

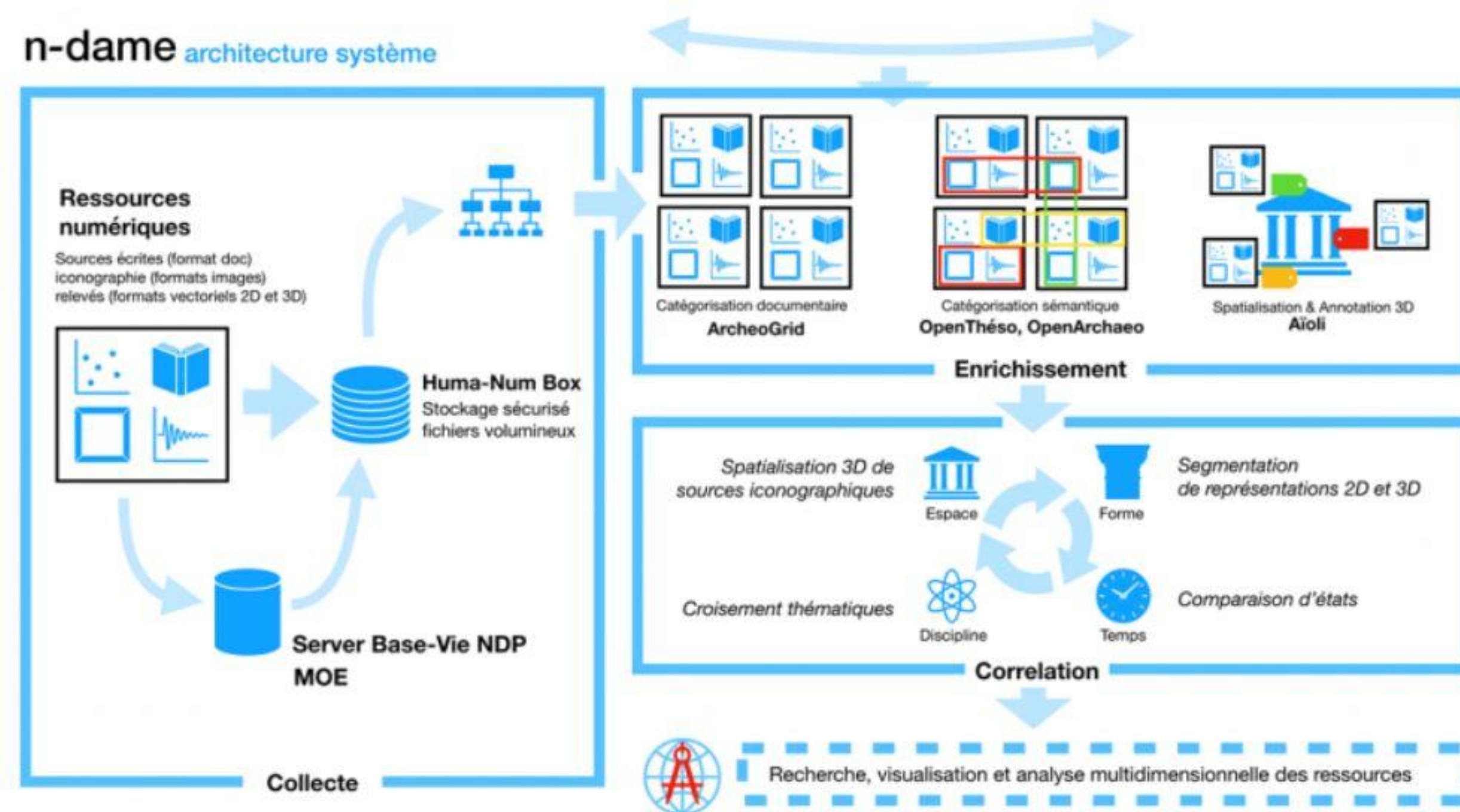
Si les données de Notre-Dame nous étaient contées... Données ouvertes, ingénierie des connaissances et maïeutique numérique

Guillem Anaïs,
UPR2002 CNRS MAP Marseille, France
Ludwig Maximilian University of Munich (LMU), Munich, Germany



Une cathédrale de données numériques et connaissances pluridisciplinaires
Journées d'études du groupe de travail "données numériques" du chantier scientifique Notre-Dame de Paris
19 – 21 juin 2024, Campus CNRS Joseph Aiguier, Marseille

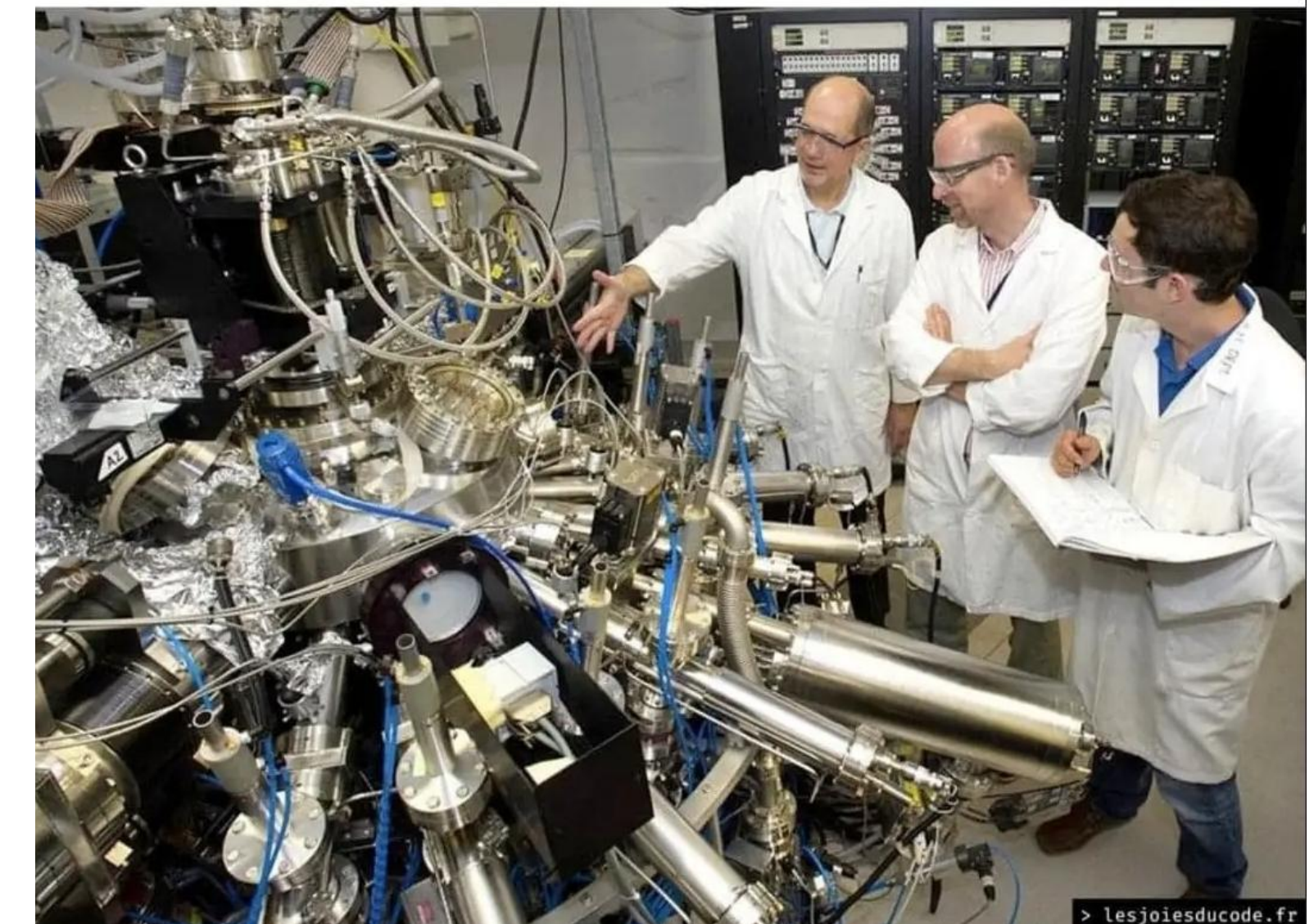
Perception of the digital ecosystem



https://www.notre-dame.science/ecosysteme_n_dame/

- Effort pédagogique et didactique nécessaire à l'appropriation
- Accompagnement des GTs dans la prise en main et l'utilisation des outils (workshops, collaborations etc)

Quand on explique le fonctionnement de notre framework maison au nouveau



Data, information, knowledge...

“Where is the **wisdom** we have lost in **knowledge**?
Where is the **knowledge** we have lost in **information**?”

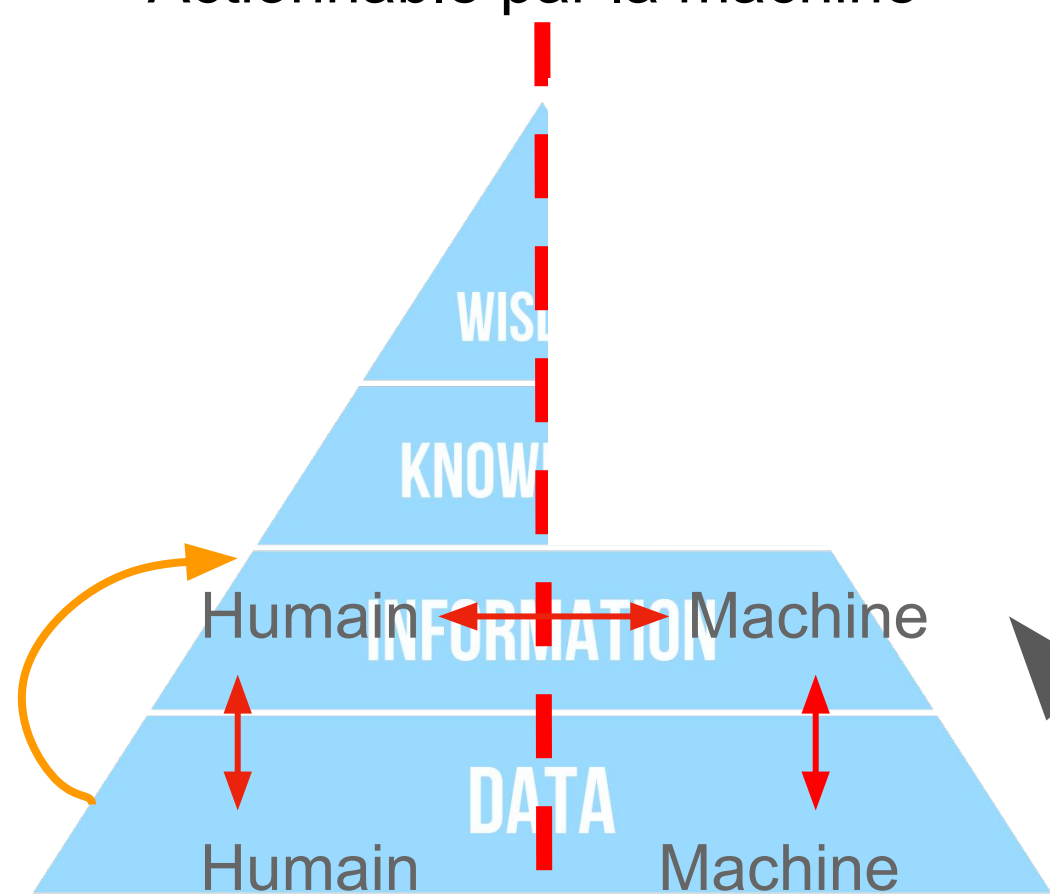
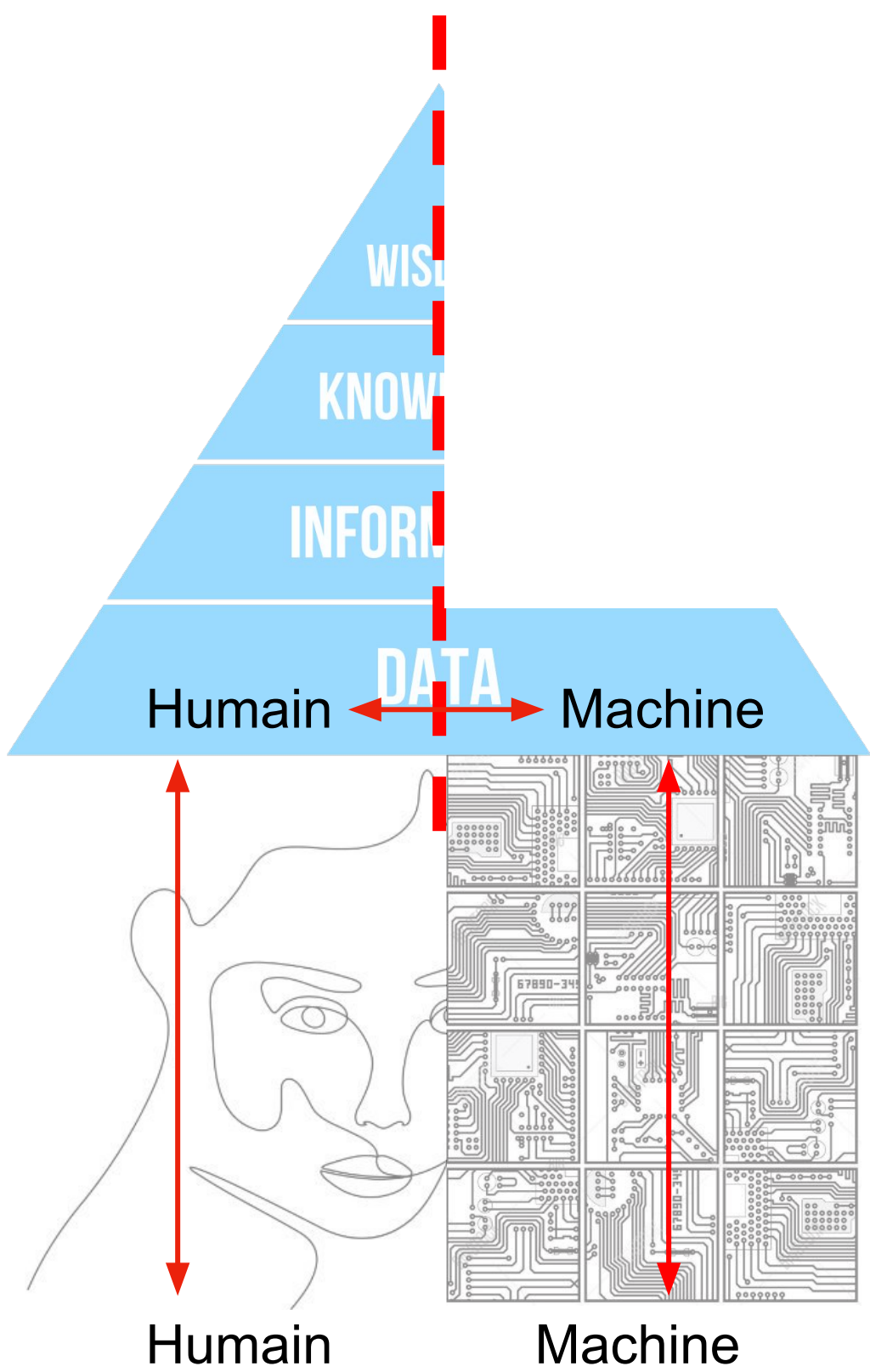
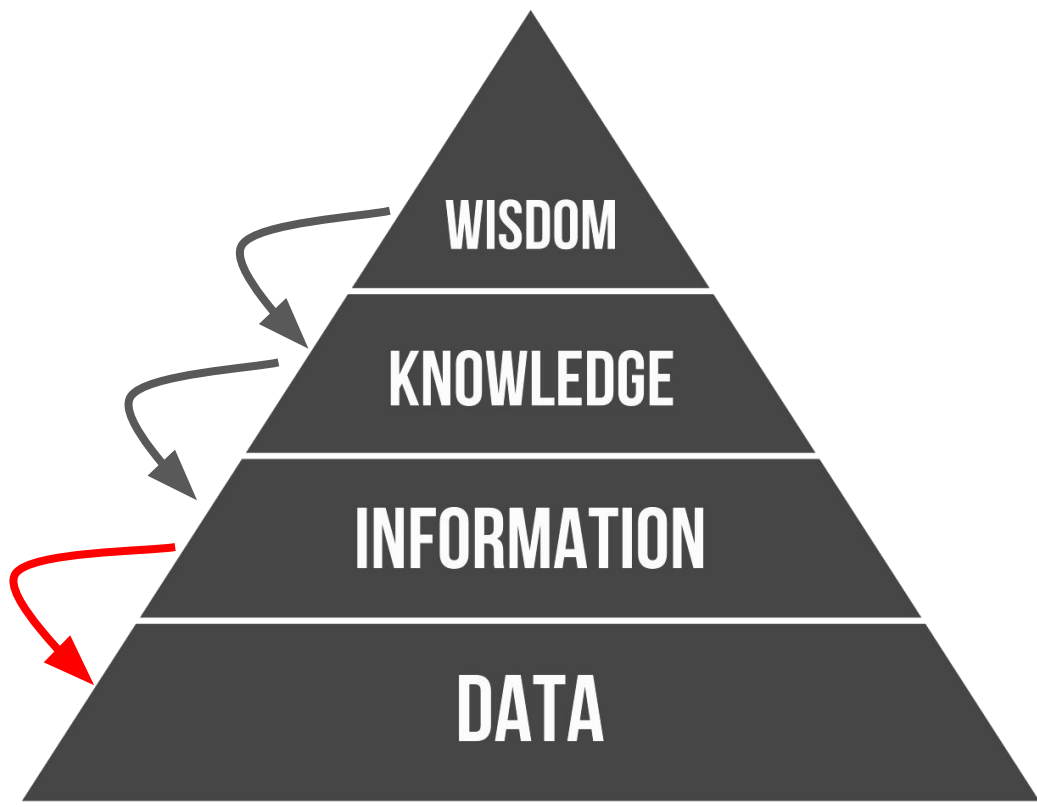
T.S Eliot, poem “The Rock” (1934)

→ Where is the **information** we have lost in **data**?

Problème de l'interopérabilité humain/machine de l'**information**

Information:

- Compréhensible par l'humain et
- Actionnable par la machine



Le conte de Cendrillon et la quête de provenance

Guillem, Anais and Lercari, Nicola (2022): Global Heritage, Knowledge Provenance, and Digital Preservation: Defining a Critical Approach. In: Lercari, Nicola; Wendrich, Willeke; Porter, Benjamin W.; Burton, Margie M. and Levy, Thomas E. (eds.): Preserving Cultural Heritage in the Digital Age. Sending Out an S.O.S. London: Equinox Publishing Ltd. pp. 26-41

- Métaphore de la pantoufle de verre
- Retracer une histoire à partir de la trajectoire :
 - provenance de l'objet
 - provenance des données



Tzitzikas, Yannis; Marketakis, Yannis, Cinderella's Stick - A Fairy Tale for Digital Preservation, 2018.

Challenge: interoperability of data and tools

FAIR data et Linked Open Data

F(indable)

A(ccessible)

I(nteroperable)

R(e-usable)

data

data

data

data

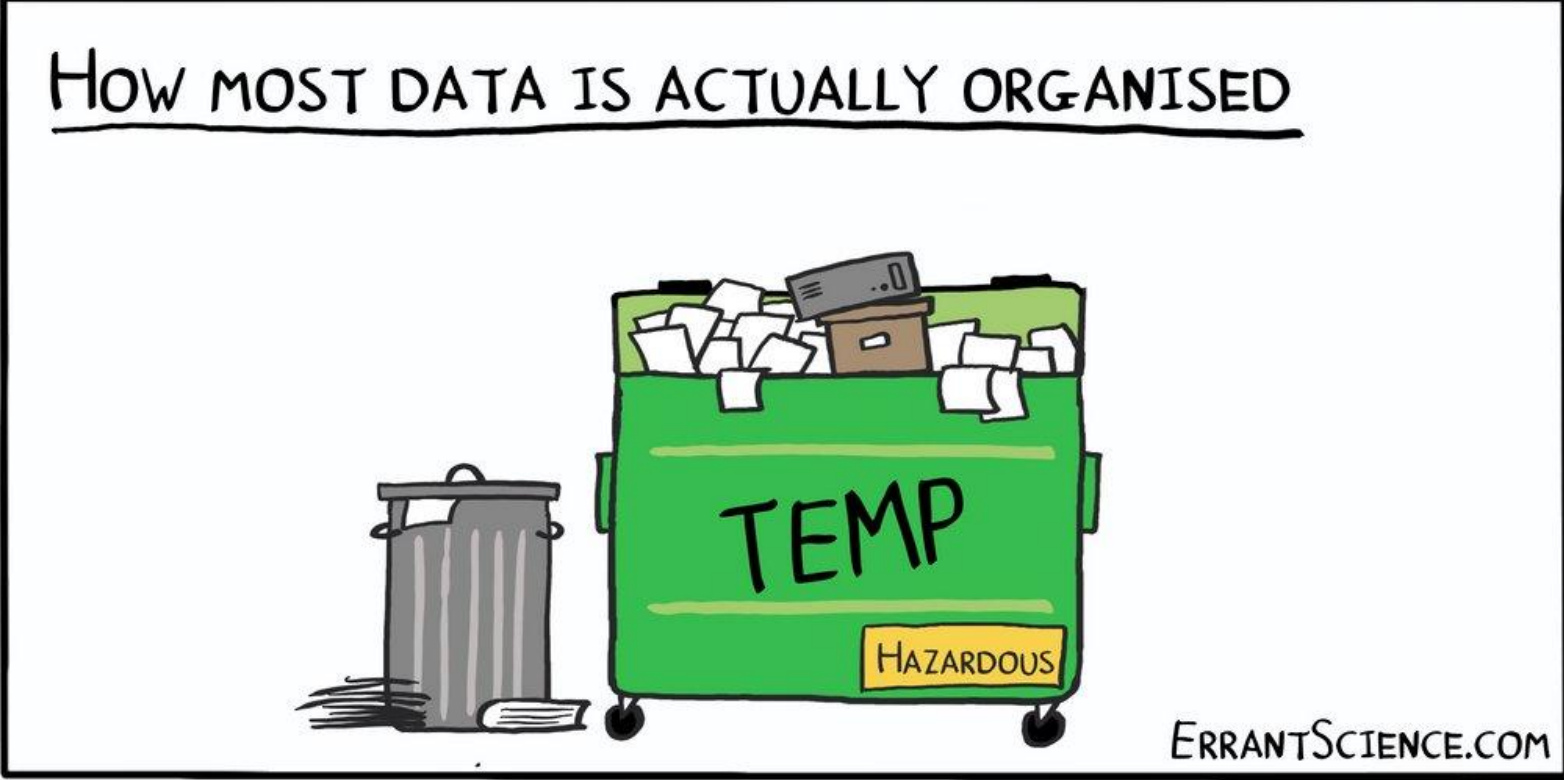
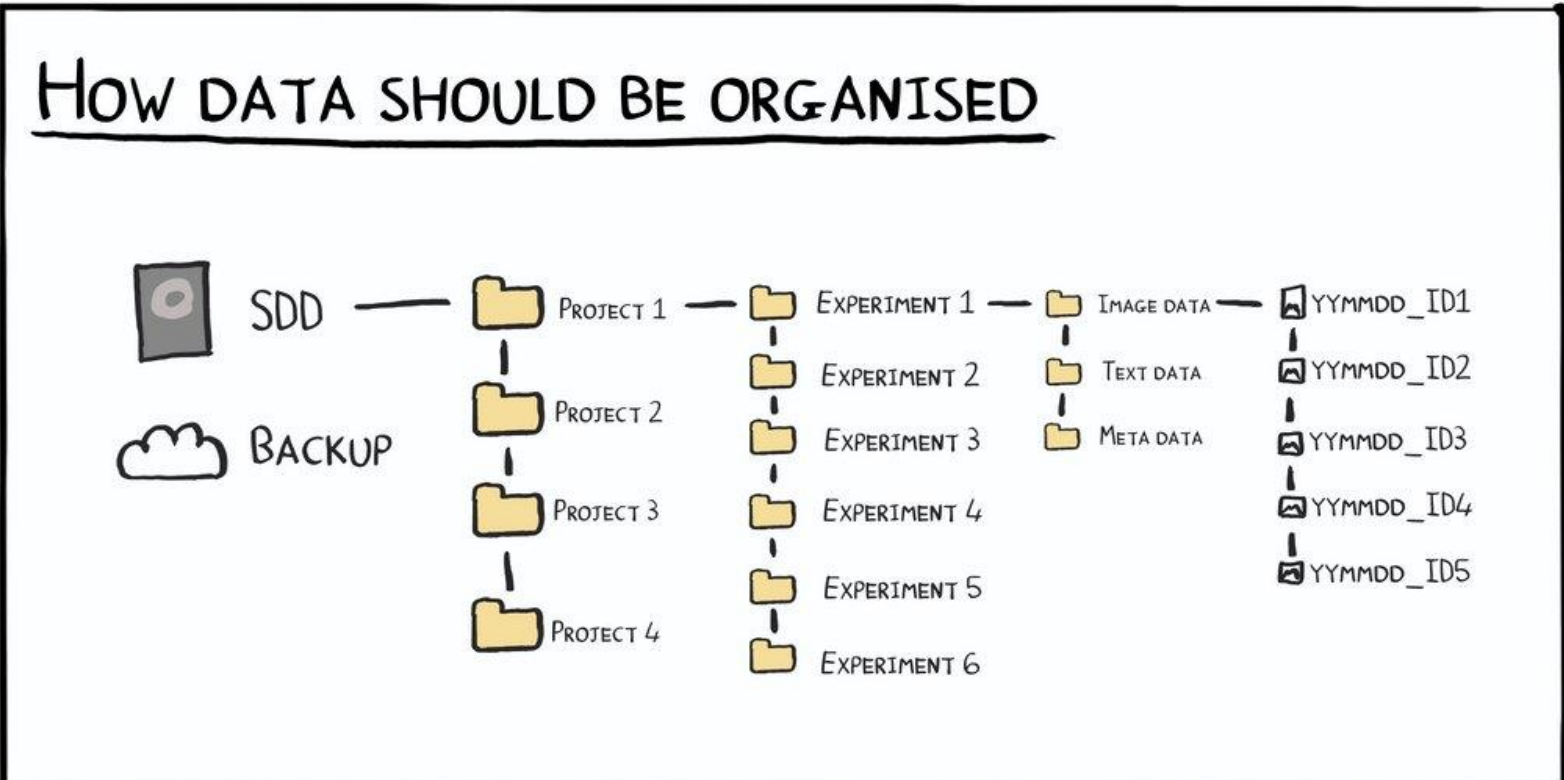
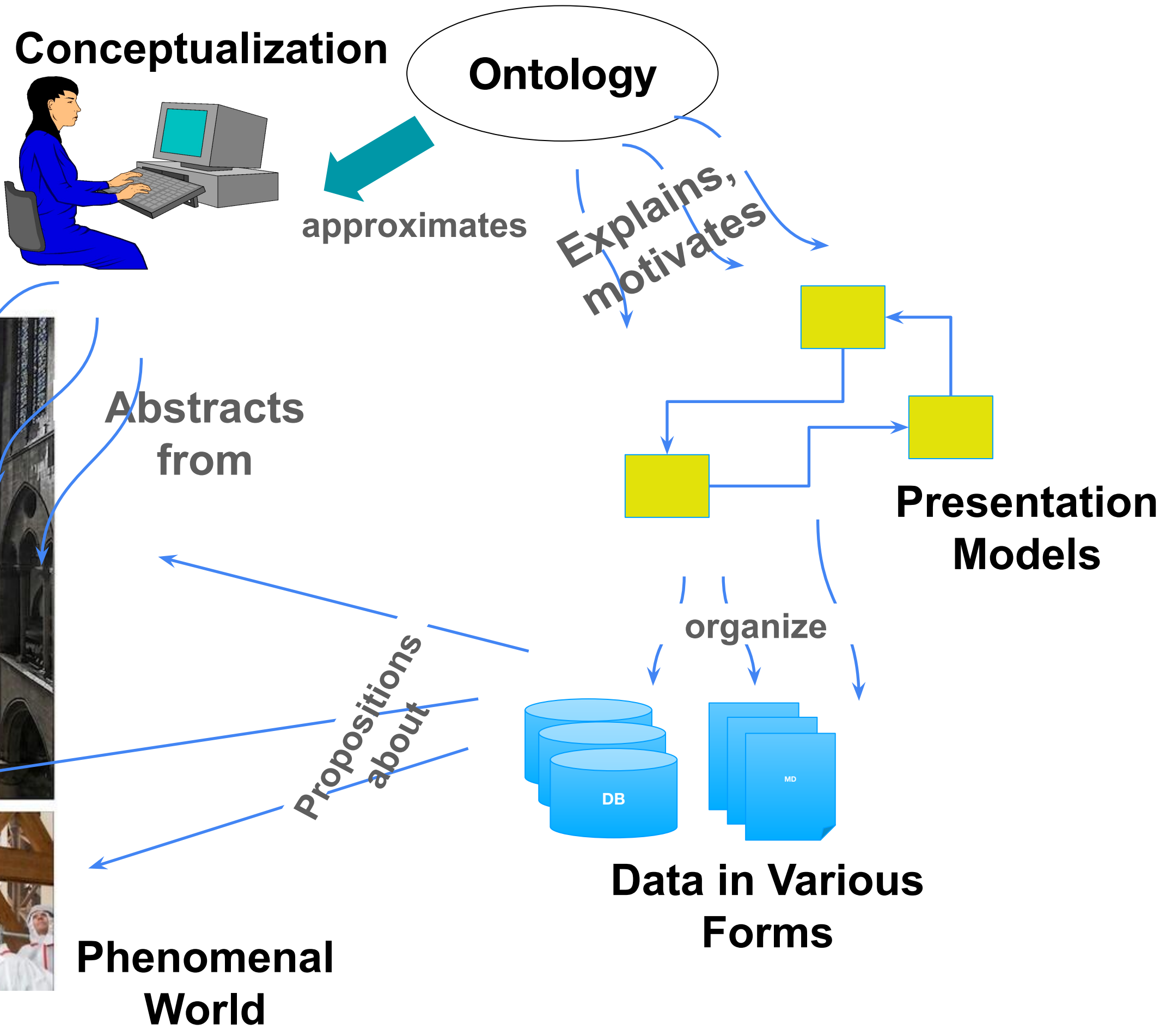
Challenge: Siloed Data

- ★ make your stuff available on the Web (whatever format) under an open license¹
- ★★ make it available as structured data (e.g., Excel instead of image scan of a table)²
- ★★★ make it available in a non-proprietary open format (e.g., CSV instead of Excel)³
- ★★★★ use URIs to denote things, so that people can point at your stuff⁴
- ★★★★★ link your data to other data to provide context⁵

Tim Berners-Lee, 5 stars Open Data
https://commons.wikimedia.org/wiki/File:Tim_Berners-Lee_5-star_Open_Data_plan.png

Data therapy or digital maïeutics

Knowledge Engineering, K-Graphs, Symbolic AI



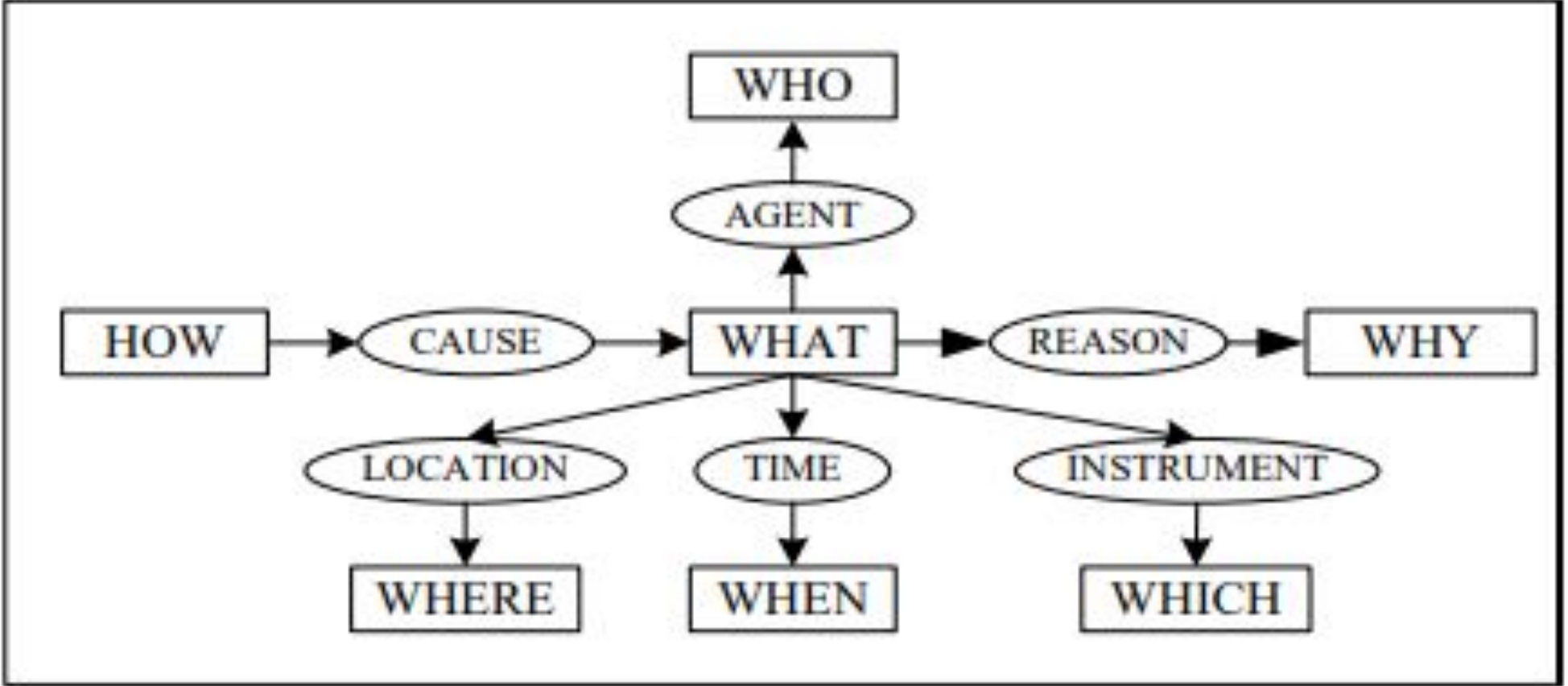
- Knowledge Engineering : building and maintaining knowledge-based systems
- Between:
 - Software engineering: how to build and maintain software systems
 - AI: how to represent, learn, and reason over knowledge computationally

Elena Simperl, Knowledge Engineering: from people to machines and back, ESWC2024, Keynote.

(méta)data enrichment

Which metadata schema(s)?

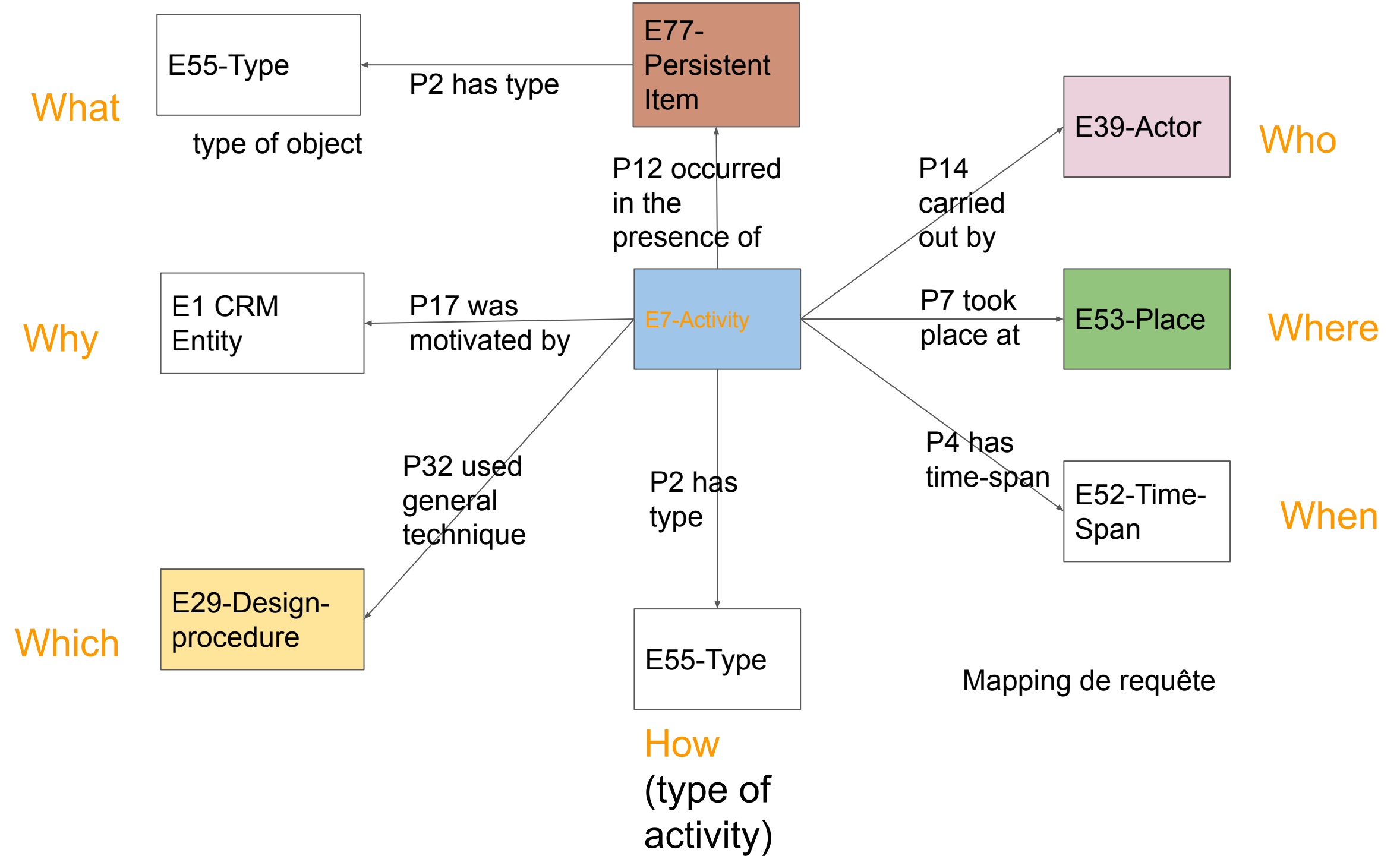
7W model



Sudha Ram and Jun Liu. 2009. A new perspective on semantics of data provenance. In Proceedings of the First International Conference on Semantic Web in Provenance Management - Volume 526 (SWPM'09). CEUR-WS.org, Aachen, DEU, 35-40.

Example of 7W model use for photogrammetric acquisition: Anthony Pamart et al. 2022. A metadata enriched system for the documentation of multi-modal digital imaging surveys. SDH, 6, 1, 1-24.

7W: WHO, WHERE, WHEN, WHAT, HOW, WHICH, and WHY expressed in basic CIDOC CRM



Mapping de requête

Anaïs Guillem, Antoine Gros, Livio De Luca. Faire parler les claveaux effondrés de la cathédrale Notre-Dame de Paris : Un récit fondé sur le web sémantique et les Linked Open Data. Humanistica 2023, Association francophone des humanités numériques, Jun 2023, Genève, Suisse. <hal-04106101>

Mapping and Linked (Open) Data

Fiche descriptive Bloc Rapport Claveaux GT Pierre - novembre 2020

1 **Site** 2 **Structure** 3 **N° inventaire** **Lieu de conservation**
 Cathédrale Notre-Dame, Paris doubleau entre les travées 1 et 2 de la nef N 1a MOE 76 - rack 17

Fonction de la pierre
 Claveau Pilier Culot Sommier Voutain Chapiteau Autre:

Nature
 Calcaire Grès Granite Schiste Marbre Autre:

Aspect
 Couleur de la pierre: épiderme: blanc-beige
 Grain: fin
 Fossiles: Nummulites, Ditrupa, Milloles, Orbitolites, Cérithes, Alvéolines
 Inclusions notaires: Silex Galets Fossiles Autres:

Géologie & Site possible
 Lutétien sup. Lutétien moy. Val-de-Grâce Cochin Charrenton Challot Saint-Maur Saint-Denis

Métriologie
 longueur: 47 cm
 largeur: 34,5 cm
 hauteur int.: 15,5 cm
 hauteur ext.: 16 cm
 courbure:


Traces de taille
 Equarissement: Chasse Pic Têtu Polka
 Dégrossissage: Pic Broche Ciseau (ciselure) larg.: Ripe
 Finition: Laie oblique croisée chevron gerbe désordonnée parallèle
 Impacts: longueur: 8 cm, traînée: > 10 mm, nb de dents: 12, larg. dents: 4 mm, latéralité: droite

Signe lapidaire
 Marque de tailleur / d'atelier Marque de montage Marque de pose Graffiti Epure Indéterminé

Levage
 Trous de pince Trou de louve Tenons Sans trace

Pose
 Trou d'agrafe Stigmates de pose

Scellement
 Trou de goujon Abrevoir Mortier

Photo


Liant associé
 Nature: Mortier Ciment Joint sec Autre:
 Couleur: Composition: Sable Argile Chaux Charbon Galet Végétal Terre cuite Eclat de pierre Incl. métalliques Autre:

Enduit initial
 Non Oui Décor Unif. Végétal Faux joints Autre Indéterminé
 Composition: Sable Argile Chaux Charbon Galet Végétal Terre cuite Eclat de pierre Incl. métalliques Autre:
 Couleur de fond: Couleur du décor:

Décor sculpté
 Feuille d'acanthe Grottesque Crochet Animalier Scène historique Héraldique Autre: tore, méplat central

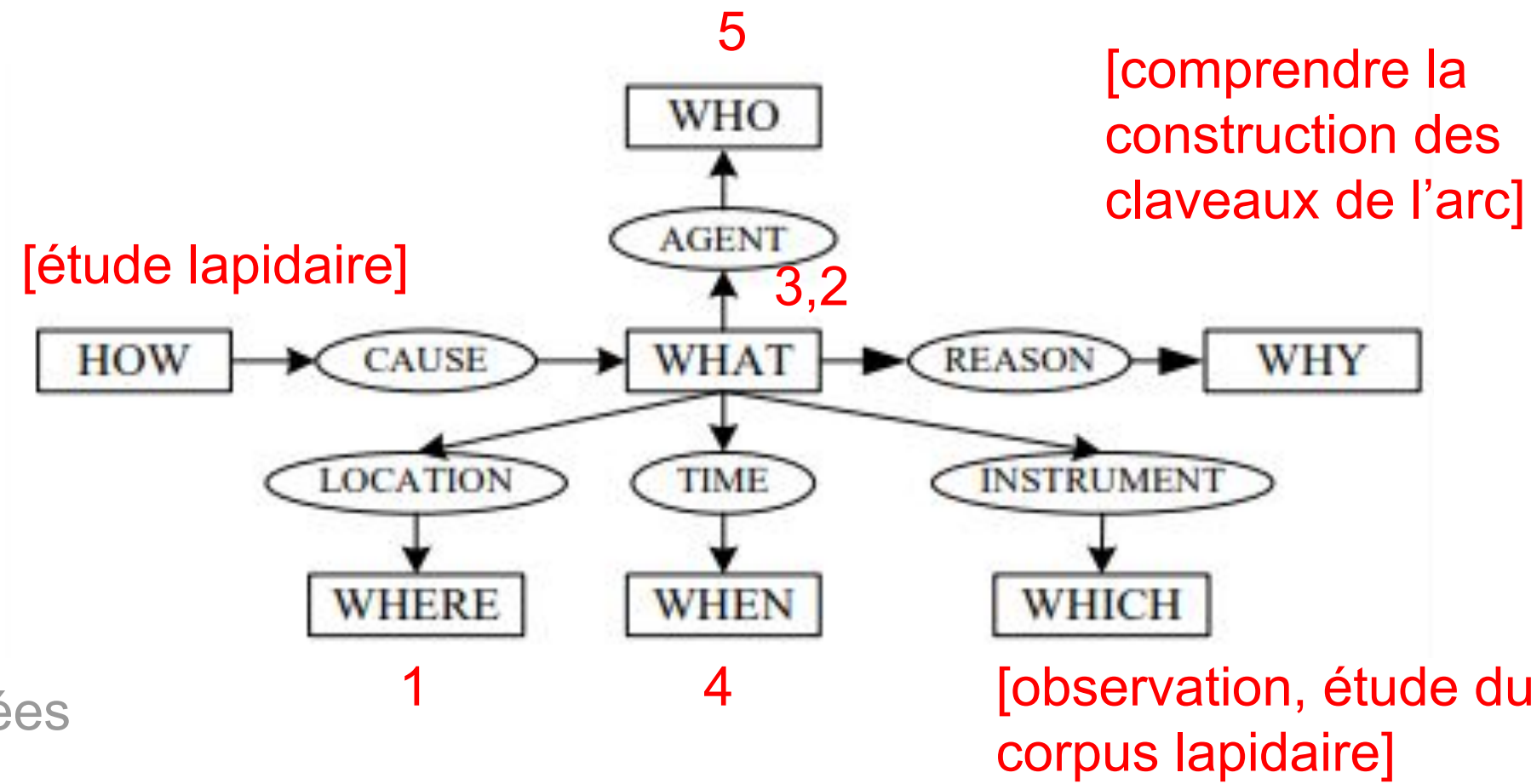
Remploi
 Non Oui, fonction primaire fonction secondaire

Ragréage
 Non enduit: rubané rouge Oui outil:

Observations
 Décor rubané rouge ajouté lors de restaurations le long de l'extradors et dans les gorges entre les tores et le méplat central. Surface visible traitée à la gradine et bretturée en frappe perpendiculaire; surface enfouie dans la maçonnerie traitée à la bretturée. Taille en gerbe sur les faces de contact, axée sur un tore. Réalisation de la croix au ciseau.
 Deux encroches de part et d'autre du claveau pour fixer les cintres des voûtes adjacents: 5,5 x 5,5 x 10 cm. et 5,5 x 5,5 x 9 cm.

4 Date de rédaction: 17 septembre 2020 Rédacteur(s): Cédric Moulis, Bruno Phalip 5

métadonnées



données

métadonnées

Exemple de la fiche GT Pierre, étude lapidaire: identification/extraction des métadonnées

Structuration avec un schéma de métadonnées et enrichissement des métadonnées

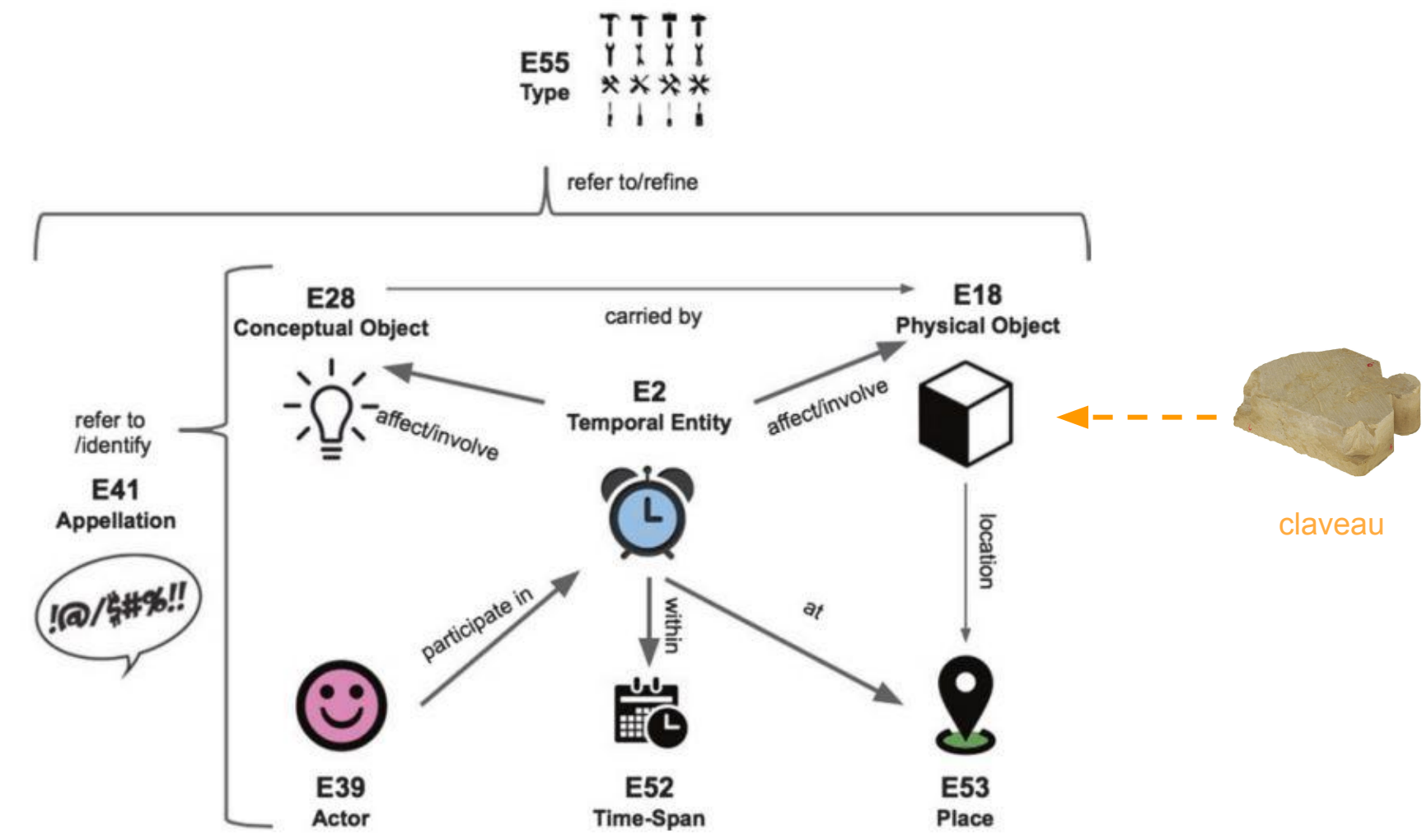


Fig.1 CIDOC-CRM Top Level Categories

[Bruseker et al. 2017, pp 112, fig.1]

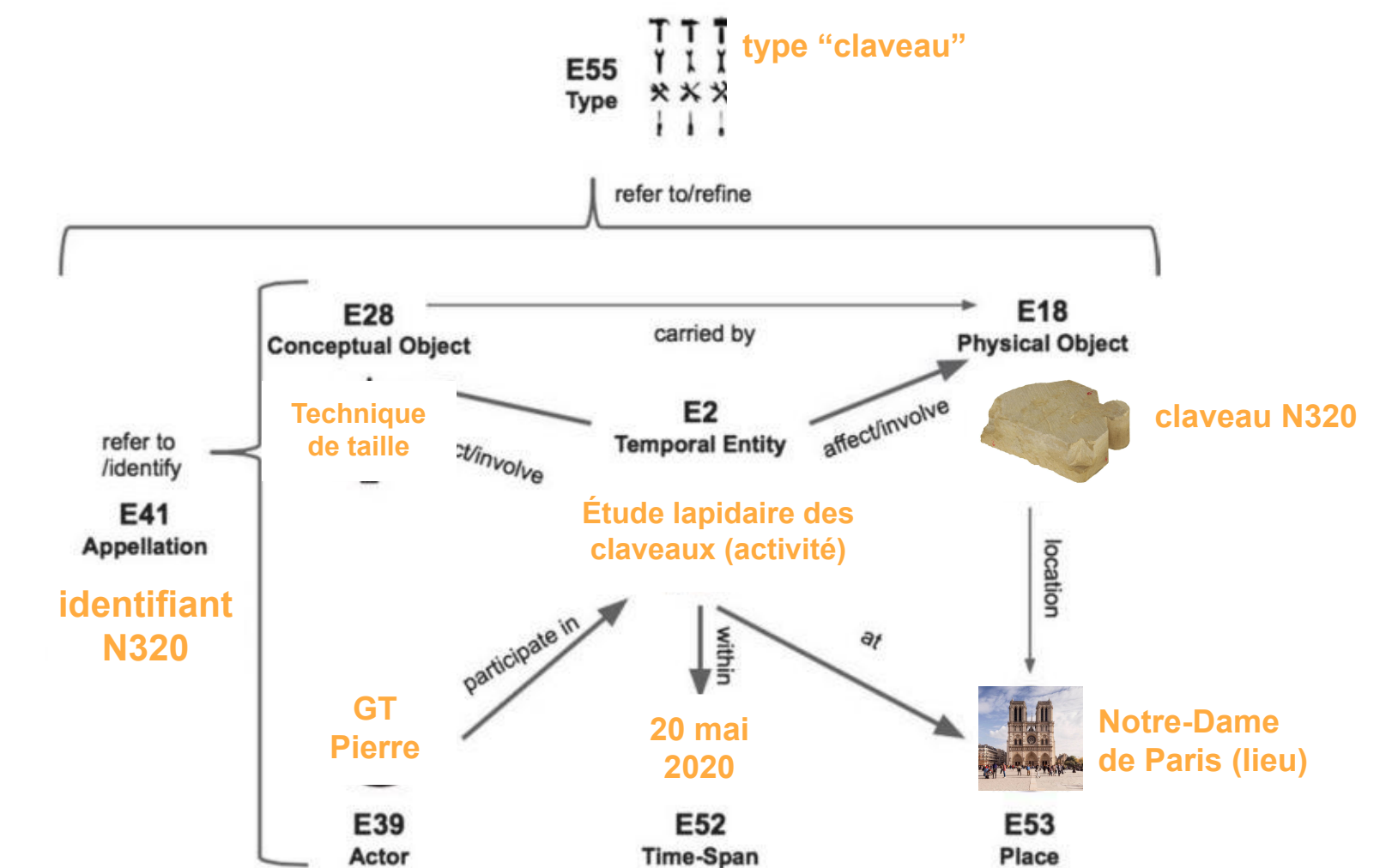
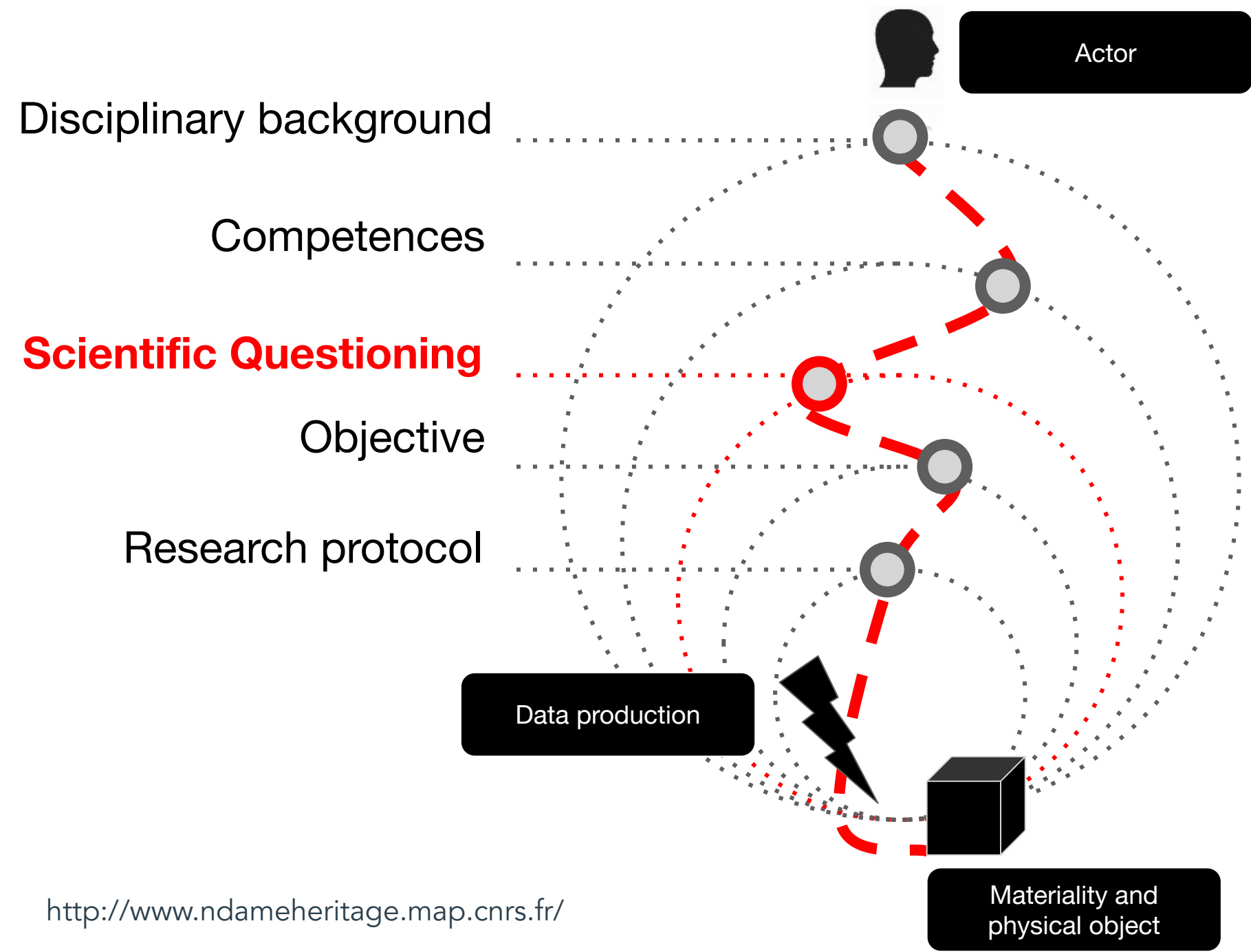


Fig.1 CIDOC-CRM Top Level Categories

Mapping avec une ontologie

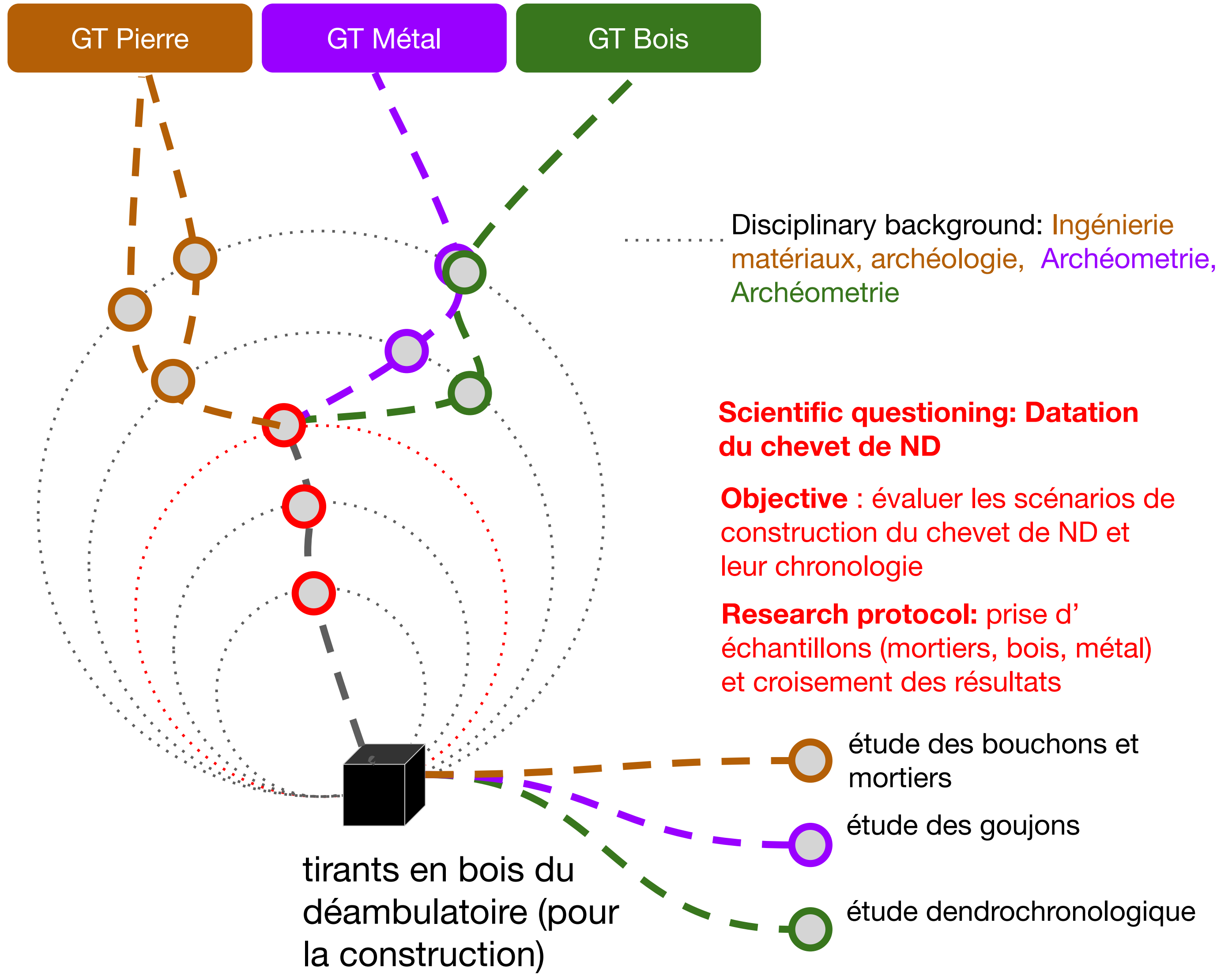
Anaïs Guillem, Antoine Gros, Livio De Luca. Faire parler les claveaux effondrés de la cathédrale Notre-Dame de Paris : Un récit fondé sur le web sémantique et les Linked Open Data. Humanistica 2023, Association francophone des humanités numériques, Jun 2023, Genève, Suisse. (hal-04106101)

Research questions



<http://www.ndameheritage.map.cnrs.fr/>

- Workshops avec les différents GTs:
- Liste des questions de recherche
- Requêtes pour les données numériques/jeux de données
- env. 120 questions de recherche à ce jour pour guider le travail sur les données avec tous les groupes de travail



Disciplinary background: Ingénierie matériaux, archéologie, Archéométrie, Archéométrie

Scientific questioning: Datation du chevet de ND

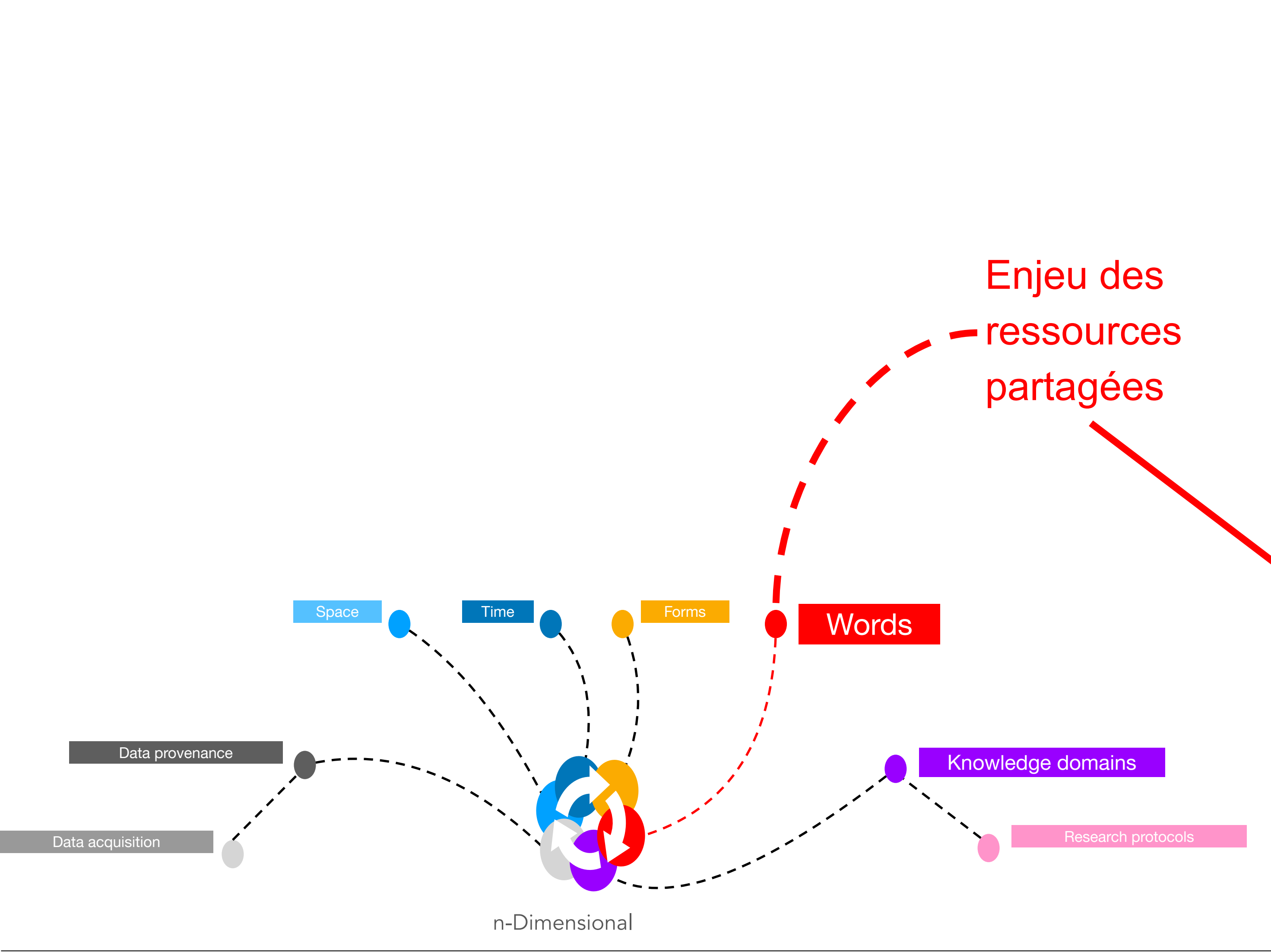
Objective : évaluer les scénarios de construction du chevet de ND et leur chronologie

Research protocol: prise d'échantillons (mortiers, bois, métal) et croisement des résultats

- étude des bouchons et mortiers
- étude des goujons
- étude dendrochronologique

Colloque Naissance et renaissance d'une cathédrale, Notre-Dame de Paris sous l'oeil des scientifiques, SESSION 2 : UNE CHRONOLOGIE REVISITÉE, Session animée par Alexa Dufraisse et Yves Gallet, 22-24 avril 2024, Cité de l'Architecture et du Patrimoine, Paris.

Thesauri and controlled vocabularies



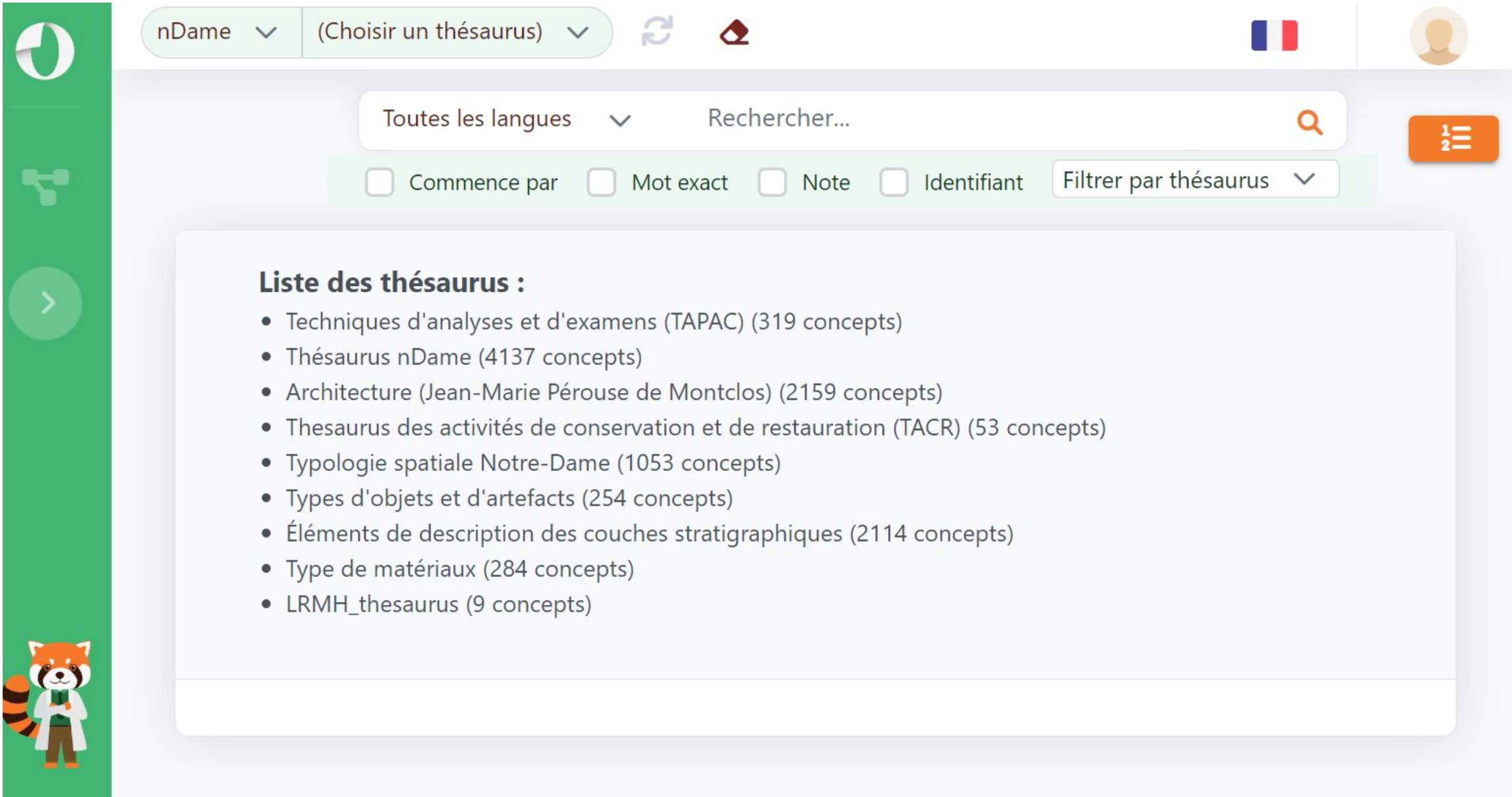
(et dans les données)

Meme (source: internet, unknown, 2023; modified)

Thesauri in NDame research:

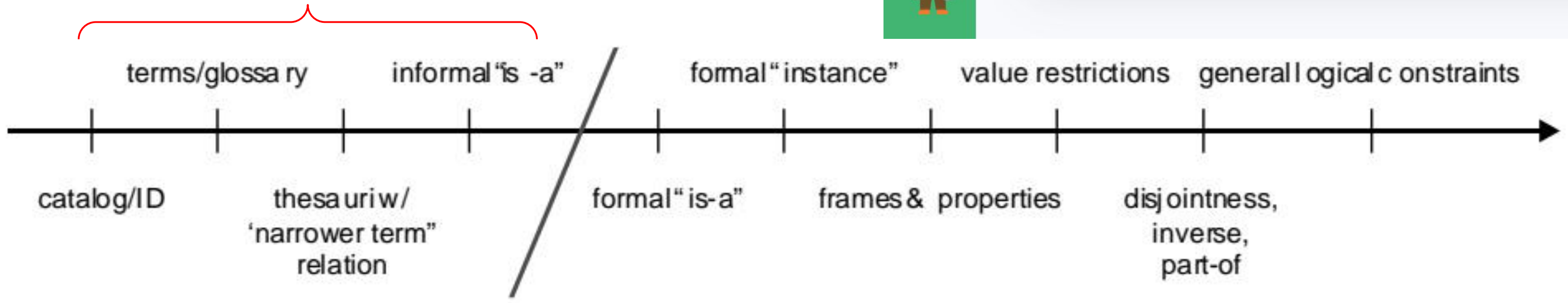
10.400 concepts / 9 thesauri

Curation manuelle des concepts et thesauri



The screenshot shows the nDame web interface. At the top, there are navigation elements: 'nDame' and '(Choisir un thesaurus)'. Below that is a search bar with 'Rechercher...' and a dropdown for 'Toutes les langues'. There are also filter options: 'Commence par', 'Mot exact', 'Note', and 'Identifiant'. A 'Filtrer par thesaurus' dropdown is also present. The main content area displays a 'Liste des thesaurus :' with the following items:

- Techniques d'analyses et d'examens (TAPAC) (319 concepts)
- Thésaurus nDame (4137 concepts)
- Architecture (Jean-Marie Pérouse de Montclos) (2159 concepts)
- Thésaurus des activités de conservation et de restauration (TACR) (53 concepts)
- Typologie spatiale Notre-Dame (1053 concepts)
- Types d'objets et d'artefacts (254 concepts)
- Éléments de description des couches stratigraphiques (2114 concepts)
- Type de matériaux (284 concepts)
- LRMH_thesaurus (9 concepts)

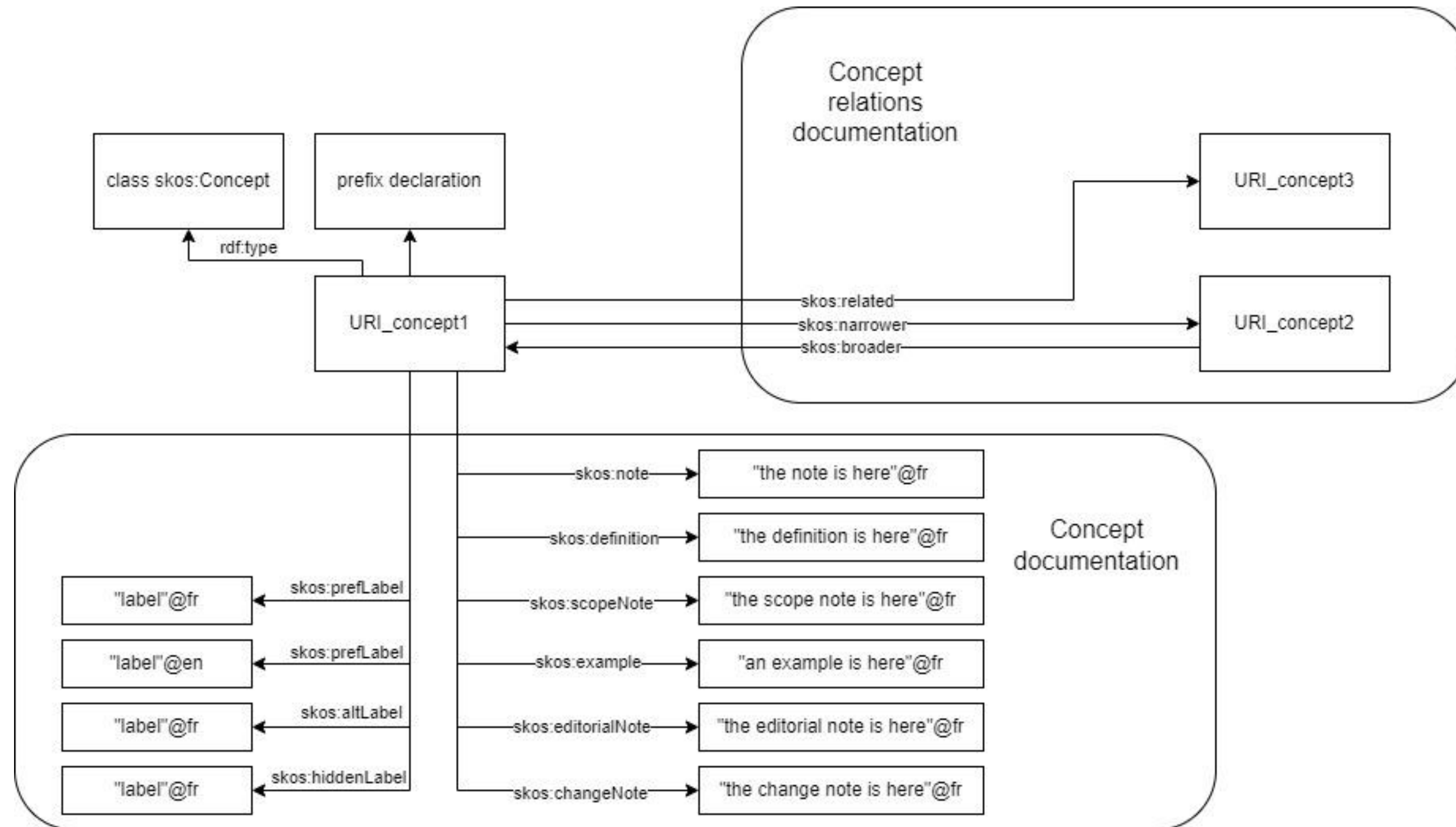


<https://frollo.notre-dame.science/opentheso/>

Lassila, O., & McGuinness, D. (2001). The role of frame-based representation on the semantic web. Linköping University Electronic Press.

Thesaurus curation

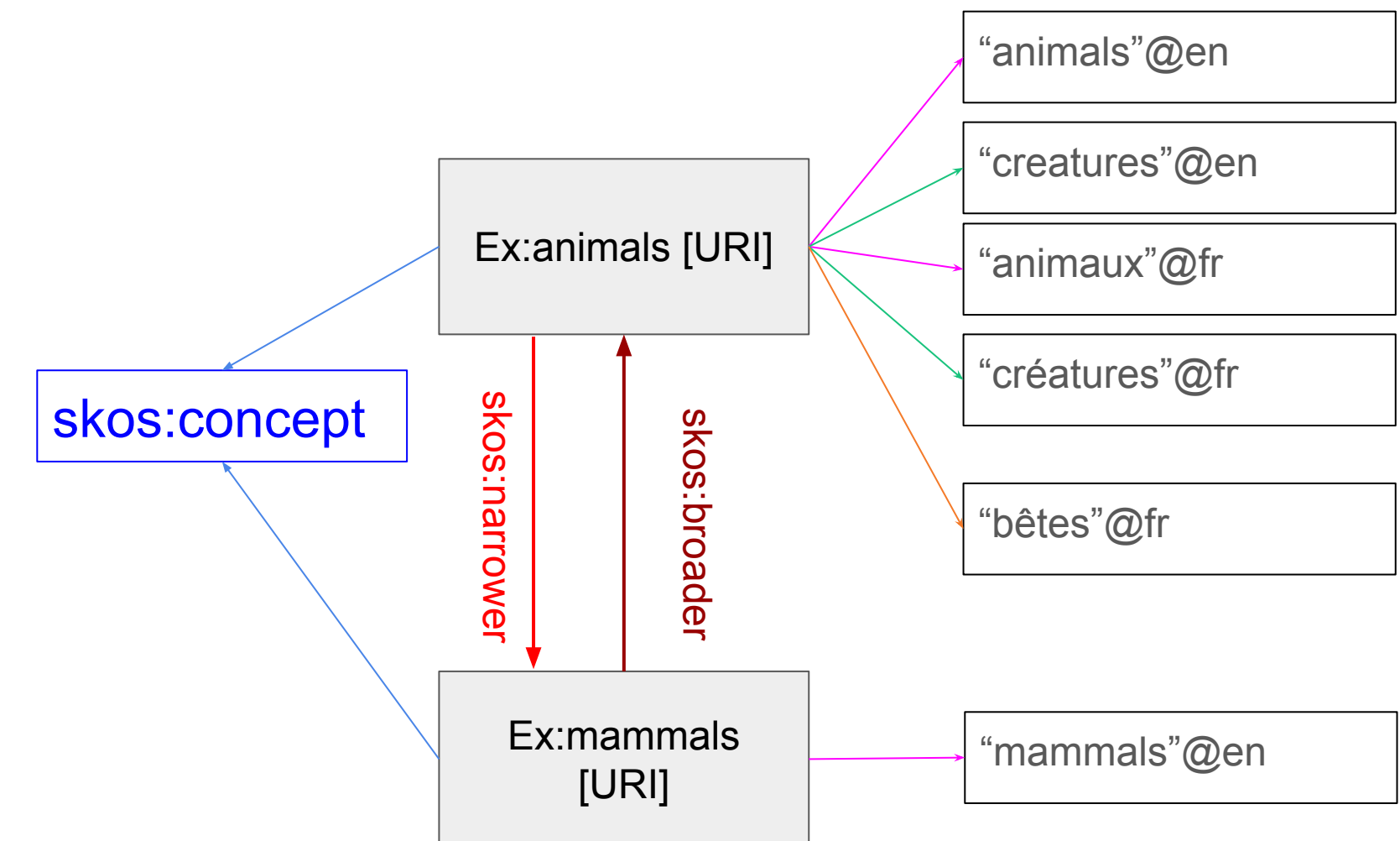
Simple Knowledge Organization System (SKOS) formalization



representation of the essential elements of the SKOS model from the SKOS Primer

<https://www.w3.org/2009/08/skos-reference/skos.html>

SKOS Example (ttl)



@prefix ex: <http://www.example.com/> .

@prefix skos: <http://www.w3.org/2004/02/skos/core#> .

@prefix rdf: <http://www.w3.org/1999/02/22-rdf-syntax-ns#> .

ex:animals **rdf:type** skos:Concept;

skos:prefLabel "animals"@en;

skos:altLabel "creatures"@en;

skos:prefLabel "animaux"@fr;

skos:altLabel "créatures"@fr;

skos:hiddenLabel "betes"@fr

skos:narrower ex:mammals.

ex:mammals **rdf:type** skos:Concept;

skos:prefLabel "mammals"@en;

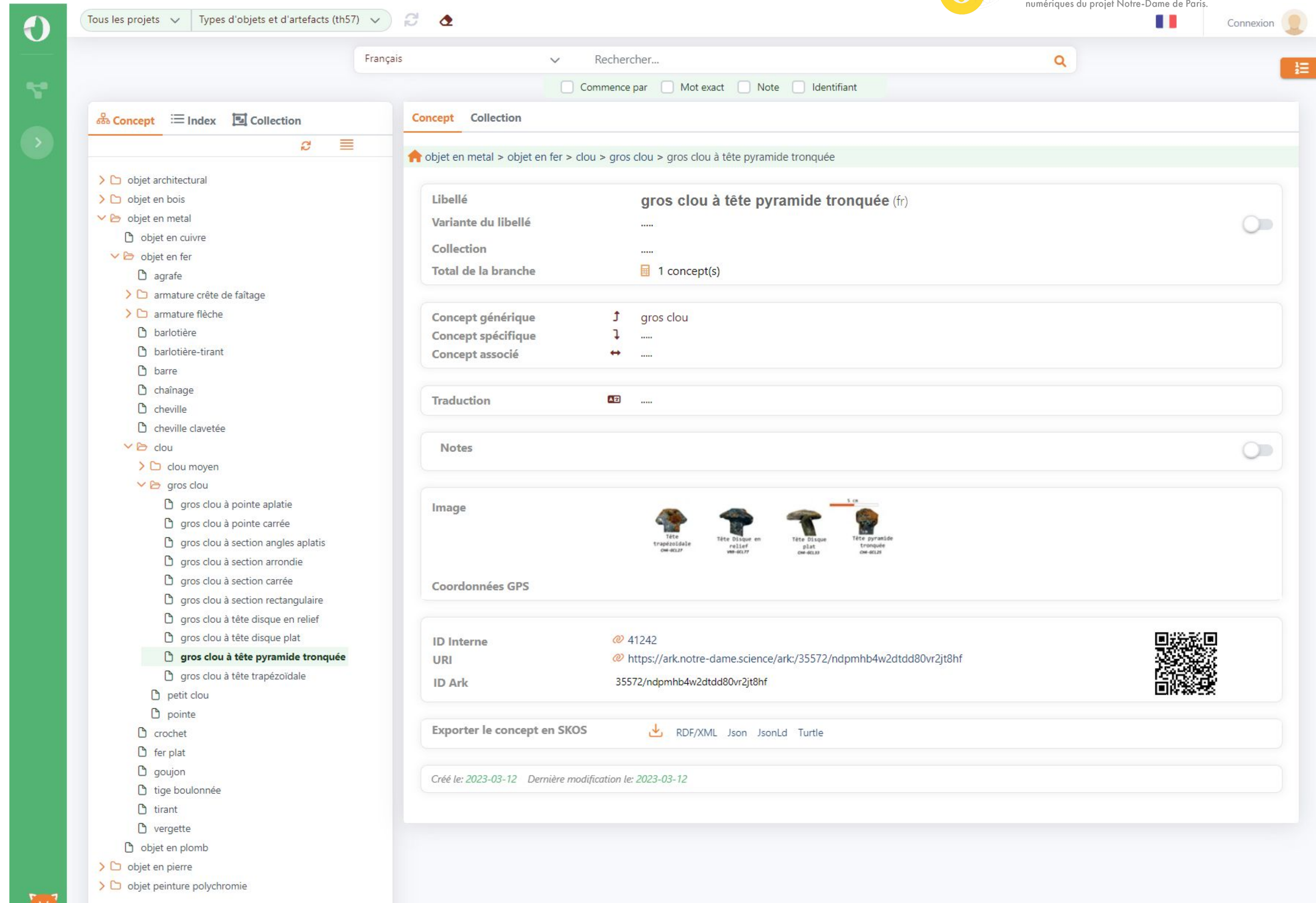
skos:broader ex:animals.

OpenTheso

Example of a concept and its documentation

<https://ark.notre-dame.science/ark:/35572/ndpmhb4w2dtdd80vr2jt8hf>

- workshops avec les différents GTs (merci à tous les participants et contributeurs)
- Mise en commun et documentation des vocabulaires de travail
- Documentation manuelle :
 - dans Opentheso
 - tableur puis ingestion csv dans Opentheso



The screenshot displays the OpenTheso web interface. At the top, there are navigation elements including 'Tous les projets', 'Types d'objets et d'artefacts (th57)', a language selector set to 'Français', and a search bar. The main content area is divided into two panels. The left panel shows a hierarchical tree of concepts, with 'gros clou à tête pyramide tronquée' selected and highlighted in green. The right panel provides detailed information for this concept, including its label, variants, collection, and total count. It also shows relationships with other concepts, translations, notes, and images. The bottom section includes identifiers (ID Interne, URI, ID Ark), a QR code, and options to export the concept in various formats (SKOS, RDF/XML, Json, JsonLd, Turtle). The creation and modification dates are also displayed.

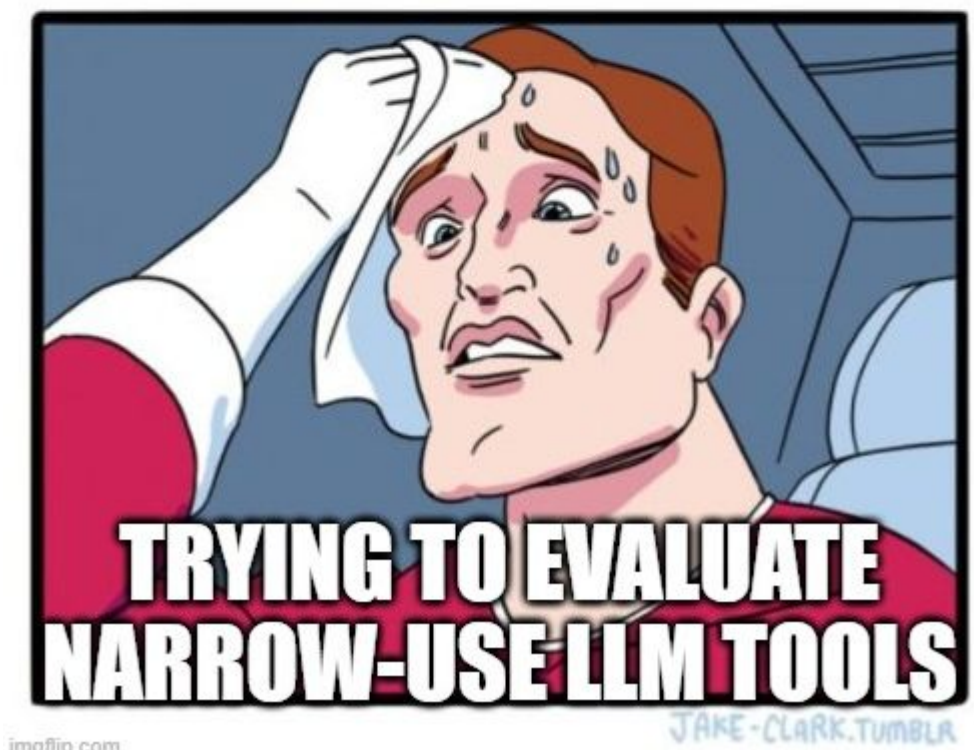
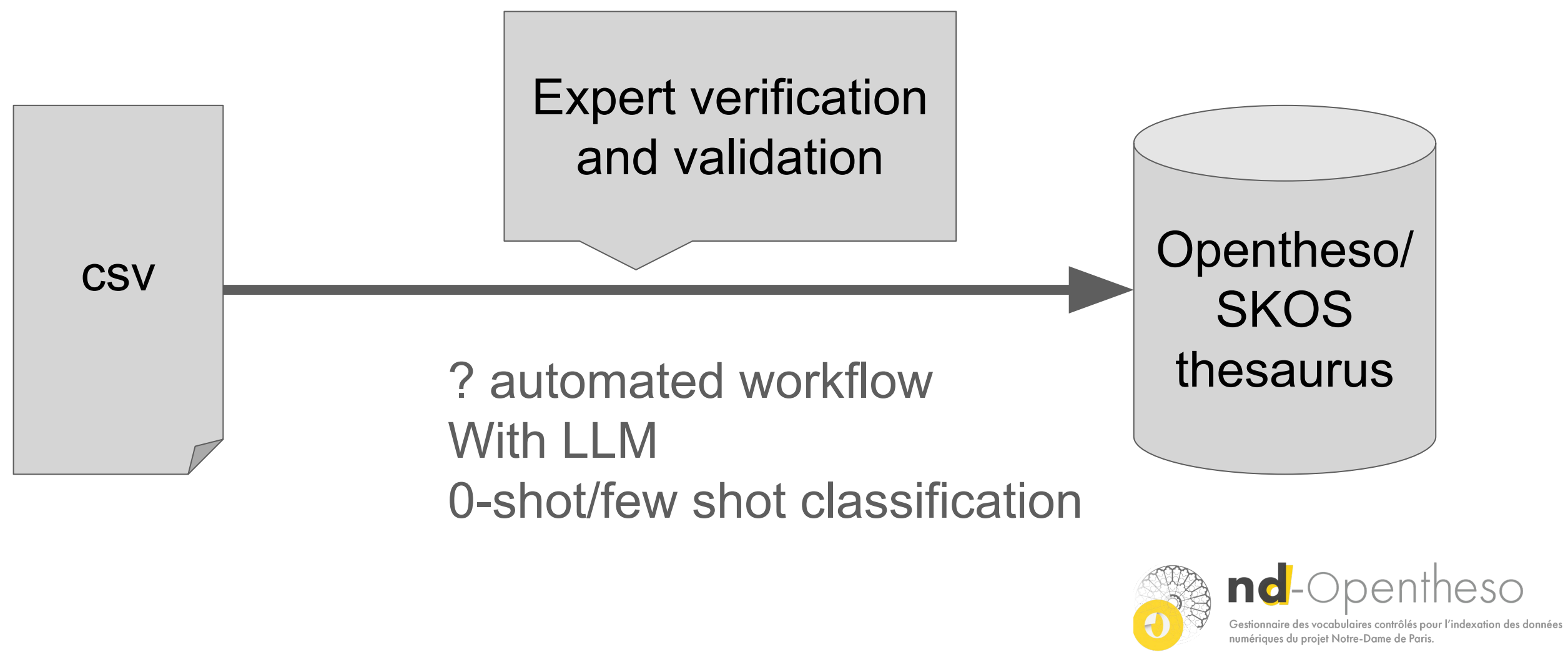
What if we could use a methodology with a LLM to help the concept curation?

Qui a déjà utilisé un LLM (ChatGPT)?

... 👍

Qui a déjà réussi à faire ce qu'il/elle voulait avec un LLM?

... 👎



Artificial Intelligence: AI waves 1, 2, 3

2 “tribes” / “religions” / “towers” in AI	
1st Wave:	2nd Wave
symbolic	subsymbolic, deep learning
reasoning	learning
logic	data
model-based	function-based
knowledge-driven	data-driven
AI system “based on manipulating symbols” (v)	AI systems “based on statistical patterns to be learned from large amount of data” (v)

The **3rd Wave** as *neuro-symbolic or hybrid systems*: “Neuro-symbolic systems are the offspring of two very different parents, roughly speaking the fields of ‘knowledge representation’ and ‘machine learning’, and each of these parents has its own strengths and weaknesses” (vi).

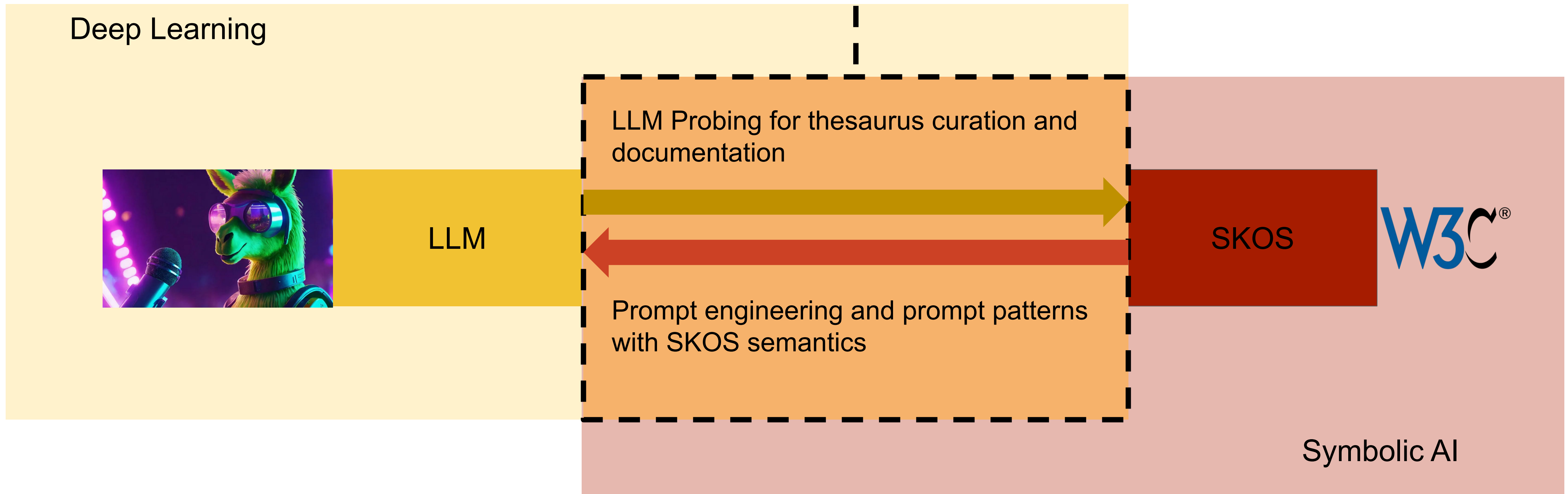
	LM-as-KB	Structured KB
Construction	Self/Unsupervised 🟢	Manual or semi-automatic 🟡
Schema	Open-ended 🟢	Typically fixed 🟡
Maintenance - adding facts - correcting/deleting	Difficult, unpredictable side effects 🟡 Difficult 🟡	Easy 🟢 Easy 🟢
Knows what it knows	No, assigns probability to everything 🟡	Yes, content enumerable 🟢
Entity disambiguation	No/limited 🟡	Common 🟢
Provenance	No 🟡	Common 🟢

Table 1
Differences of LMs-as-KBs and structured KBs

Hitzler P and Sarker MK (eds). Neuro-Symbolic Artificial Intelligence: The State of the Art, Vol. 342 of Frontiers of Artificial Intelligence and Applications. Amsterdam: IOS Press, 2022.

Razniewski, Simon, Andrew Yates, Nora Kassner, and Gerhard Weikum. "Language models as or for knowledge bases." arXiv preprint arXiv:2110.04888 (2021), p.2)

Neuro-symbolic methodology



How to use LLMs for building and curating a KB (in this case a thesaurus)?

How to benefit from the advantages of LLMs and KBs without the disadvantages of both?

Prompt example with prompt patterns

Results

A triple consists of three components: (subject, relationship, object). Triples need to be extracted from the given text. {input} indicates an element to be retrieved as input.

You are an expert in conservation and restoration in the field of cultural heritage architecture. The {subjects} are entities from the list of terms used to describe and document the field of conservation and restoration in heritage and historic monuments.

The relationships are SKOS relationships: skos:definition, skos:altLabel, skos:prefLabel, and skos:hiddenLabel.

If {input} is a concept of historical heritage, it is defined as [Mask_definition]@fr in French and [Mask_definition]@en in English, is another label of [Mask_altLabel]@fr in French and [Mask_altLabel]@en in English, and has a not frequently used label (or hidden label) [Mask_altHiddenLabel]@fr in French and [Mask_altHiddenLabel]@en in English.

Generate the following triples for each term:

('{input}', skos:definition, '[Mask_definition]@fr')

('{input}', skos:definition, '[Mask_definition]@en')

('{input}', skos:altLabel, '[Mask_altLabel]@fr')

('{input}', skos:prefLabel, '[Mask_altLabel]@en')

('{input}', skos:hiddenLabel, '[Mask_altHiddenLabel]@fr')

('{input}', skos:hiddenLabel, '[Mask_altHiddenLabel]@en')

Replace the masks [Mask_definition], [Mask_altLabel], and [Mask_altHiddenLabel] with appropriate information from the text for each term in the {input} list. This will allow you to extract triples for all concepts related to the conservation and restoration of cultural heritage architecture.

Here is an **expected example** from the {input} and the result as triples:

{input}:

édifice religieux

Église

Altération

#Knowledge Probing

Result:

('édifice religieux', skos:definition, 'Bâtiment consacré à un culte'@fr)

('édifice religieux', skos:definition, 'Building built or used for religious ceremonies or other functions having to do with a particular religion'@en)

('édifice religieux', skos:prefLabel, 'religious building'@en)

('édifice religieux', skos:altLabel, 'monument religieux'@fr)

('Église', skos:definition, 'Édifice consacré au culte de la religion chrétienne, surtout catholique'@fr)

('Église', skos:definition, 'Building for public Christian worship that are distinguished historically from chapels and oratories, which are buildings that are in some respect private, or not public in the widest sense'@en)

('Église', skos:altLabel, 'chapelle'@fr)

('Église', skos:altLabel, 'chapel'@en)

('Altération', skos:definition, 'Changement physique ou chimique d'un matériau'@fr)

('Altération', skos:definition, 'The process of changing something in some particular characteristic such as measure, dimension, course, arrangement, or inclination, without changing into something else'@en)

('Altération', skos:altLabel, 'dégradation'@fr)

('Altération', skos:altLabel, 'degradation'@en)

('Altération', skos:hiddenLabel, 'délabrement'@fr)

('Altération', skos:hiddenLabel, 'dilapidation'@en)

Generate the results only with triples for the following {input}:

#Few-shot learning

#Persona

#Meta-Language Creation

('peinture', skos:definition, 'Application de couleurs sur une surface à des fins esthétiques, expressives ou protectrices'@fr)

('peinture', skos:definition, 'Process of applying pigment to a surface such as paper, canvas, wood, or wall'@en)

('peinture', skos:altLabel, 'tableau'@fr)

('peinture', skos:prefLabel, 'painting'@en)

('peinture', skos:hiddenLabel, 'œuvre picturale'@fr)

('peinture', skos:hiddenLabel, 'pictorial work'@en)

('cathédrale', skos:definition, 'Édifice religieux chrétien principal d'un diocèse, siège de l'évêque'@fr)

('cathédrale', skos:definition, 'Principal church of a diocese, containing the bishop's throne'@en)

('cathédrale', skos:altLabel, 'église épiscopale'@fr)

('cathédrale', skos:prefLabel, 'cathedral'@en)

('cathédrale', skos:hiddenLabel, 'basilique'@fr)

('cathédrale', skos:hiddenLabel, 'basilica'@en)

('peinture murale', skos:definition, 'Peinture réalisée directement sur un mur ou un plafond'@fr)

('peinture murale', skos:definition, 'Mural painting executed directly onto a wall or ceiling'@en)

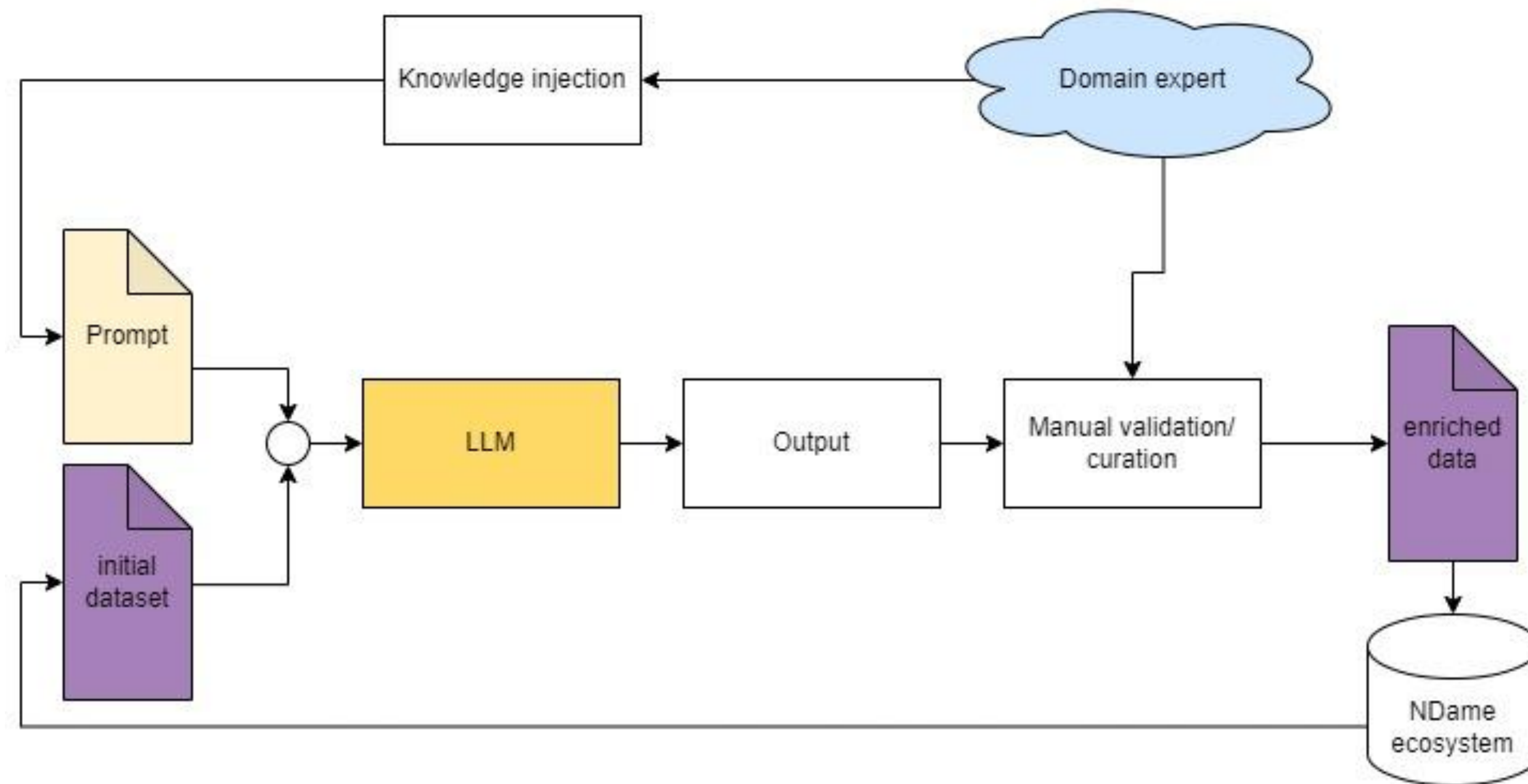
('peinture murale', skos:altLabel, 'fresque'@fr)

('peinture murale', skos:prefLabel, 'mural painting'@en)

('peinture murale', skos:hiddenLabel, 'art mural'@fr)

('peinture murale', skos:hiddenLabel, 'wall art'@en)

Results human-in-the-loop + LLM

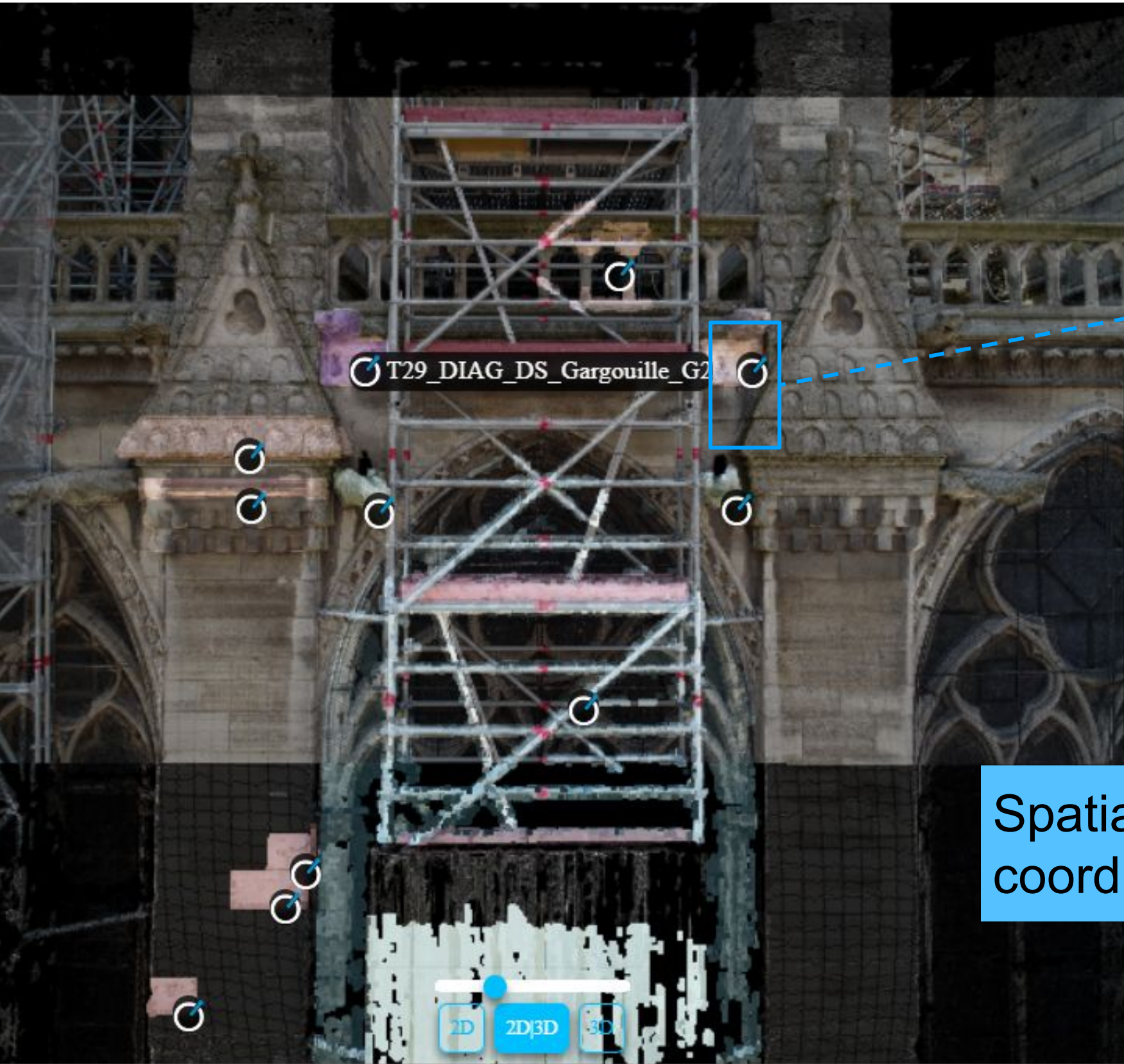


test sur 13000 concepts

- ++ vers un traitement + automatisé des vocabulaires contrôlés et thesauri
- étape de validation humaine est toujours nécessaire

Semantics of space

Article:
 Anaïs Guillem, Antoine Gros, Kévin Réby, Violette Abergel, Livio De Luca. RCC8 for CIDOC CRM: Semantic Modeling of Mereological and Topological Spatial Relations in Notre-Dame de Paris. SWODCH'23 : International Workshop on Semantic Web and Ontology Design for Cultural Heritage, Nov 2023, Athènes, Greece. (hal-04275714v2)

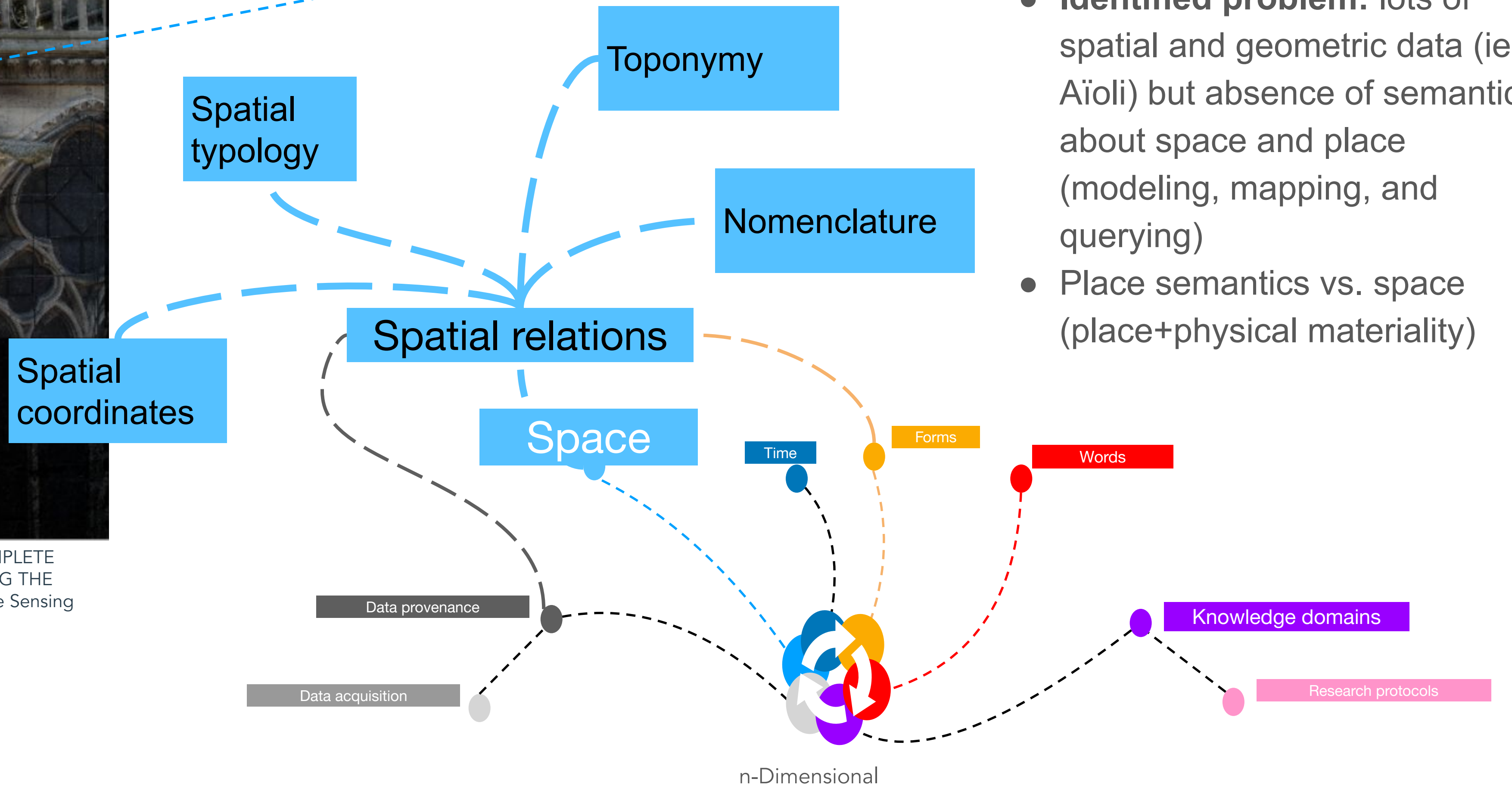


Data: Roussel, R., and L. De Luca. 2023. "AN APPROACH TO BUILD A COMPLETE DIGITAL REPORT OF THE NOTRE DAME CATHEDRAL AFTER THE FIRE, USING THE AIOLI PLATFORM." The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences XLVIII-M-2-2023 (June): 1359-65.

Annotation

T29_DIAG_DS_Gargouille_G1

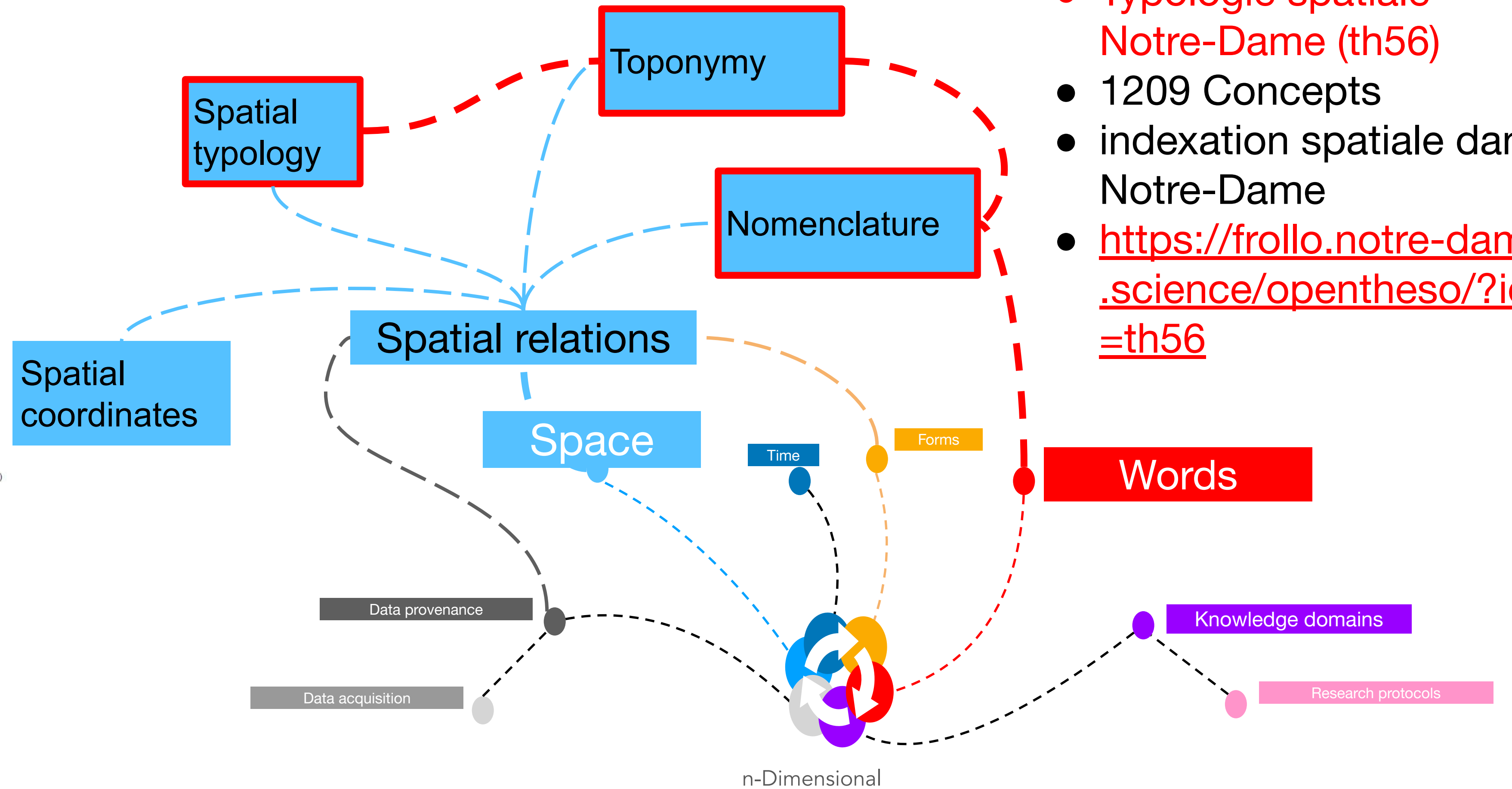
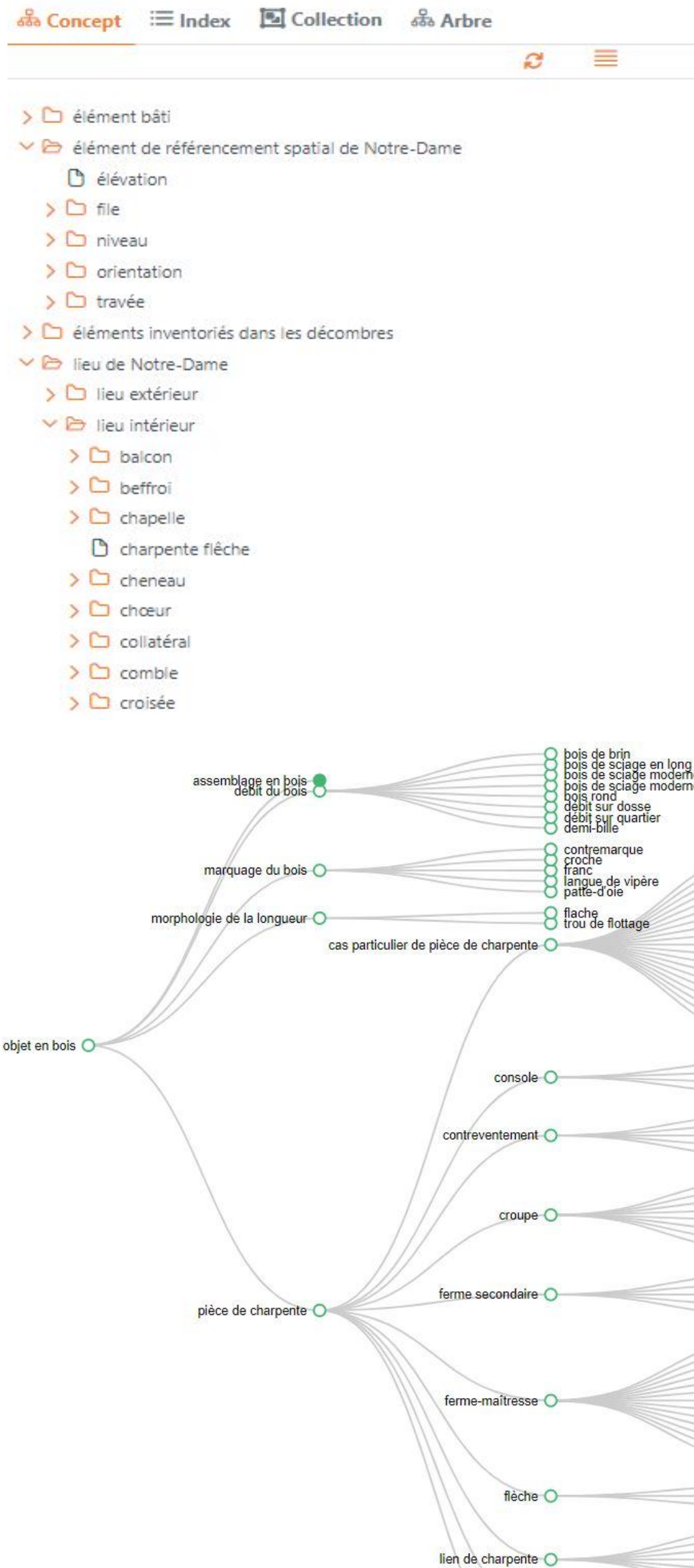
A nettoyer par micro-gommage.



- **Identified problem:** lots of spatial and geometric data (ie. Aioli) but absence of semantics about space and place (modeling, mapping, and querying)
- Place semantics vs. space (place+physical materiality)

Semantics of space

Article:
 Anaïs Guillem, Antoine Gros, Kévin Réby, Violette Abergel, Livio De Luca. RCC8 for CIDOC CRM: Semantic Modeling of Mereological and Topological Spatial Relations in Notre-Dame de Paris. SWODCH'23 : International Workshop on Semantic Web and Ontology Design for Cultural Heritage, Nov 2023, Athènes, Greece. (hal-04275714v2)



Création d'un thésaurus partagé:

- **Typologie spatiale Notre-Dame (th56)**
- 1209 Concepts
- indexation spatiale dans Notre-Dame
- <https://frollo.notre-dame.science/opentheso/?idt=th56>

Words

Knowledge domains

Research protocols

n-Dimensional

Data provenance

Data acquisition

Semantics of Complex Spatial Data

Nomenclature: structure hiérarchique des espaces

> Collatéral

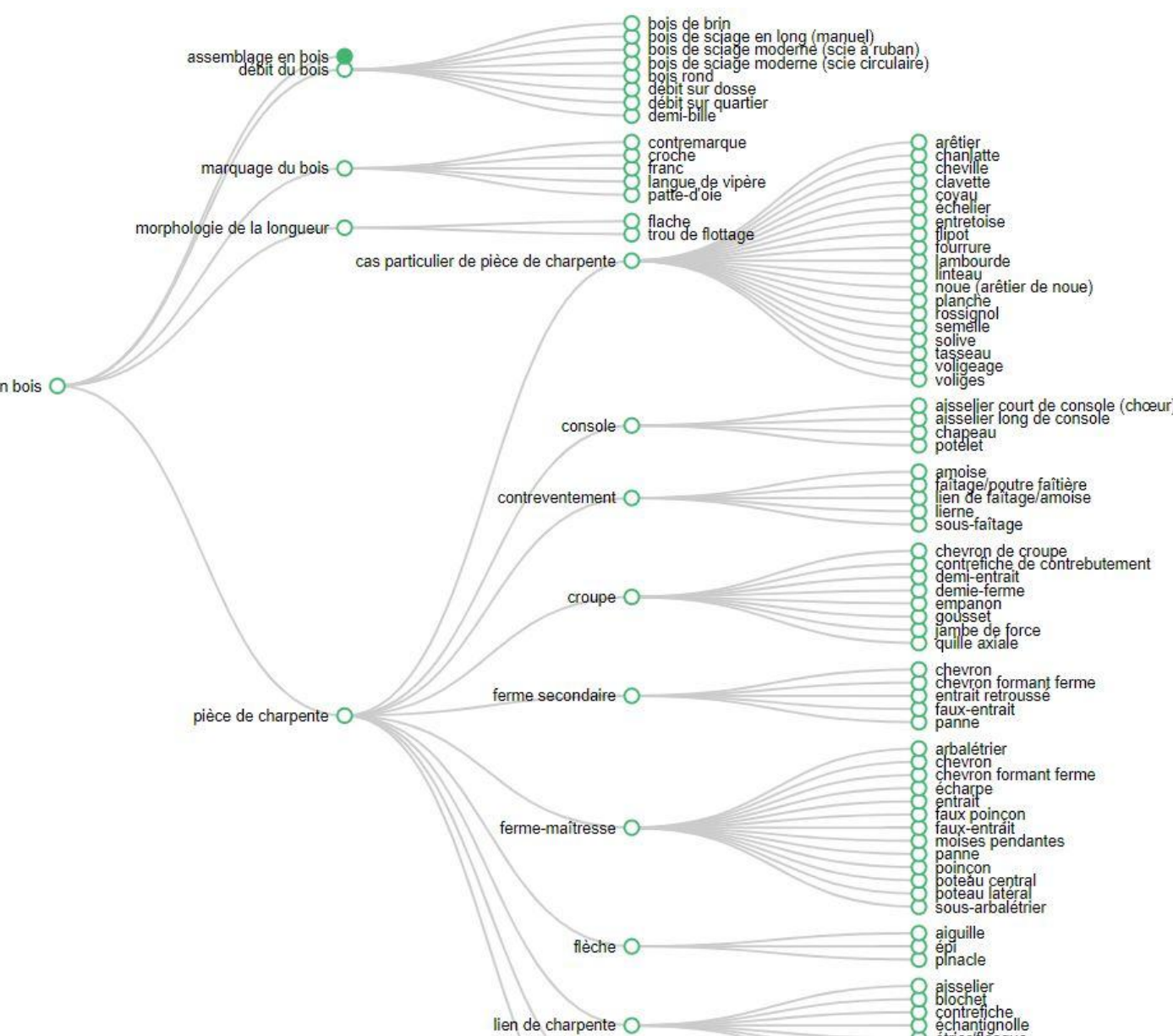
> collatéral intérieur

> collatéral intérieur sud

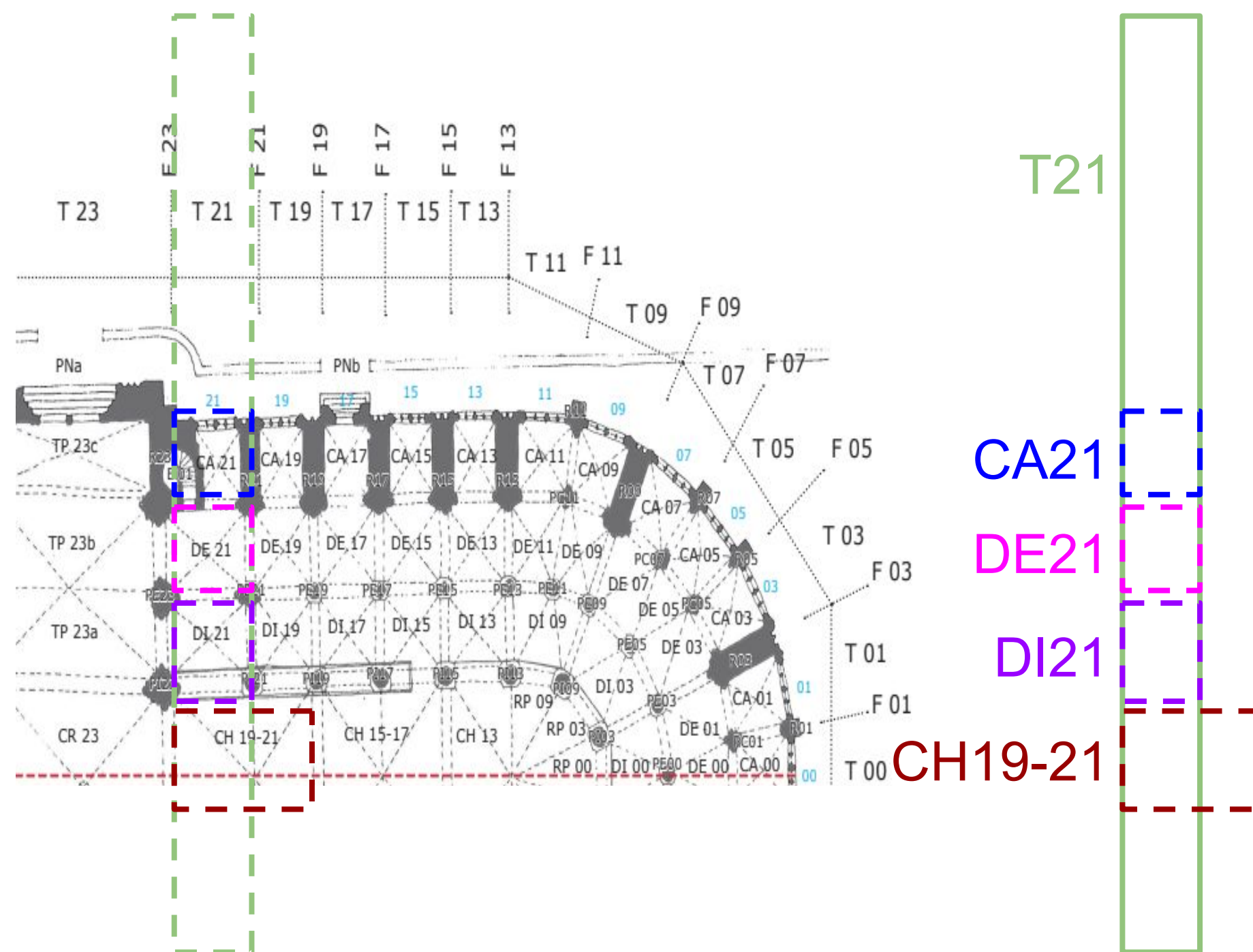
> CI28

Thésaurus partagé (th56)

Typologie spatiale Notre-Dame



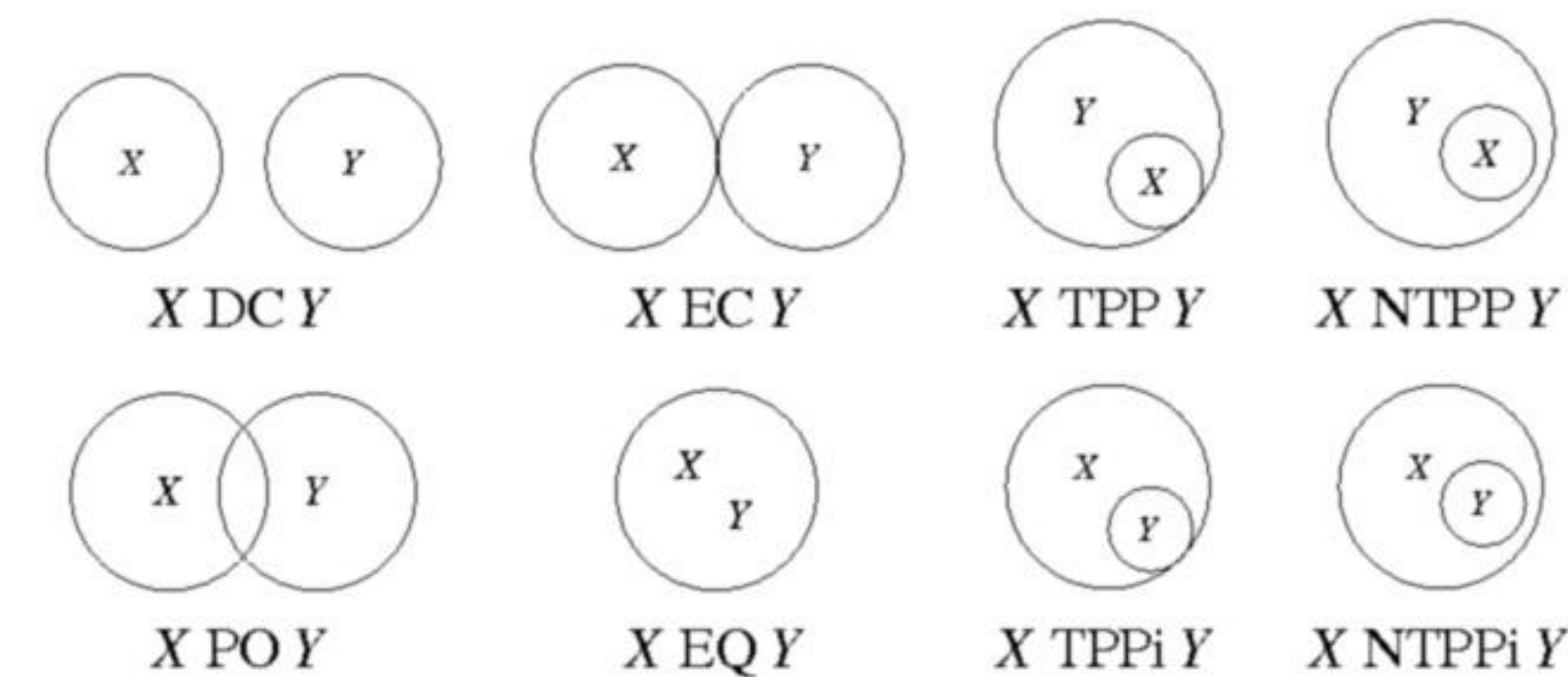
Exemple de relations spatiales topologiques non représentées dans la hiérarchie du thésaurus :



Article:

Anaïs Guillem, Antoine Gros, Kévin Réby, Violette Abergel, Livio De Luca. RCC8 for CIDOC CRM: Semantic Modeling of Mereological and Topological Spatial Relations in Notre-Dame de Paris. SWODCH'23 : International Workshop on Semantic Web and Ontology Design for Cultural Heritage, Nov 2023, Athènes, Greece. (hal-04275714v2)

RCC8: topological model

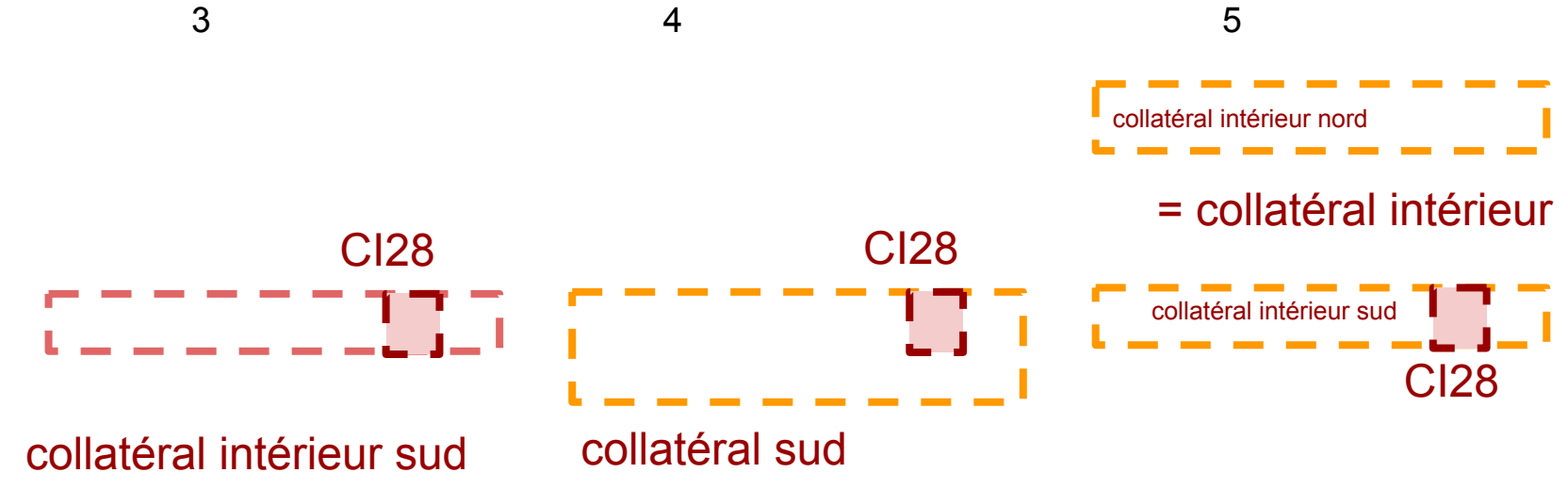
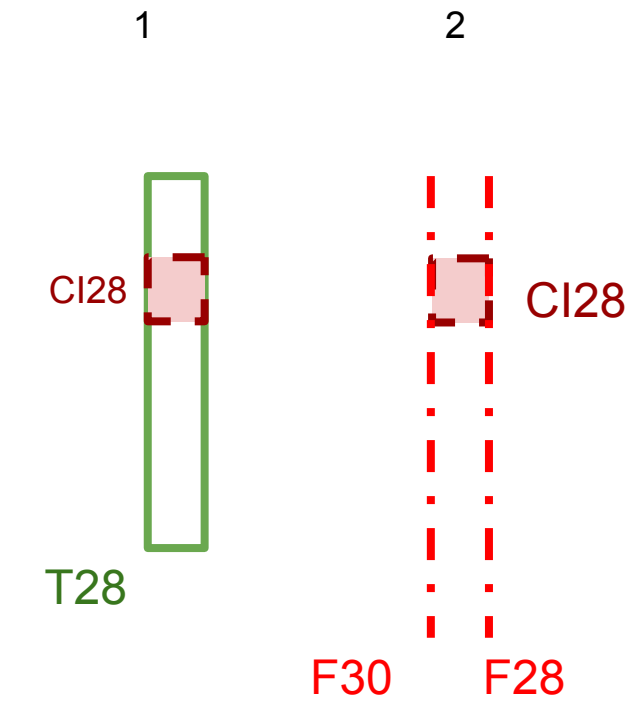
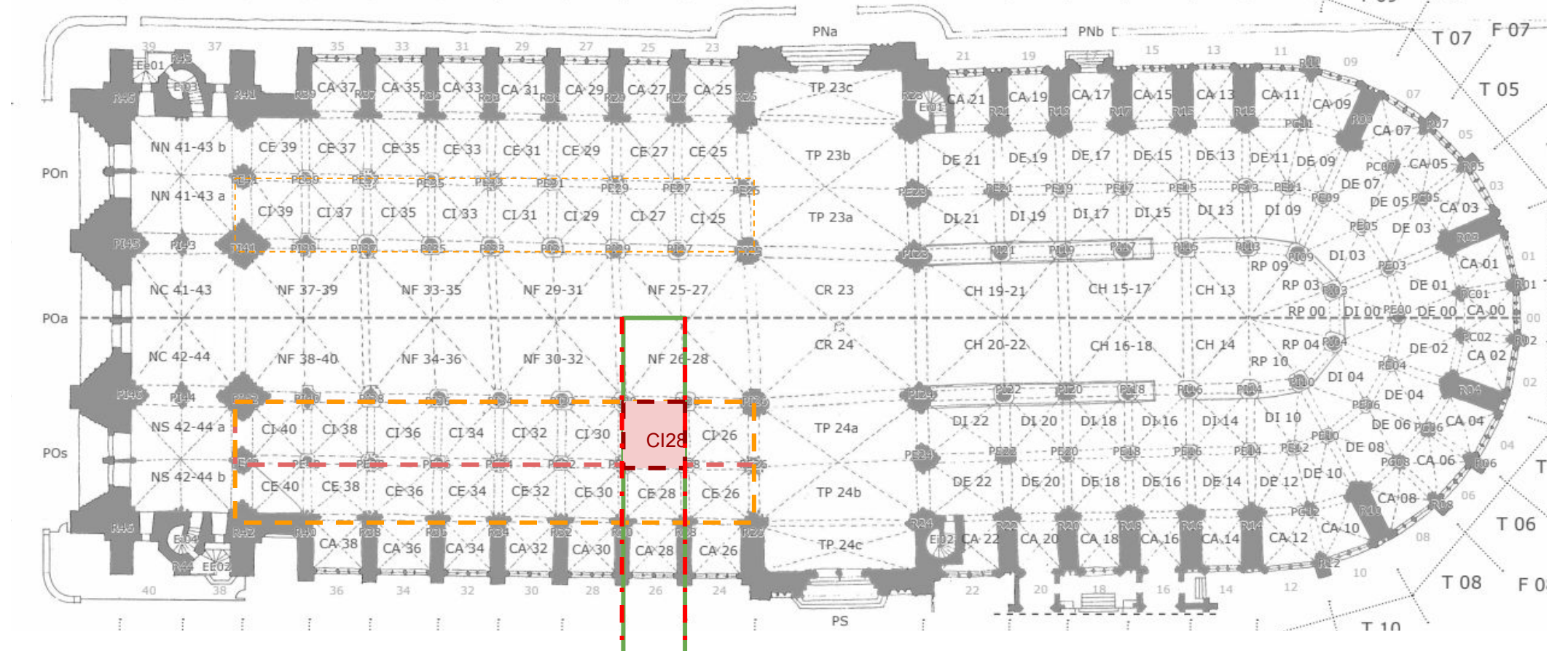
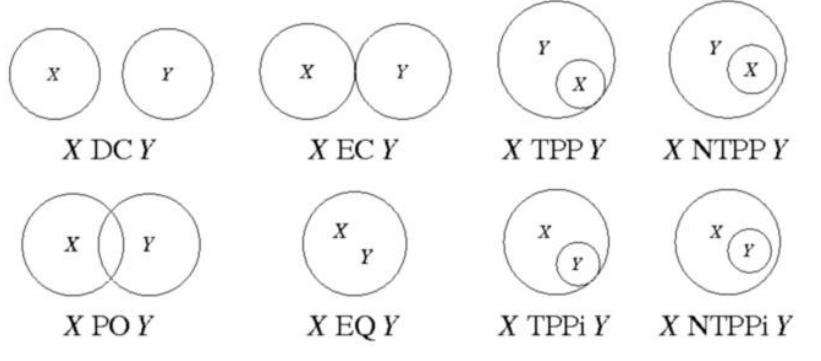


Symbol	Name	Note
DC	Disconnected	The two regions are completely disconnected (there are no common pieces)
EC	Externally Connected	The boundaries of the regions touch, but their interiors are disjoint
PO	Partially Overlapping	The two regions partially overlap (there are disjoint sub parts, and some part of one is included in some part of the other)
EQ	Equal	Two regions have the same spatial extent
TPP	Tangential Proper Part	The first region is entirely inside the second region and their boundaries touch each other from the inside
TPPi	Tangential Proper Part Inverse	The first region contains the second region and their boundaries touch each other from the inside
NTPP	Non-Tangential Proper Part	The first region is entirely inside the second region and their boundaries do not touch
NTPPi	Non-Tangential Proper Part Inverse	The first region contains the second region and their boundaries do not touch

Knaufl, M., Rauh, R. and Renz, J. (1997) A Cognitive Assessment of Topological Spatial Relations: Results from an Empirical Investigation. Proceedings of the International Conference on Spatial Information Theory: A Theoretical Basis for GIS, p. 206. Available at: https://doi.org/10.1007/3-540-63623-4_51.

Semantics of Complex Spatial Data

Article:
 Anaïs Guillem, Antoine Gros, Kévin Réby, Violette Abergel, Livio De Luca. RCC8 for CIDOC CRM: Semantic Modeling of Mereological and Topological Spatial Relations in Notre-Dame de Paris. SWODCH'23 : International Workshop on Semantic Web and Ontology Design for Cultural Heritage, Nov 2023, Athènes, Greece. (hal-04275714v2)



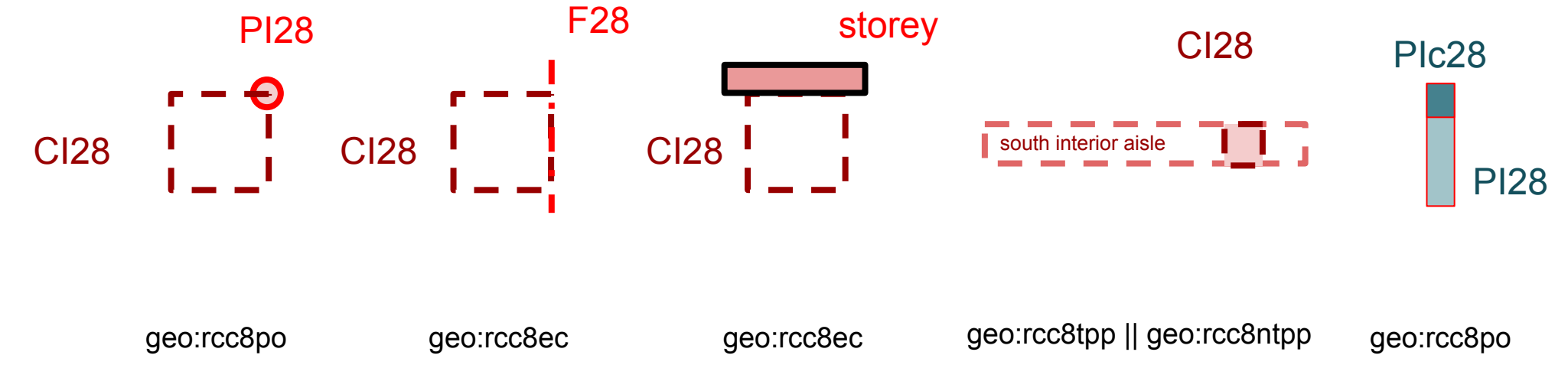
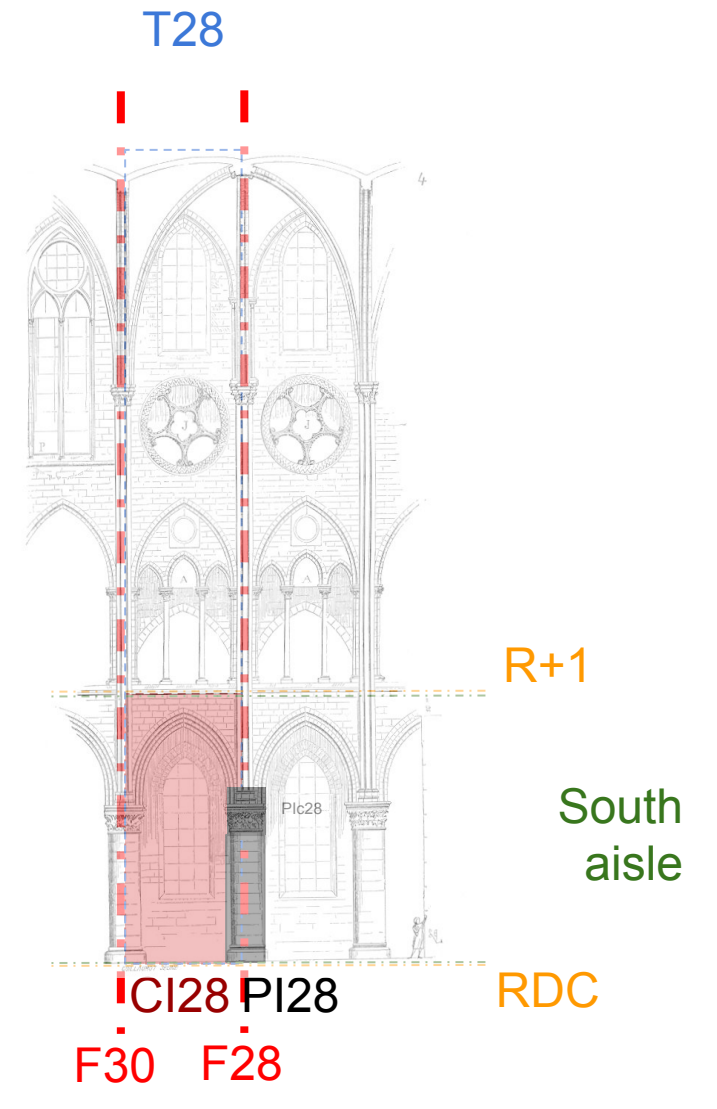
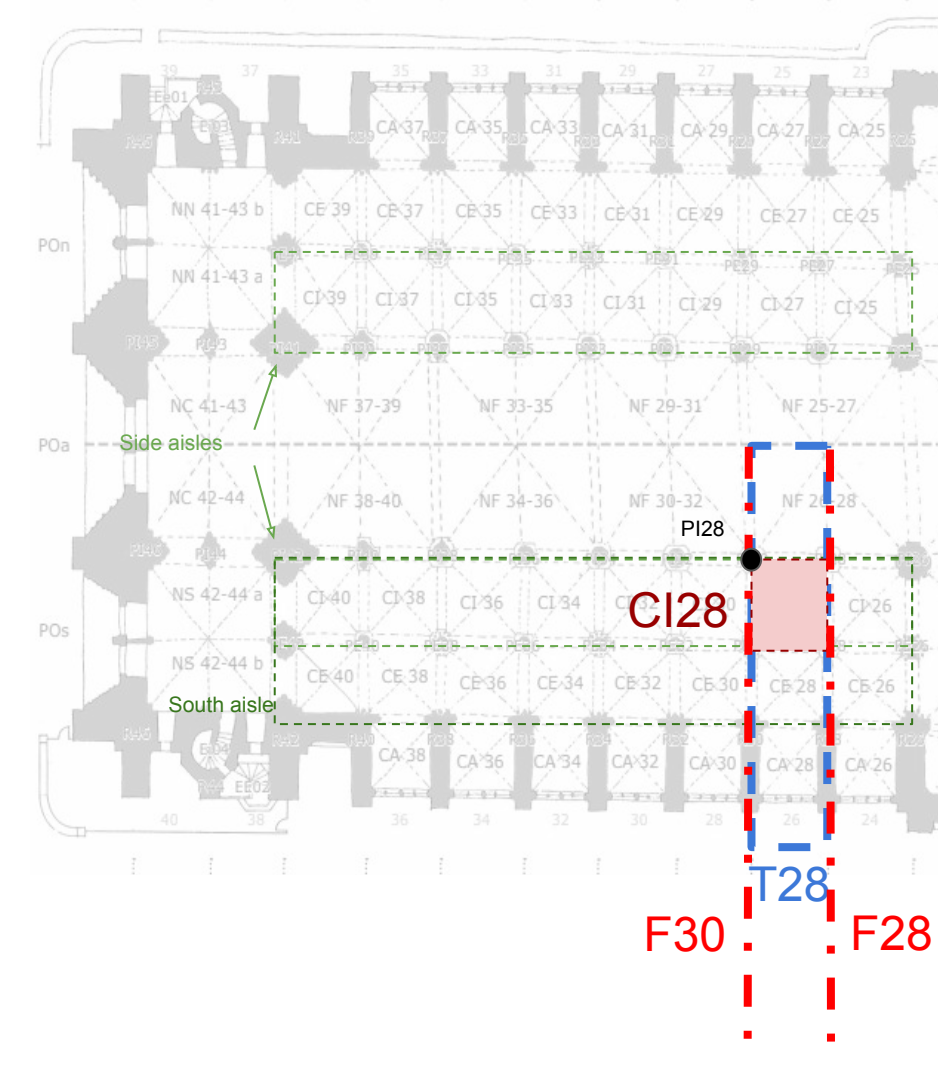
1:
 CI28 <geo:rcc8-nttp> T28
 2:
 CI28 <geo:rcc8-po> F28
 CI28 <geo:rcc8-po> F30

Topological Relation:
 Place - Spatial
 Primitive

Mereological Relation:
 Place - Place

3:
 CI28 <geo:rcc8-nttp> collatéral intérieur sud
 4:
 CI28 <geo:rcc8-nttp> collatéral sud
 5:
 CI28 <geo:rcc8-nttp> collatéral intérieur

 CI28 <geo:rcc8-nttp> Niveau rdc
 CI28 <geo:rcc8-ec> Niveau tribune

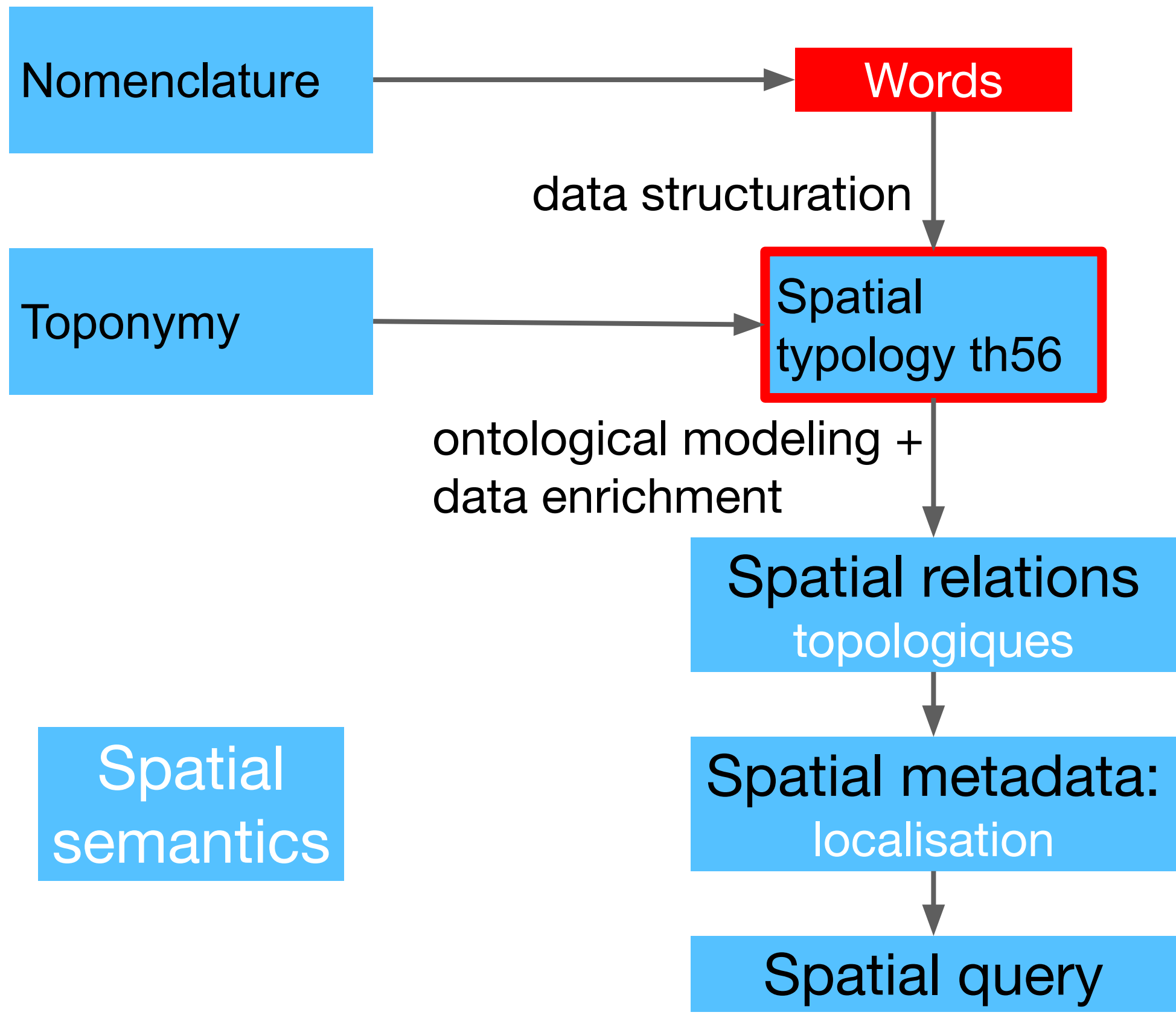


Topological Relation:
 Place - Object/Spatial
 Primitive

Results: Matrix of Topological Relations, test dataset

Article:
 Anaïs Guillem, Antoine Gros, Kévin Réby, Violette Abergel, Livio De Luca. RCC8 for CIDOC CRM: Semantic Modeling of Mereological and Topological Spatial Relations in Notre-Dame de Paris. SWODCH'23 : International Workshop on Semantic Web and Ontology Design for Cultural Heritage, Nov 2023, Athènes, Greece. (hal-04275714v2)

	entity_notation	Spatial indexing element								Space								Building element											
		R1	RDC	F27	F28	F29	F30	T27	T28	CA27	CA28	CE27	CE28	CI27	CI28	NF25	NF27	NF26	NF28	PE27	PE28	PE29	PE30	PI27	PI28	PI29	PI30	R27	R28
Spatial indexing element	R1	EQ																											
Spatial indexing element	RDC	EC	EQ																										
Spatial indexing element	F27	PO	PO	EQ																									
Spatial indexing element	F28	PO	PO	DC	EQ																								
Spatial indexing element	F29	PO	PO	EC	DC	EQ																							
Spatial indexing element	F30	PO	PO	DC	EC	EC	EQ																						
Spatial indexing element	T27	PO	PO	PO	DC	PO	DC	EQ																					
Spatial indexing element	T28	PO	PO	DC	PO	DC	PO	EC	EQ																				
Space	CA27	EC	nTPPi	PO	DC	PO	DC	nTPPi	DC	EQ																			
Space	CA28	EC	nTPPi	DC	PO	DC	PO	DC	nTPPi	DC	EQ																		
Space	CE27	EC	nTPPi	PO	DC	PO	DC	nTPPi	DC	EC	DC	EQ																	
Space	CE28	EC	nTPPi	DC	PO	DC	PO	DC	nTPPi	DC	EC	DC	EQ																
Space	CI27	EC	nTPPi	PO	DC	PO	DC	nTPPi	DC	DC	DC	EC	DC	EQ															
Space	CI28	EC	nTPPi	DC	PO	DC	PO	DC	nTPPi	DC	DC	DC	EC	DC	EQ														
Space	NF25	PO	PO	PO	EC	DC	DC	EC	EC	DC	DC	DC	DC	EC	DC	EQ													
Space	NF27	PO	PO	PO	EC	PO	EC	nTPPi	EC	DC	DC	DC	DC	EC	DC	EC	EQ												
Space	NF26	PO	PO	EC	PO	DC	DC	EC	EC	DC	DC	DC	DC	DC	EC	EC	EC	EQ											
Space	NF28	PO	PO	EC	PO	DC	PO	EC	nTPPi	DC	DC	DC	DC	DC	EC	EC	EC	EQ											
Building element	PE27	nTPPi	EC	PO	DC	DC	DC	PO	DC	DC	DC	PO	DC	DC	DC	DC	DC	DC	EQ										
Building element	PE28	nTPPi	EC	DC	PO	DC	DC	PO	DC	DC	DC	PO	DC	PO	DC	DC	DC	DC	DC	EQ									
Building element	PE29	nTPPi	EC	DC	DC	DC	DC	DC	DC	DC	DC	PO	DC	PO	DC	DC	DC	DC	DC	EQ									
Building element	PE30	nTPPi	EC	DC	DC	DC	DC	DC	DC	DC	DC	PO	DC	PO	DC	DC	DC	DC	DC	EQ									
Building element	PI27	DC	nTPPi	PO	DC	DC	DC	PO	DC	DC	DC	DC	PO	DC	PO	DC	DC	DC	DC	EQ									
Building element	PI28	DC	nTPPi	DC	PO	DC	DC	PO	DC	DC	DC	DC	PO	DC	DC	PO	DC	DC	DC	EQ									
Building element	PI29	DC	nTPPi	DC	DC	DC	DC	DC	DC	DC	DC	DC	PO	DC	DC	DC	DC	DC	DC	EQ									
Building element	PI30	DC	nTPPi	DC	DC	DC	DC	DC	DC	DC	DC	DC	PO	DC	DC	DC	DC	DC	DC	EQ									
Building element	R27	PO	PO	PO	DC	DC	DC	PO	DC	PO	DC	PO	DC	DC	DC	DC	DC	DC	DC	EQ									
Building element	R28	PO	PO	DC	PO	DC	DC	PO	DC	PO	DC	PO	DC	DC	DC	DC	DC	DC	DC	EQ									
Building element	R29	PO	PO	DC	DC	DC	DC	DC	DC	PO	DC	PO	DC	DC	DC	DC	DC	DC	DC	EQ									
Building element	R30	PO	PO	DC	DC	DC	DC	DC	DC	PO	DC	PO	DC	DC	DC	DC	DC	DC	DC	EQ									



exemple de requete spatiale complexe:
 afficher tous les documents de l'écosystème ayant pour sujet/localisation la nef en excluant les chapelles

Case study: transverse arch F29-30 Reconstruction

Elise Baillieul, Yves Gallet, Antoine Gros, Anaïs Guillem, Andreas Hartmann-Virnich, et al.. La mise en œuvre des élévations et des voûtes de Notre-Dame de Paris : bilan des recherches et des protocoles en cours. Pierre à pierre III. Économie de la pierre aux périodes historiques entre Loire et Rhin, 1er s. av. J.-C. – XVIIe s., Nov 2021, Charleville-Mézières, Sedan, France. <hal-04479729>

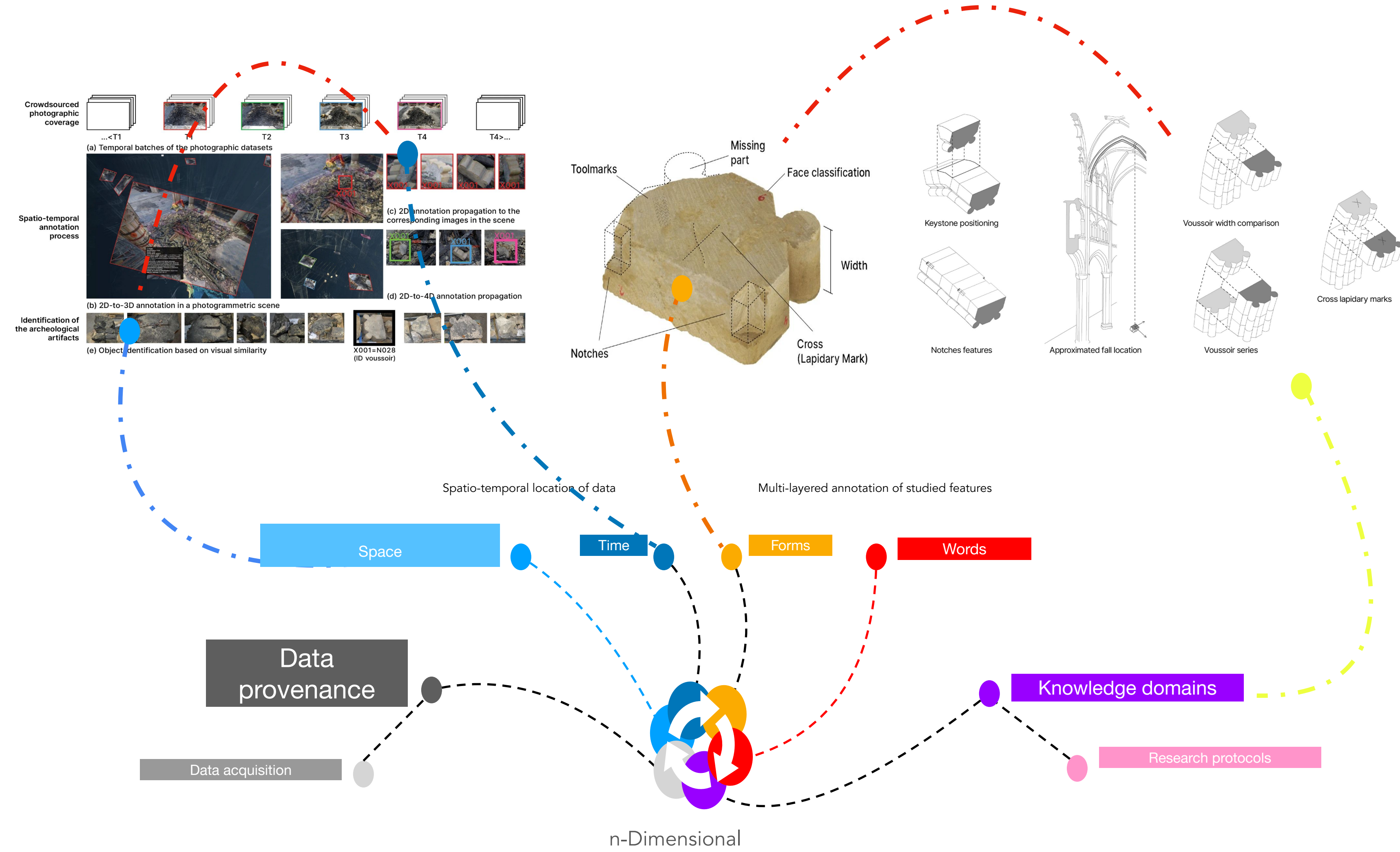
Antoine Gros, Anaïs Guillem, Livio De Luca, Élise Baillieul, Benoit Duvocelle, et al.. Faceting the post-disaster built heritage reconstruction process within the digital twin framework for Notre-Dame de Paris. Scientific Reports, 2023, 13 (1), pp.5981. <10.1038/s41598-023-32504-9>. <hal-04094074>

Anaïs Guillem, Antoine Gros, Livio De Luca. Faire parler les claveaux effondrés de la cathédrale Notre-Dame de Paris : Un récit fondé sur le web sémantique et les Linked Open Data. Humanistica 2023, Association francophone des humanités numériques, Jun 2023, Genève, Suisse. <hal-04106101>

Anaïs Guillem, Antoine Gros, Violette Abergel, Livio De Luca. Reconstruction beyond Representation in Notre-Dame de Paris. 2023 IMEKO TC-4 International Conference on Metrology for Archaeology and Cultural Heritage, International Measurement Confederation (IMEKO), Oct 2023, Rome, Italy. <hal-04275571v2>

Elise Baillieul, Anaïs Guillem, Antoine Gros. Du claveau physique aux données numériques : démêler les hypothèses de restitution de l'arc doubleau de la nef de Notre-Dame. Les voûtes de Notre-Dame de Paris, recherches récentes (2019-2023), Élise Baillieul (IRHiS-ULille); Yves Gallet (Ansonius, UBordeaux-Montaigne), Nov 2023, Villeneuve d'Ascq, France. <hal-04472657>

A. Guillem, J. Samuel, G. Gesquière, L. De Luca, V. Abergel, Let the fallen Voussoirs of Notre-Dame de Paris Speak: Scientific Narration and 3D Visualization of Virtual Reconstruction Hypotheses and Reasoning, SEMMES'24, Semantic Methods for Events and Stories, 20th Extended Semantic Web Conference (ESWC2024), 2024.



Restitution en 3D avec le relevé avant incendie

Elise Baillieul, Yves Gallet, Antoine Gros, Anaïs Guillem, Andreas Hartmann-Virnich, et al.. La mise en œuvre des élévations et des voûtes de Notre-Dame de Paris : bilan des recherches et des protocoles en cours. Pierre à pierre III. Économie de la pierre aux périodes historiques entre Loire et Rhin, 1er s. av. J.-C. – XVIIe s., Nov 2021, Charleville-Mézières, Sedan, France. (hal-04479729)

Current reconstruction hypothesis in the nDame_viewer:

<https://public.aioli.map.cnrs.fr/reperage/index.html?projectId=645389afd3da2>



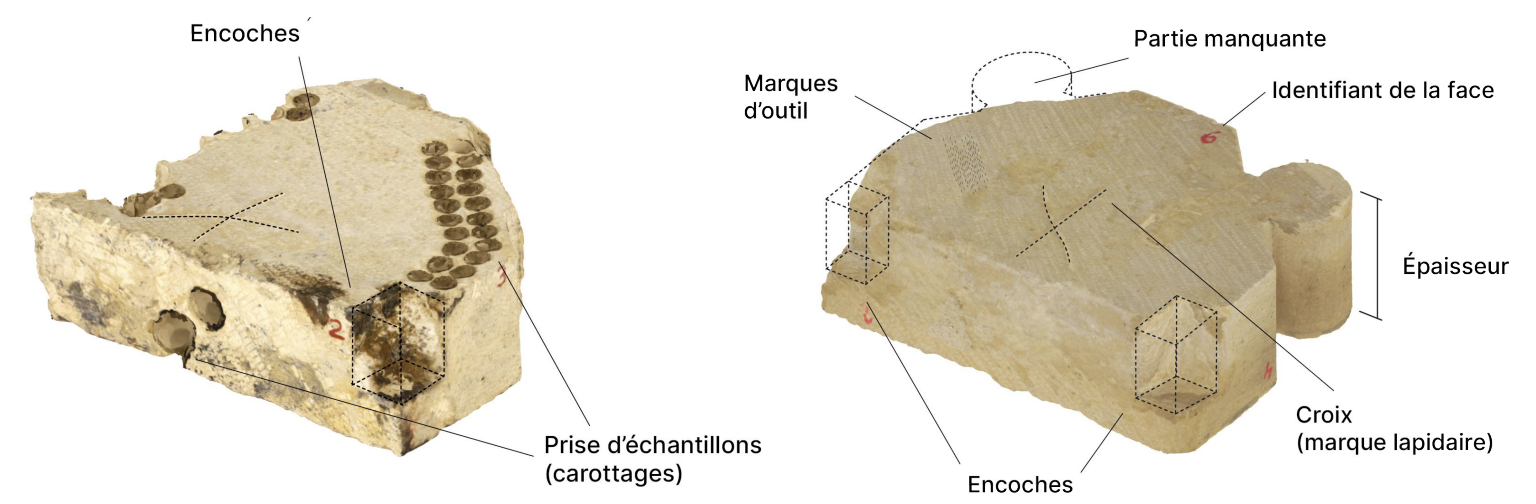
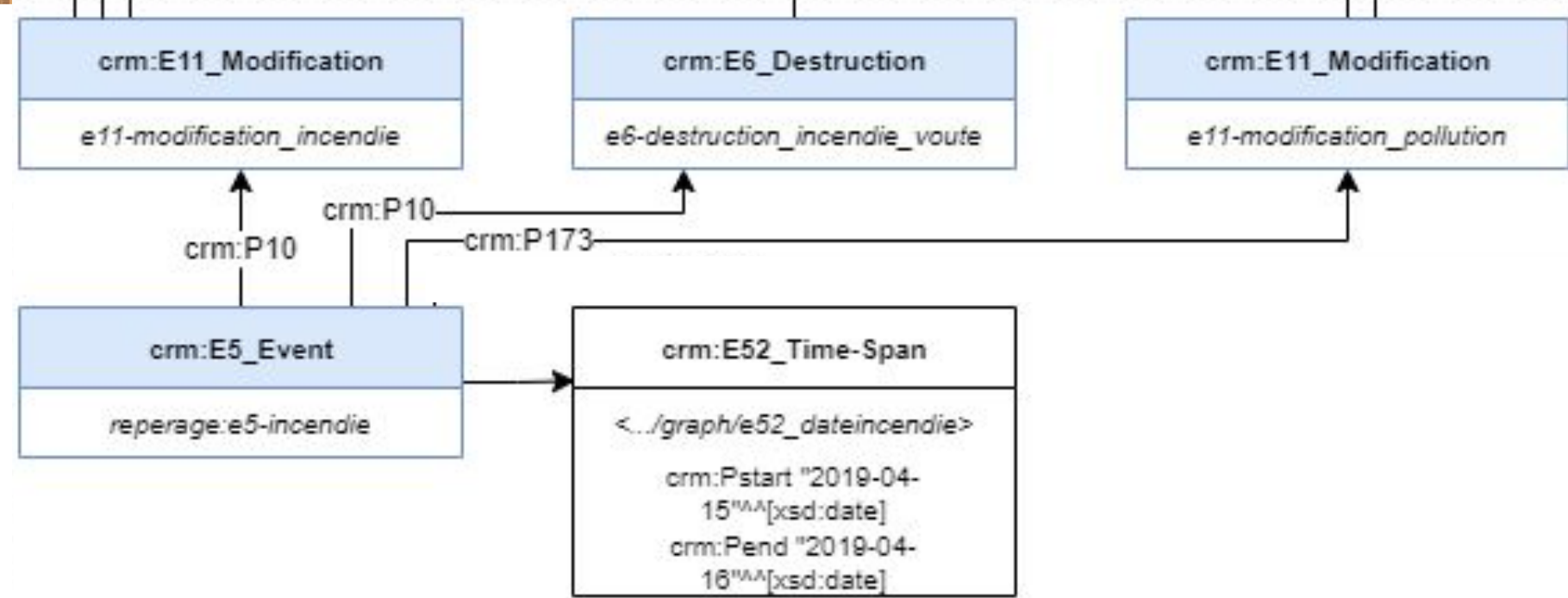
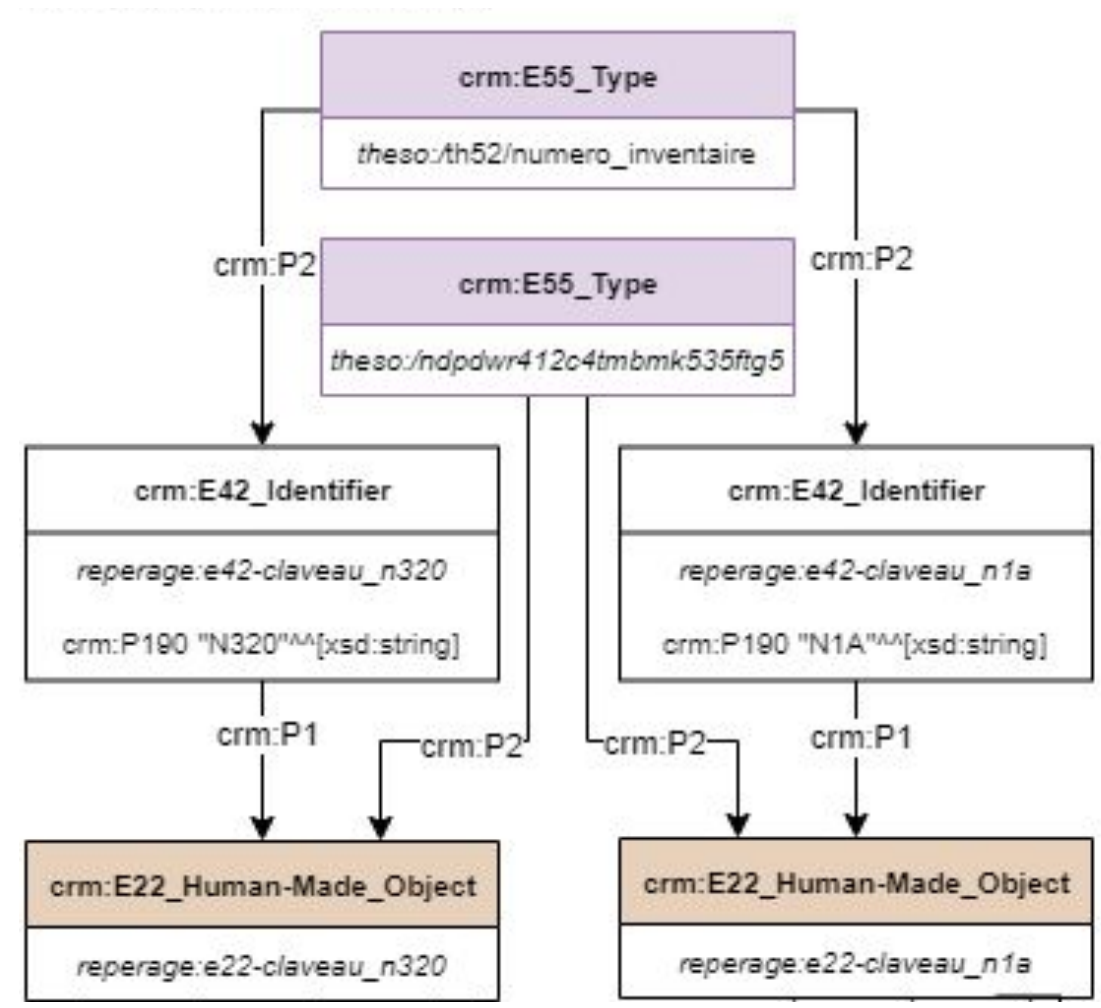
Hypothèse hybride de restitution dans le viewer 3D (V. Abergel, 2022) (Gros et al., 2023)

Mapping with CIDOC CRM: event-centered ontology (voussoirs)

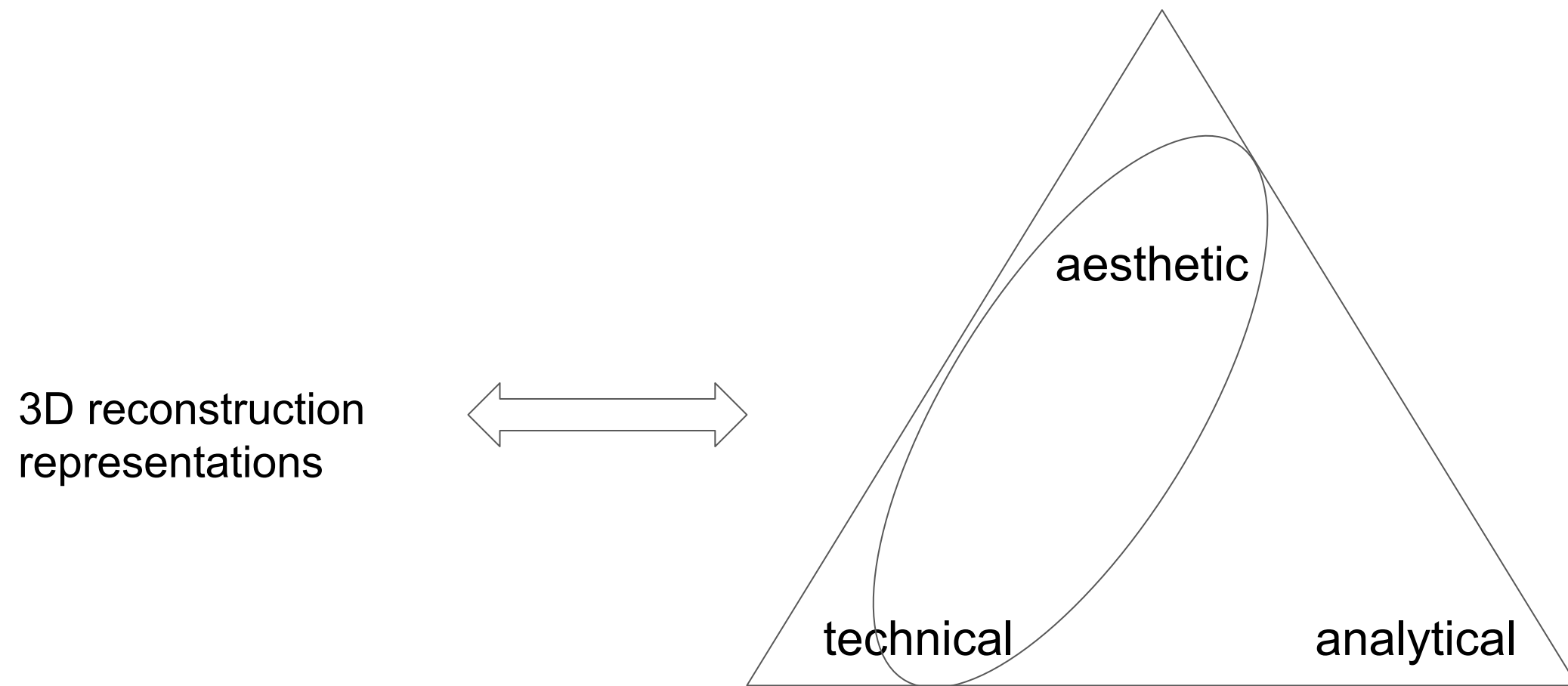


Tzitzikas, Yannis;
Marketakis, Yannis,
Cinderella's Stick - A Fairy
Tale for Digital Preservation,
2018.

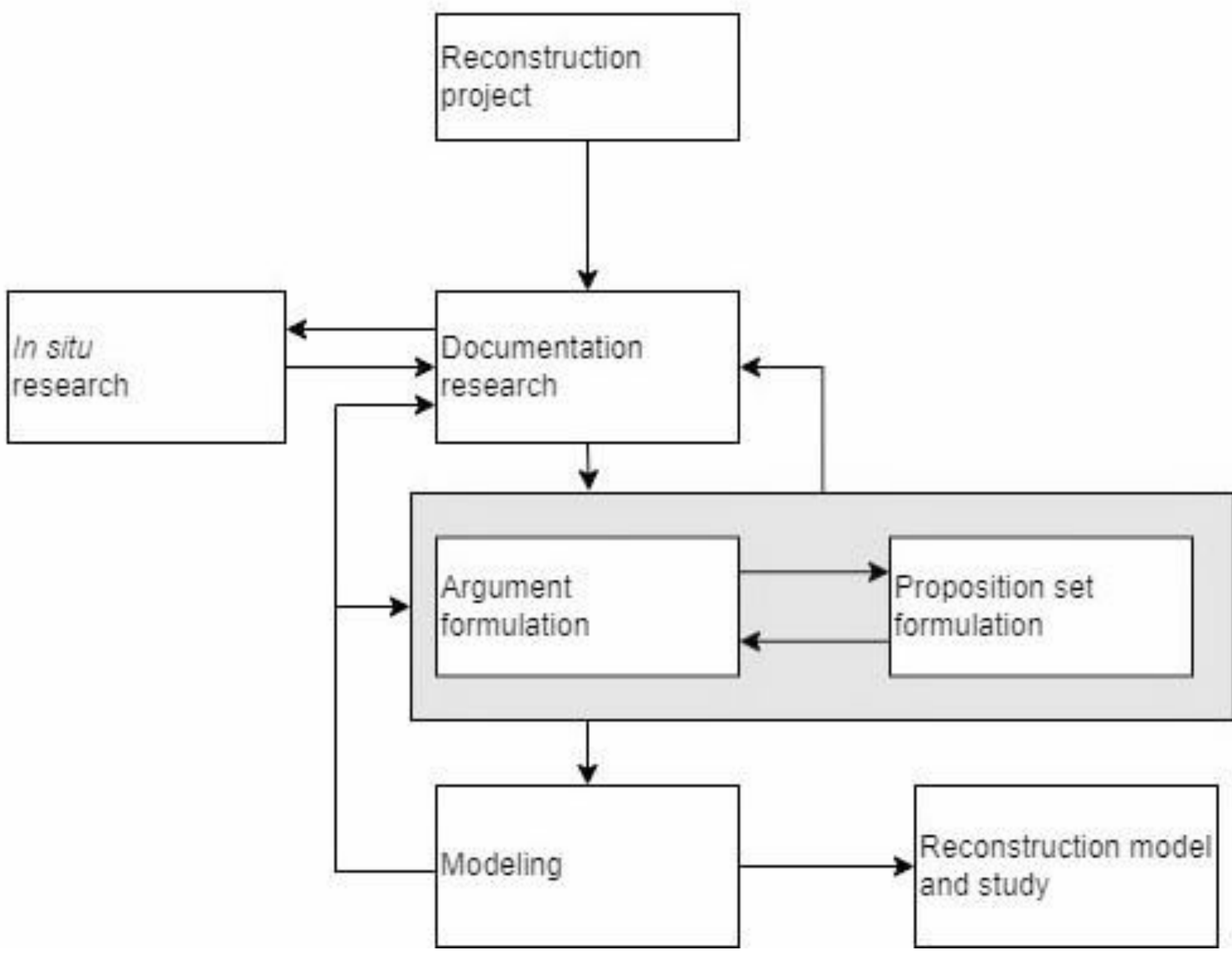
Anaïs Guillem, Antoine Gros, Livio De Luca. Faire parler les
claveaux effondrés de la cathédrale Notre-Dame de Paris : Un
récit fondé sur le web sémantique et les Linked Open Data.
Humanistica 2023, Association francophone des humanités
numériques, Jun 2023, Genève, Suisse. {hal-04106101}



The central need for documenting argumentation and scientific reasoning in reconstructions

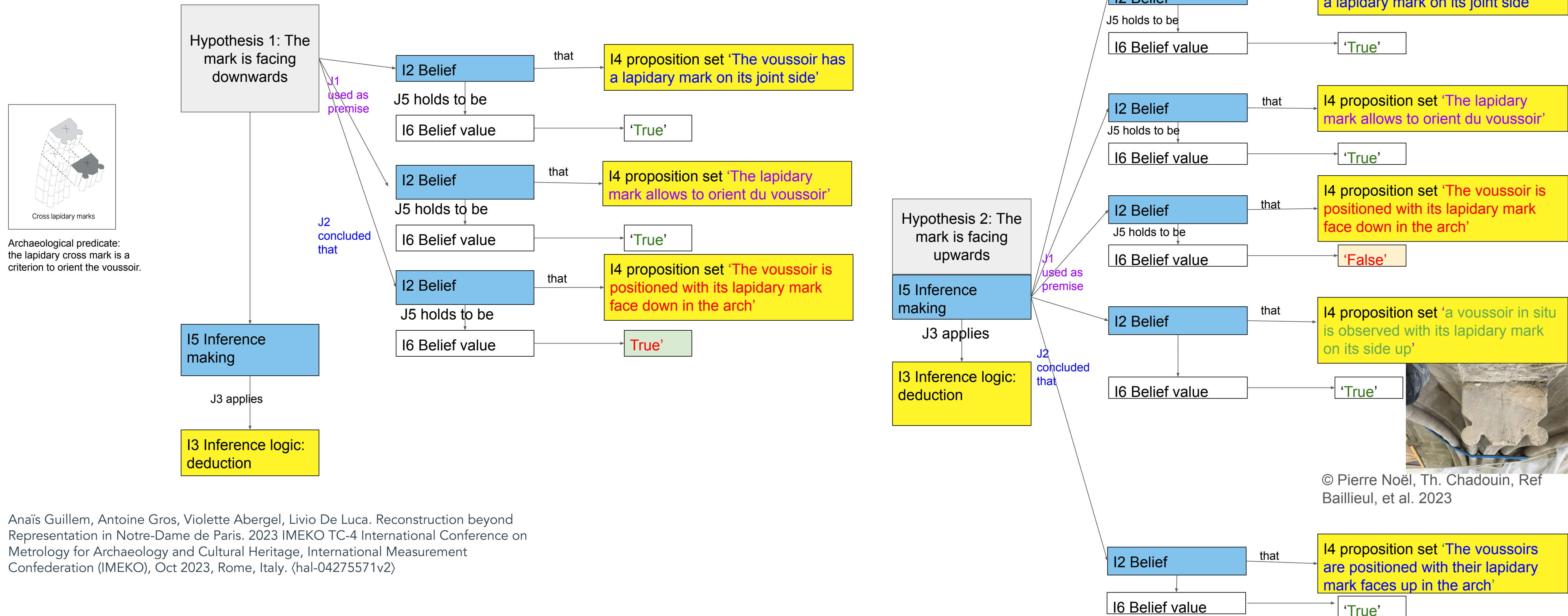


Anaïs Guillem, Antoine Gros, Violette Abergel, Livio De Luca. Reconstruction beyond Representation in Notre-Dame de Paris. 2023 IMEKO TC-4 International Conference on Metrology for Archaeology and Cultural Heritage, International Measurement Confederation (IMEKO), Oct 2023, Rome, Italy. (hal-04275571v2)



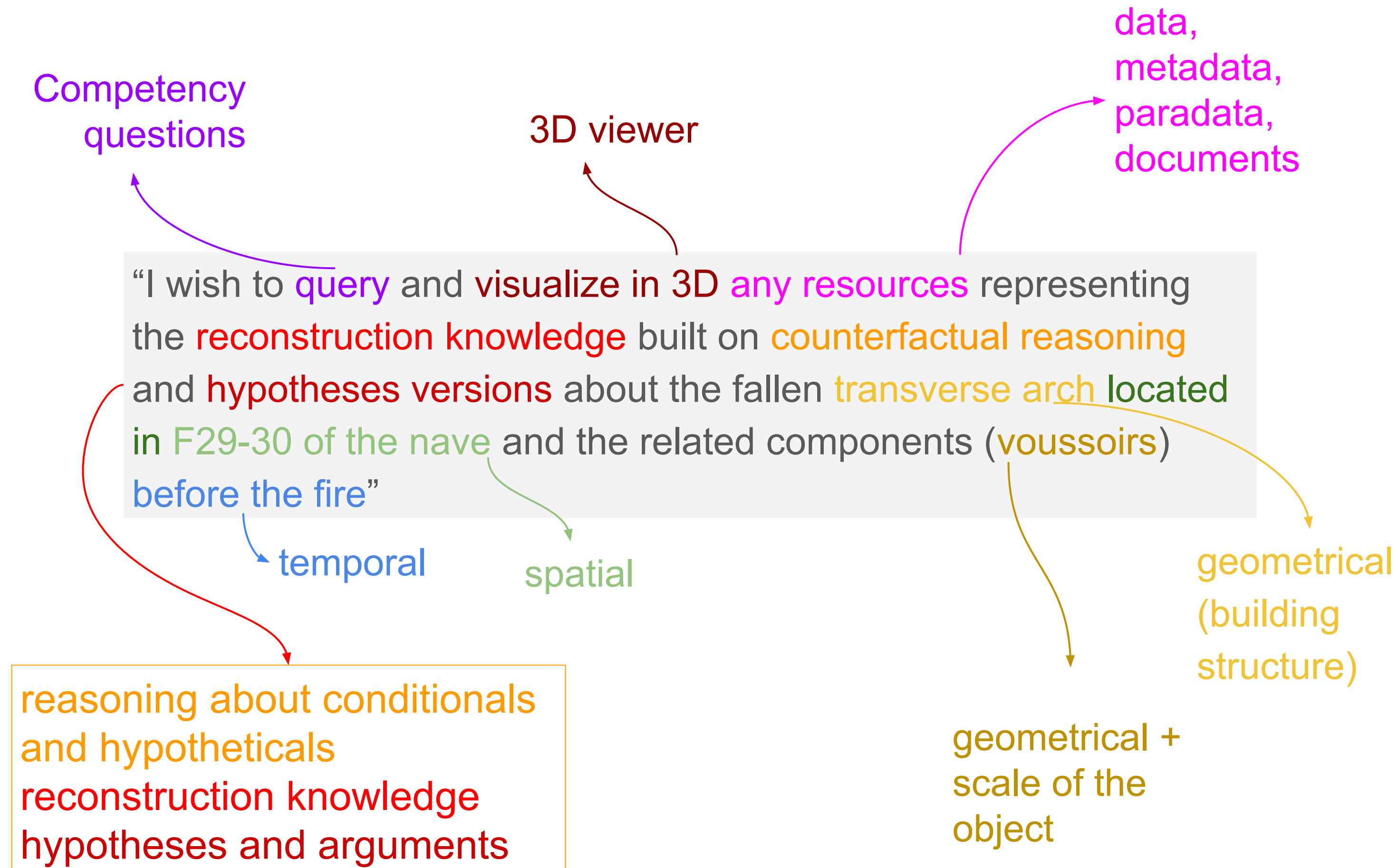
The central need for documenting argumentation and scientific reasoning in reconstructions

CIDOC CRM inf expressing conflicting arguments with CRMInf



Anaïs Guillem, Antoine Gros, Violette Abergel, Livio De Luca. Reconstruction beyond Representation in Notre-Dame de Paris. 2023 IMEKO TC-4 International Conference on Metrology for Archaeology and Cultural Heritage, International Measurement Confederation (IMEKO), Oct 2023, Rome, Italy. (hal-04275571v2)

Scientific narrative and research questions of the reconstruction



In : A. Guillem, J. Samuel, G. Gesquière, L. De Luca, V. Abergel, Let the fallen Voussoirs of Notre-Dame de Paris Speak: Scientific Narration and 3D Visualization of Virtual Reconstruction Hypotheses and Reasoning, SEMMES'24, Semantic Methods for Events and Stories, 20th Extended Semantic Web Conference (ESWC2024), 2024.



T1 T2 T3 T4-T9
Linear timeline

The reconstruction study formulates hypotheses about the cathedral's condition at the time T1

reconstruction hypothesis and reasoning

Time

Voussoir as digital object



Voussoir as physical object

Forms

Knowledge domains

Data provenance

argumentation & hypotheses about the arch reconstruction

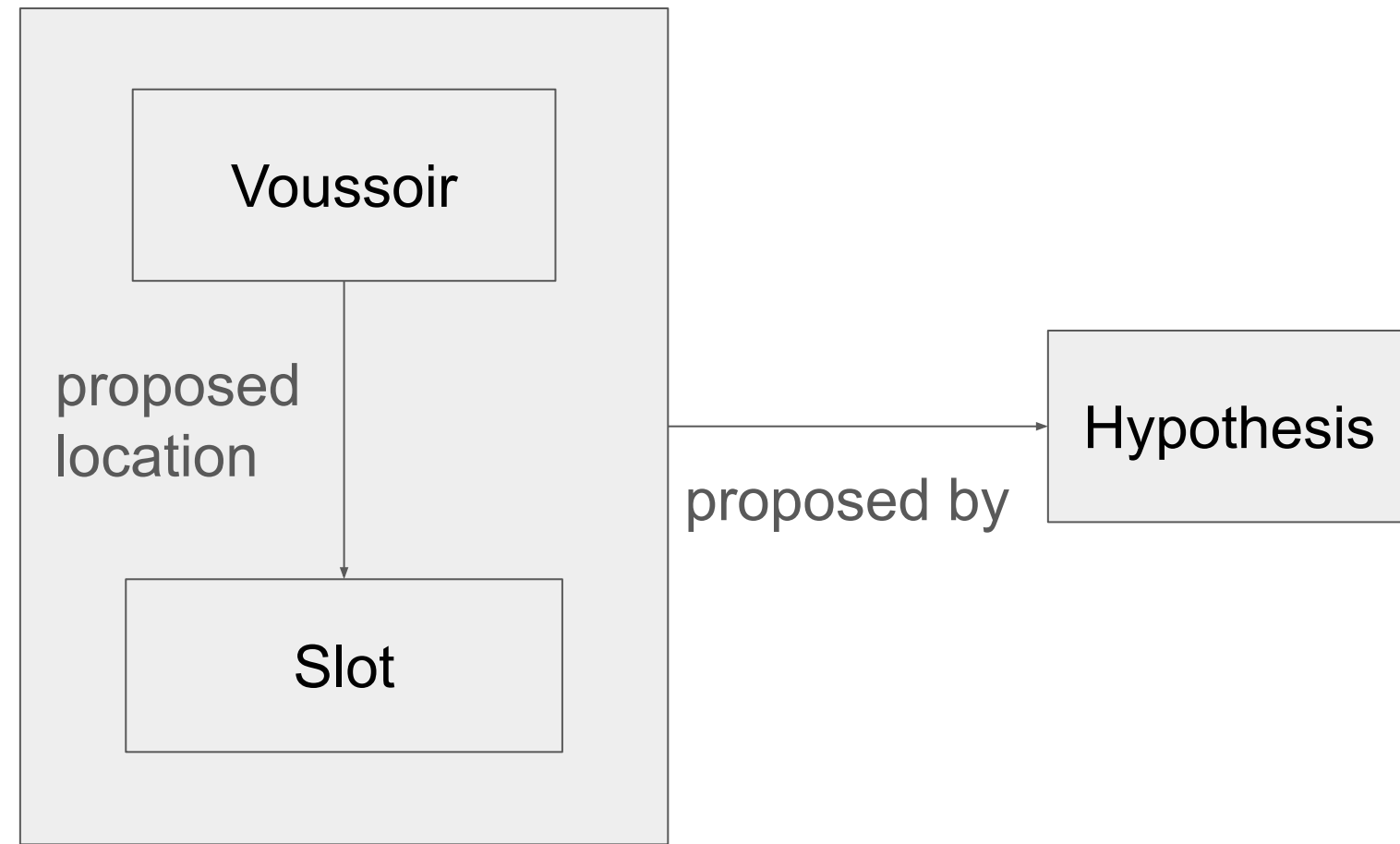
query

3D-visualization

Do the 3D-visualization and querying have this ability to explicitly convey the reconstruction study process and arguments?



Data curation, modeling, processing, and formalization



Reference	Width	Cross face location	Notches matrix
v_ref	v_largeur	v_cross	v_notch
N232A	1	5	[[1. 1.]]
N114	1	6	[[1. 1.]]
N119	27,5	5	[[1. 1.]]
N12	15,5	6	[[1. 2.]]
N137	16,5	6	[[1. 1.]]
N145	17,5	5	[[1. 1.]]
N160	1	6	[[1. 1.]]
N169A	17,5	6	[[1. 1.]]
N169B	1	6	[[1. 1.]]
N169C	18,5	6	[[0. 1.]]
N16A	15,5	6	[[1. 1.]]
N16B	17,5	6	[[0. 2.]]
N177	16,5	6	[[2. 2.]]
N17	1	6	[[1. 0.]]
N181	1	6	[[0. 1.]]
N1A	15,5	6	[[1. 1.]]
N1B	17,5	6	[[1. 1.]]
N1C	17,5	6	[[1. 0.]]
N1D	14,5	6	[[1. 1.]]
N210	1	6	[[1. 1.]]
N211	14,5	6	[[2. 1.]]
N212B	14,5	5	[[1. 0.]]
N212C	14,5	6	[[2. 0.]]
N212D	15,5	6	[[0. 0.]]
N212A	14,5	6	[[2. 0.]]
N214	14,5	5	[[1. 0.]]
N216A	18,5	6	[[1. 1.]]
N216B	1	6	[[1. 1.]]
N218	1	6	[[1. 0.]]
N222	1	6	[[0. 2.]]
N223	2	6	[[1. 1.]]
N224B	1	5	[[0. 0.]]
N224	1	5	[[0. 0.]]
N227	1	6	[[1. 1.]]
N229	14,5	5	[[1. 1.]]
N231	10,5	6	[[1. 1.]]
N232B	13,5	6	[[0. 1.]]
N233	14,5	5	[[0. 0.]]
N236	18,5	6	[[1. 0.]]
N238	1	6	[[0. 1.]]
N239	15,5	5	[[1. 1.]]
N244	1	6	[[1. 2.]]
N261	1	6	[[0. 1.]]
N263	11,5	6	[[1. 1.]]
N265	1	6	[[1. 1.]]
N272	1	6	[[0. 0.]]

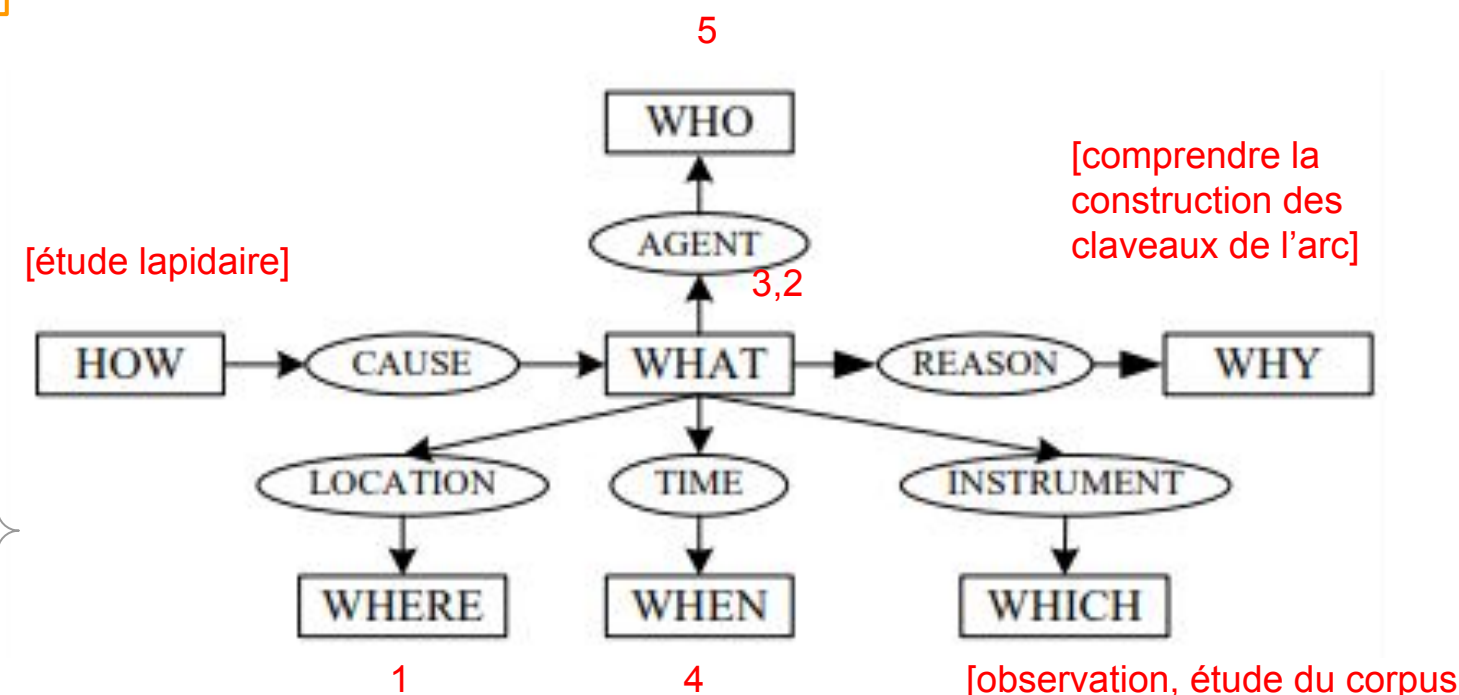
Data voussoir (N#)

In : A. Guillem, J. Samuel, G. Gesquière, L. De Luca, V. Abergel, Let the fallen Voussoirs of Notre-Dame de Paris Speak: Scientific Narration and 3D Visualization of Virtual Reconstruction Hypotheses and Reasoning, SEMMES'24, Semantic Methods for Events and Stories, 20th Extended Semantic Web Conference (ESWC2024), 2024.

Reference	Width	Location (center of gravity)			
r_ref	v_largeur	r_coordx	r_coordy	r_coordz	r_coordz
R72	28,6	1081,484483	1986,34106	63,663642	63,663642
R70	21,3	1081,531678	1986,46278	64,038687	64,038687
R68	17,6	1081,570618	1986,563208	64,038687	64,038687
R66	20,7	1081,610184	1986,665249	64,195998	64,195998
R64	19,6	1081,653524	1986,777025	64,358118	64,358118
R62	19,3	1081,697435	1986,890272	64,51049	64,51049
R60	20,6	1081,743959	1987,01026	64,662938	64,662938
R58	16,6	1081,789064	1987,126587	64,800895	64,800895
R56	18,2	1081,832855	1987,239526	64,925936	64,925936
R54	18,3	1081,879703	1987,360348	65,054407	65,054407
R52	15,9	1081,924824	1987,476716	65,171272	65,171272
R50	16,3	1081,968738	1987,589973	65,276524	65,276524
R48	16,2	1082,014166	1987,707132	65,379179	65,379179
R46	17,3	1082,061802	1987,829987	65,482828	65,482828
R44	16,5	1082,110505	1987,955596	65,585612	65,585612
R42	14,2	1082,155356	1988,071268	65,676641	65,676641
R40	14,5	1082,19776	1988,180628	65,75945	65,75945
R38	17,2	1082,24493	1988,302281	65,849404	65,849404
R36	17	1082,296662	1988,435701	65,943013	65,943013
R34	15,4	1082,346779	1988,564955	66,026307	66,026307
R32	16	1082,395773	1988,691311	66,105023	66,105023
R30	19	1082,450752	1988,833103	66,191753	66,191753
R28	19	1082,5115	1988,989777	66,280842	66,280842
R26	16,6	1082,568991	1989,138047	66,361157	66,361157
R24	14,1	1082,61863	1989,266067	66,429759	66,429759
R22	18,1	1082,671252	1989,401781	66,498469	66,498469
R20	23,2	1082,739573	1989,577984	66,581397	66,581397
R18	18,3	1082,808572	1989,755935	66,661895	66,661895
R16	17,6	1082,868306	1989,90999	66,73175	66,73175
R14	17,4	1082,92631	1990,059585	66,801744	66,801744

Data slot (R#)

métadonnées



[étude lapidaire]

[comprendre la construction des claveaux de l'arc]

[observation, étude du corpus lapidaire]

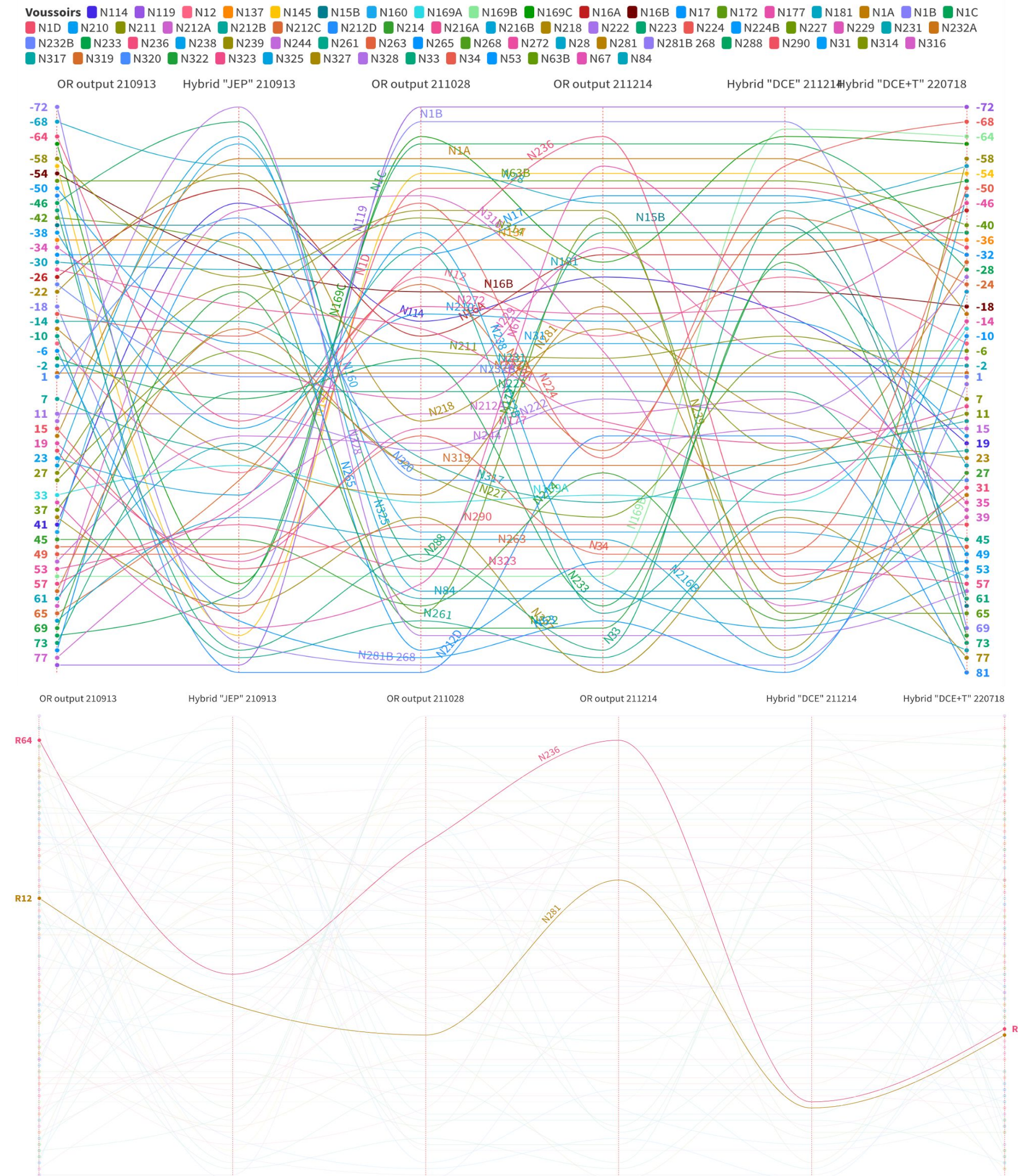
données

métadonnées

From formalization to visualization (2D)

CQ#4: Give me pairs of voussoirs-slots- and the associated hypotheses
 hyppair(N,H,R) :- hypothesis(H, R, N, _), voussoir(N,_,_,_,_,_), slot(R,_,_,_,_,_).

N114	"sol_glecr_0x4fbefadd", "sol_hh_glecr_0xat	[R41,R46,R26,R16,R19]
N119	"sol_pa_201218", "sol_glecr_0x4fbefadd", "s	[R79,R79,R79,R72,R72,R72]
N12	"sol_pa_201218", "sol_glecr_0x4fbefadd", "s	[R27,R8,R27,R10,R26,R8]
N137	"sol_glecr_0x4fbefadd", "sol_hh_glecr_0xat	[R36,R36,R36,R36,R36]
N145	"sol_glecr_0x4fbefadd", "sol_hh_glecr_0xat	[R56,R71,R54,R54,R54]
N15B	"sol_glecr_0x4fbefadd", "sol_hh_glecr_0xat	[R40,R40,R40,R40,R63]
N160	"sol_glecr_0x4fbefadd", "sol_hh_glecr_0xat	[R43,R62,R43,R43,R55]
N169A	"sol_pa_201218", "sol_glecr_0x4fbefadd", "s	[R53,R33,R25,R33,R35,R12]
N169B	"sol_pa_201218", "sol_glecr_0x4fbefadd", "s	[R55,R55,R55,R55,R66,R64]
N169C	"sol_pa_201218", "sol_glecr_0x4fbefadd", "s	[R57,R62,R57,R30,R64,R62]
N16A	"sol_pa_201218", "sol_glecr_0x4fbefadd", "s	[R50,R26,R50,R32,R32,R44]
N16B	"sol_glecr_0x4fbefadd", "sol_hh_glecr_0xat	[R54,R30,R22,R22,R18]
N17	"sol_glecr_0x4fbefadd", "sol_hh_glecr_0xat	[R32,R32,R48,R48,R32]
N172	"sol_pa_201218", "sol_glecr_0x4fbefadd", "s	[R34,R42,R34,R42,R65,R65]
N177	"sol_pa_201218", "sol_glecr_0x4fbefadd", "s	[R51,R19,R51,R15,R33,R14]
N181	"sol_glecr_0x4fbefadd", "sol_hh_glecr_0xat	[R30,R28,R28,R28,R25]
N1A	"sol_pa_201218", "sol_glecr_0x4fbefadd", "s	[R63,R17,R58,R58,R58,R16]
N1B	"sol_pa_201218", "sol_glecr_0x4fbefadd", "s	[R61,R18,R61,R68,R68,R69]
N1C	"sol_pa_201218", "sol_glecr_0x4fbefadd", "s	[R59,R71,R59,R62,R62,R28]
N1D	"sol_pa_201218", "sol_glecr_0x4fbefadd", "s	[R65,R21,R65,R50,R50,R34]
N210	"sol_glecr_0x4fbefadd", "sol_hh_glecr_0xat	[R38,R15,R14,R14,R17]
N211	"sol_glecr_0x4fbefadd", "sol_hh_glecr_0xat	[R27,R24,R4,R10,R7]
N212A	"sol_pa_201218", "sol_glecr_0x4fbefadd", "s	[R37,R77,R37,R11,R7,R37]
N212B	"sol_glecr_0x4fbefadd", "sol_hh_glecr_0xat	[R7,R21,R65,R27,R21]
N212C	"sol_pa_201218", "sol_glecr_0x4fbefadd", "s	[R29,R65,R29,R21,R42,R24]
N212D	"sol_glecr_0x4fbefadd", "sol_hh_glecr_0xat	[R48,R81,R17,R17,R81]
N214	"sol_glecr_0x4fbefadd", "sol_hh_glecr_0xat	[R45,R45,R27,R67,R27]
N216A	"sol_pa_201218", "sol_glecr_0x4fbefadd", "s	[R18,R28,R18,R13,R19,R9]



Voussoir
N236

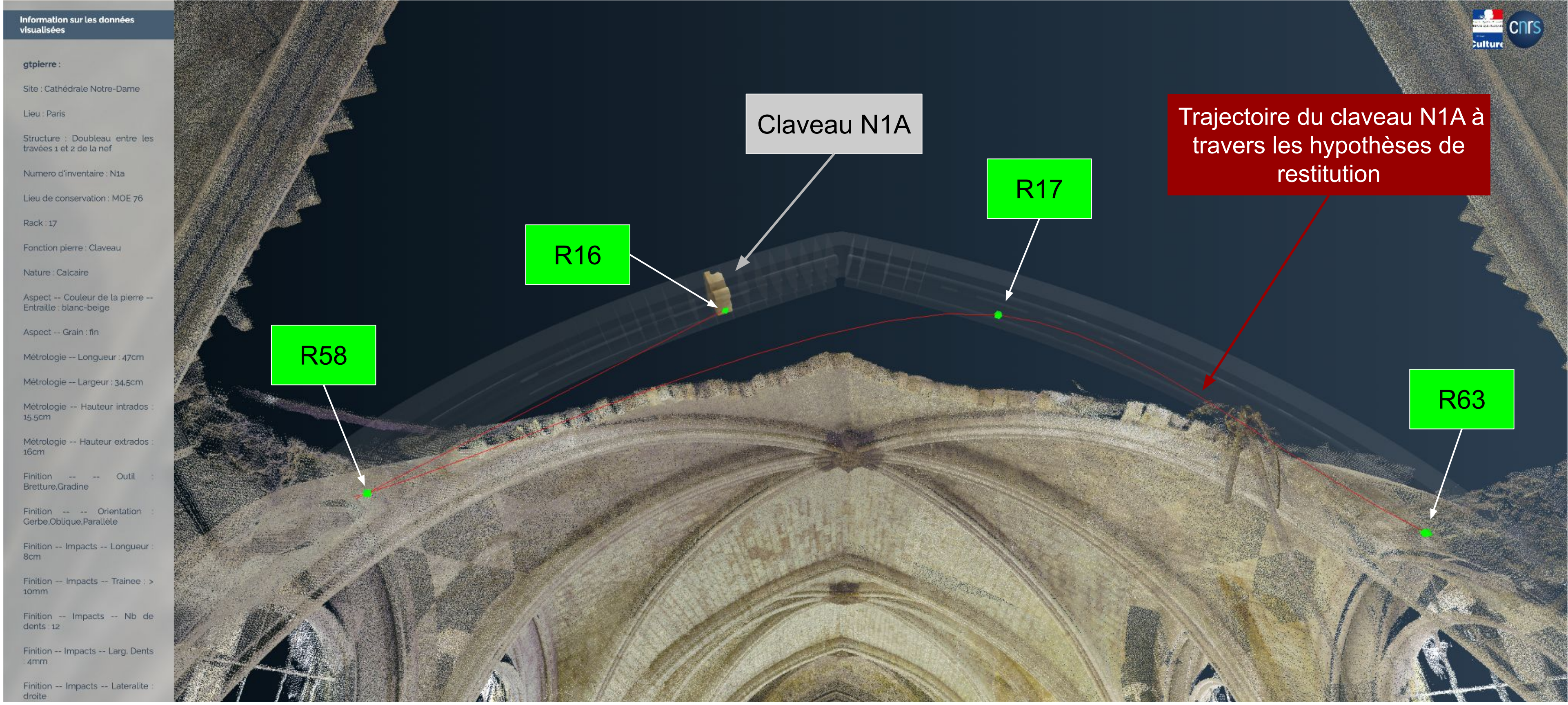
Voussoir
N281

visualization of both N236 (pink)
and N281 (ocre) trajectories

In : A. Guillem, J. Samuel, G. Gesquière, L. De Luca, V. Abergel, Let the fallen Voussoirs of Notre-Dame de Paris Speak: Scientific Narration and 3D Visualization of Virtual Reconstruction Hypotheses and Reasoning, SEMMES'24, Semantic Methods for Events and Stories, 20th Extended Semantic Web Conference (ESWC2024), 2024.

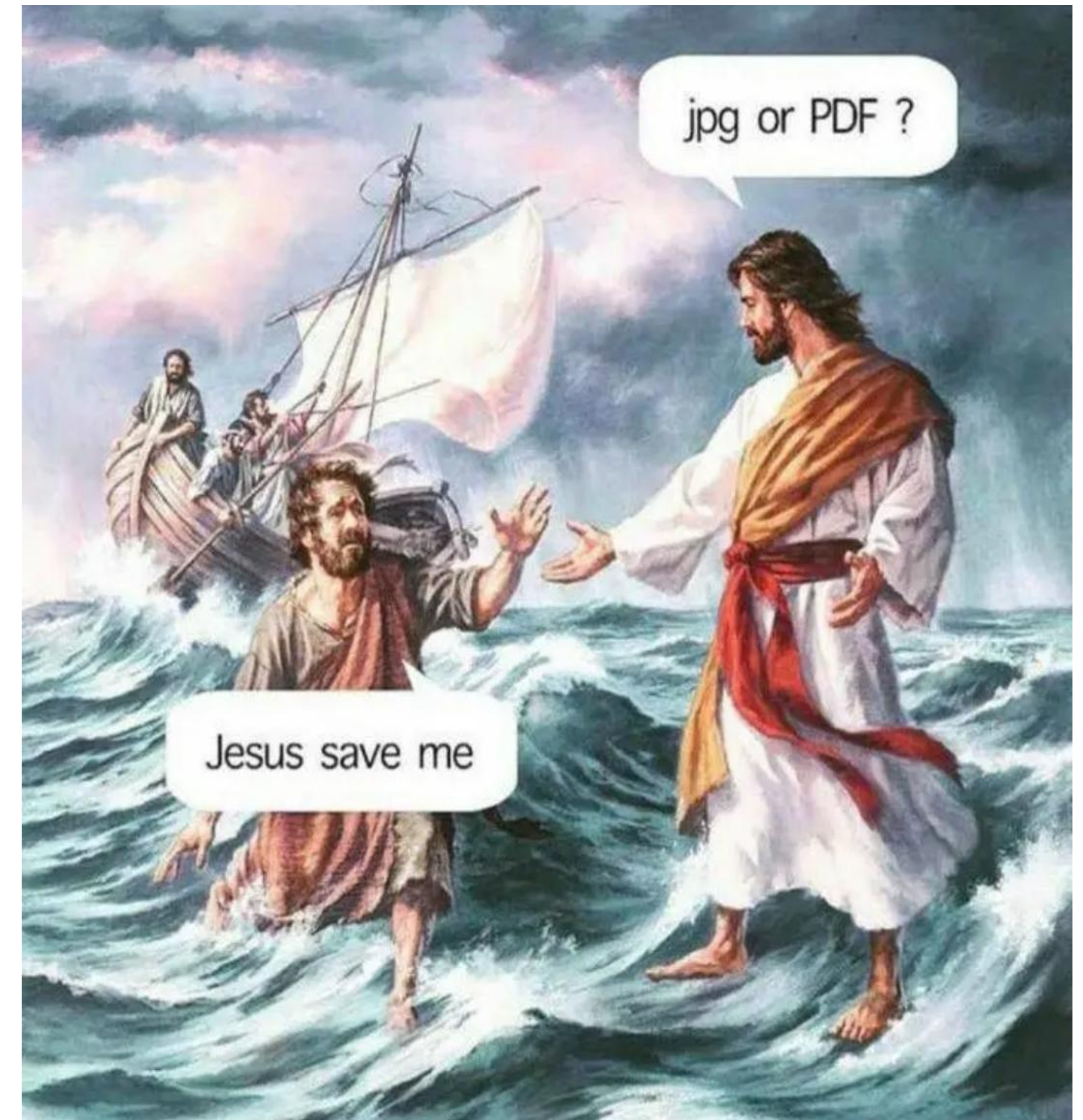
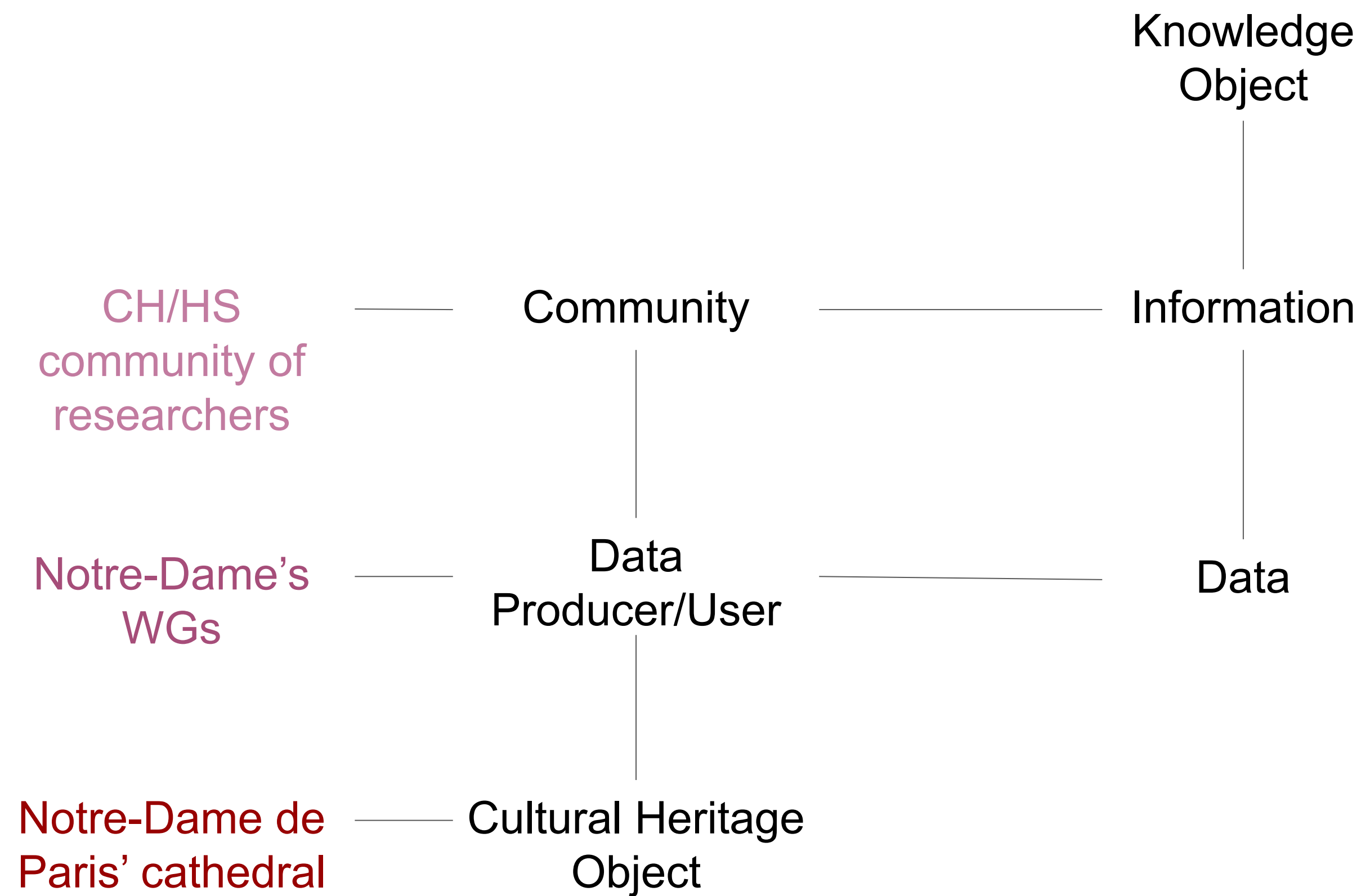
Visualisation de la trajectoire d'un claveau au fil des hypothèses de restitution

Exemple de l'itinéraire du claveau N1a au fil des différentes hypothèses de restitution (emplacements R16, R58, R17, R63) associé à ses informations archéologiques



In : A. Guillem, J. Samuel, G. Gesquière, L. De Luca, V. Abergel, Let the fallen Voussoirs of Notre-Dame de Paris Speak: Scientific Narration and 3D Visualization of Virtual Reconstruction Hypotheses and Reasoning, SEMMES'24, Semantic Methods for Events and Stories, 20th Extended Semantic Web Conference (ESWC2024), 2024.

Information easily decoupled from its support



“the dependence of information on the occurrence of syntactically well-formed data, and of data on the occurrence of differences variously implementable physically, explain why **information can so easily be decoupled from its support**”

[Floridi, 2010, pp24-25]

Thank you for your attention!

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 - DRAC IdF
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