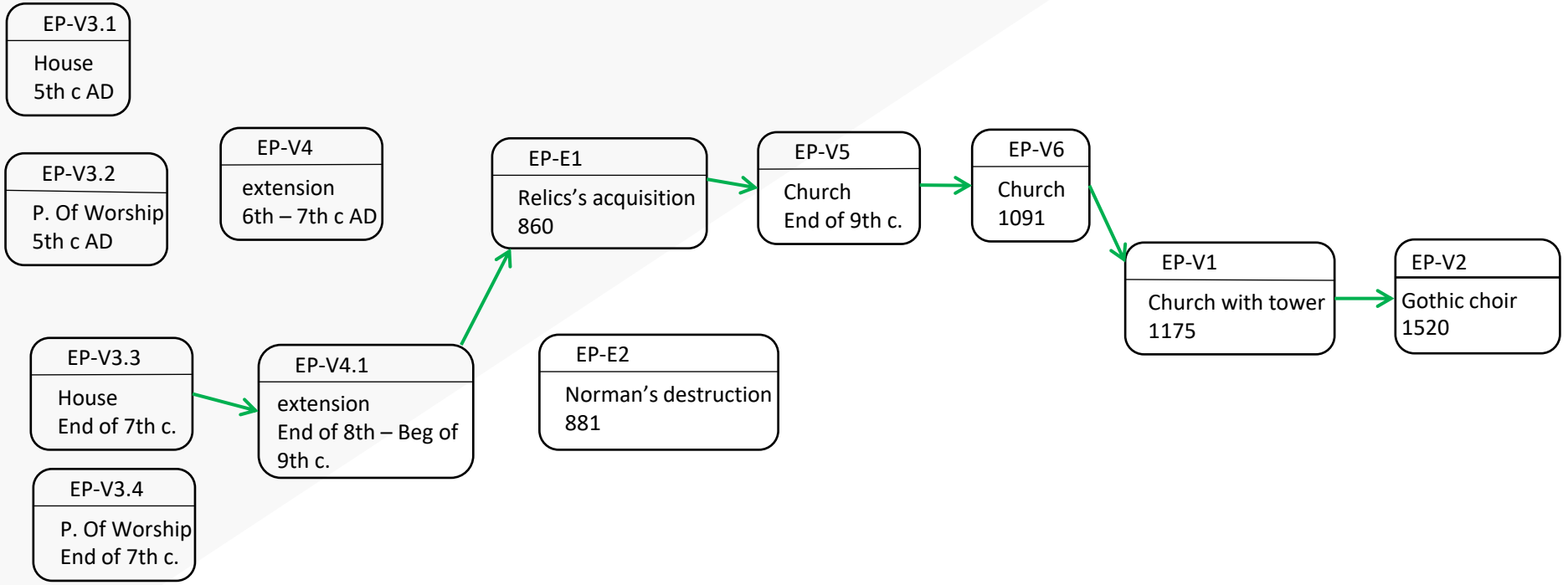
MIDM - Example

Record of new Episodes (version and event) about the Church of Theux



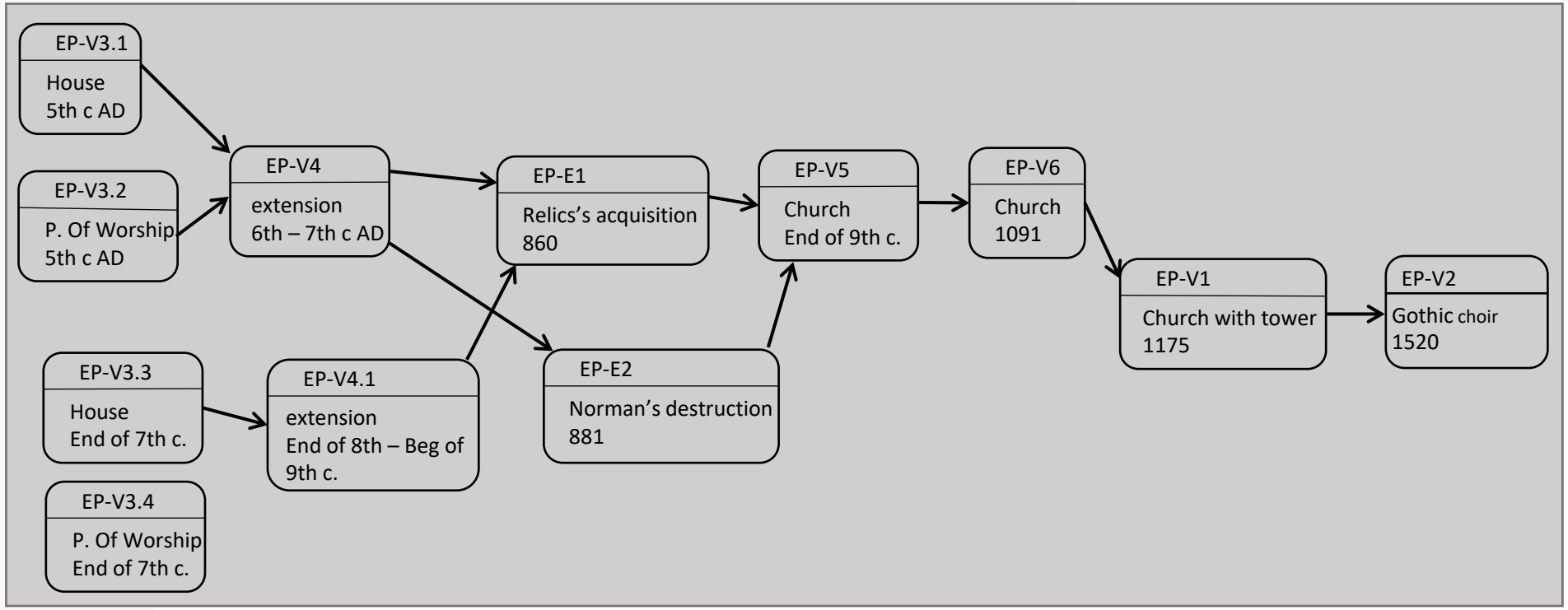
MIDM - Example

Record of one Interpretative Sequence by author 3



MIDM - Example

New Life Map of the Church of Theux

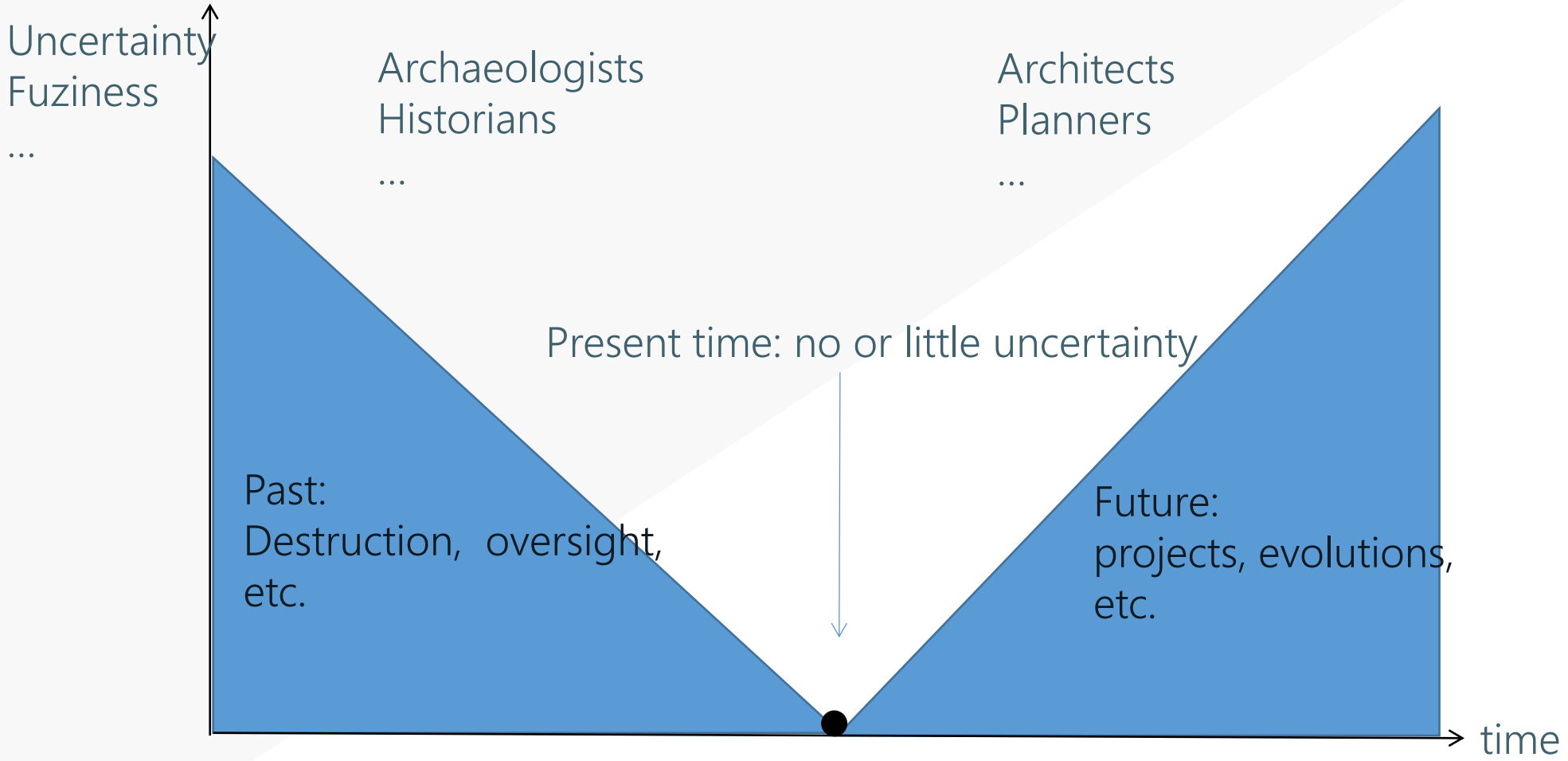


MIDM Future

- MIDM first version has been mapped to CityGML
  - Chaturvedi K., Smyth C.S., Gesquière G., Kutzner T., Kolbe T.H. (2017) Managing Versions and History Within Semantic 3D City Models for the Next Generation of CityGML. In: Abdul-Rahman A. (eds) Advances in 3D Geoinformation. Lecture Notes in Geoinformation and Cartography. Springer, Cham

- MIDM last version has been mapped to CIDOC CRM

Is MIDM just for CH and history?



Conclusions

- SPC is a new way to use point cloud as structural spatial elements carrying semantic information
- SPC is obviously not limited to CH application… can be plugged to other domains

- MIDM is a new way to encompass complexity of CH information and variability of experts' interpratations
- MIDM not only model the past but could be used to model the uncertainty of the future

These papers can interest you (SPC):

- Poux, F., Hallot, P., Neuville, R., Billen, R., 2016. SMART POINT CLOUD: DEFINITION AND REMAINING CHALLENGES. ISPRS Ann. Photogramm. Remote Sens. Spat. Inf. Sci. IV-2/W1, 119–127. doi:10.5194/isprs-annals-IV-2-W1-119-2016
- Poux, F., Neuville, R., Billen, R., 2017a. 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. IV-2/W2, 203–211. doi:10.5194/isprs-annals-IV-2-W2-203-2017
- Poux, F., Neuville, R., Hallot, P., Billen, R., 2017b. MODEL FOR REASONING FROM SEMANTICALLY RICH POINT CLOUD DATA. ISPRS Ann. Photogramm. Remote Sens. Spat. Inf. Sci. in press.
- Poux, F., Neuville, R., Wersch, L. Van, Nys, G.-A., Billen, R., 2017c. 3D Point Clouds in Archaeology: Advances in Acquisition, Processing and Knowledge Integration Applied to Quasi-Planar Objects. Geosci. 2017, Vol. 7, Page 96 7, 96. doi:10.3390/GEOSCIENCES7040096

These papers can interest you (MIDM):

- Pfeiffer, M., Carré, C., Delfosse, V., Hallot, P., & Billen, R. (2013). Virtual Leodium: from an historical 3D city scale model to an archaeological information system. *ISPRS Annals–Volume II-5/W1, 2013*.
- Van Ruymbeke, M., Carré, C., Delfosse, V., Pfeiffer, M., & Billen, R. (2015). Towards an Archaeological Information System: improving the core data model. In *CAA 2014 21st century Archaeology: Concepts methods and tools: Proceedings of the 42nd Annual Conference on Computer Applications and Quantitative Methods in Archaeology* (pp. 245-253). Archaeopress.
- Van Ruymbeke, M, Hallot, P. & Billen, R. (2017). Enhancing CIDOC - CRM and compatible models with the concept of multiple interpretation. ISPRS Annals of the Photogrammetry, Remote Sensing and Spatial Information Sciences, Volume IV-2/W2 , 287-294.
- Van Ruymbeke, M, Hallot, P. & Billen, R. (Forthcoming) IMPLEMENTATION OF MULTIPLE INTERPRETATION CONCEPT IN CIDOC-CRM AND COMPATIBLE MODELS, *Virtual Archaeology Review*

Thank you !

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geomatics.ulg.ac.be (temporary)