



Journal of
Cultural Heritage

Premières expérimentations sur la sémantisation et l'interrelation de sources textuelles

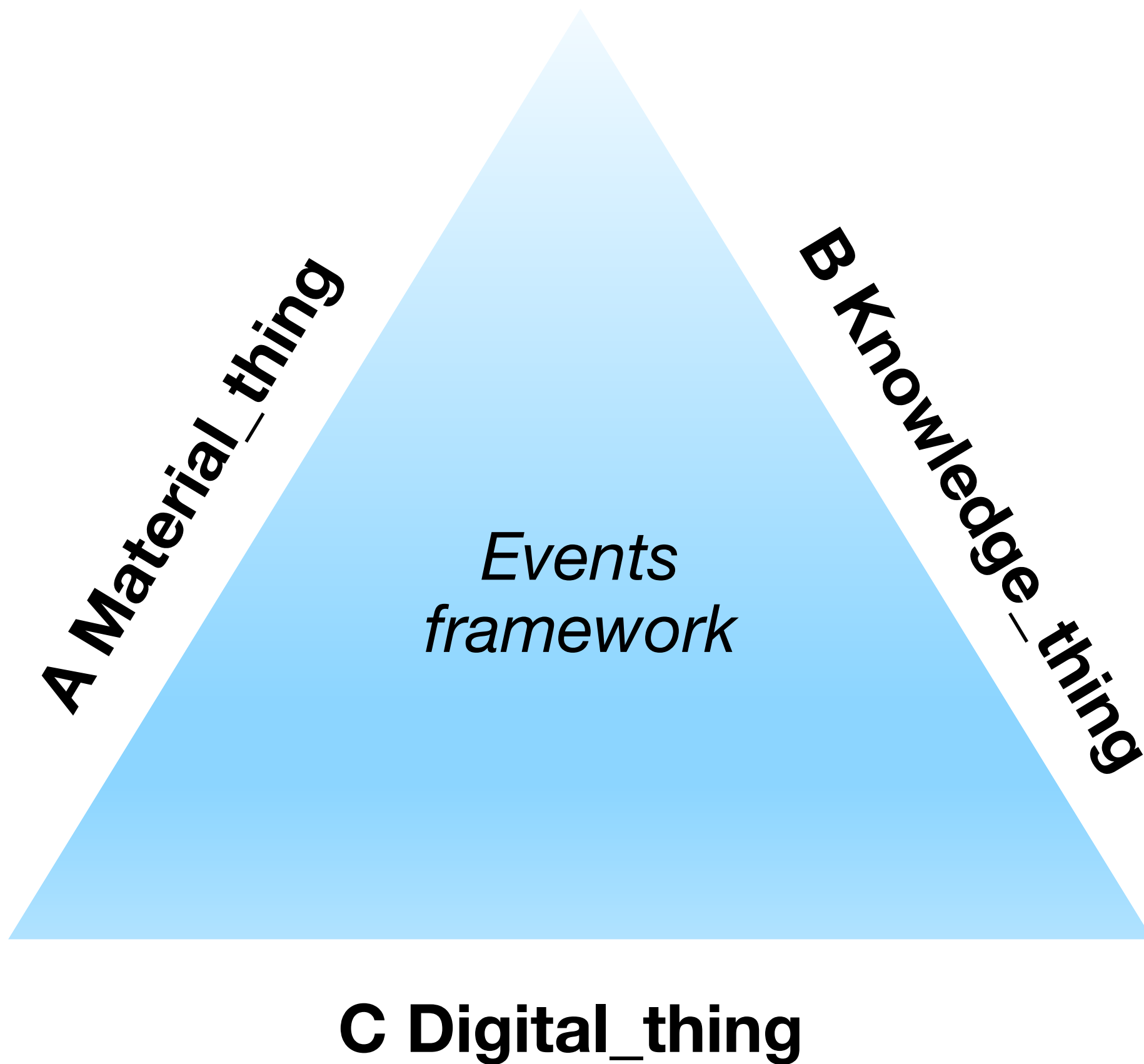
Arese P., De Luca L. MAP – UPR 2002 CNRS



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

Catégorisation



A Material_thing

A1 Alteration_Phenomena

A2 Architectural_Composition

A3 Constructive_Details

A4 Elements_of_Architecture

A5 Material_Sampling

A6 Materials

A7 Remains_Vestiges

A8 Tools

A9 Cultural_Goods

B Knowledge_thing

B1 Disciplinary_Areas

B2 Knowledge_Domains

B3 Research_Methodologies

B4 Research_Questions

B5 Institutions

C Digital_thing

C1 Digital_Representation

C2 Digital_Tools

C3 Metadata_and_Documentation

D Events

D1 Scientific / Professional_Activities

D2 Spatial_Framework

D3 Temporal Framework

D4 Actors_and_Organisms

L'Objet d'étude



Source image : <https://heritagetribune.eu/>



Source image : *Notre-Dame de Paris : a multidisciplinary scientific site*, Journal of Cultural Heritage, Vol.65, pp 1 – 240, January-February 2024

« Fire »

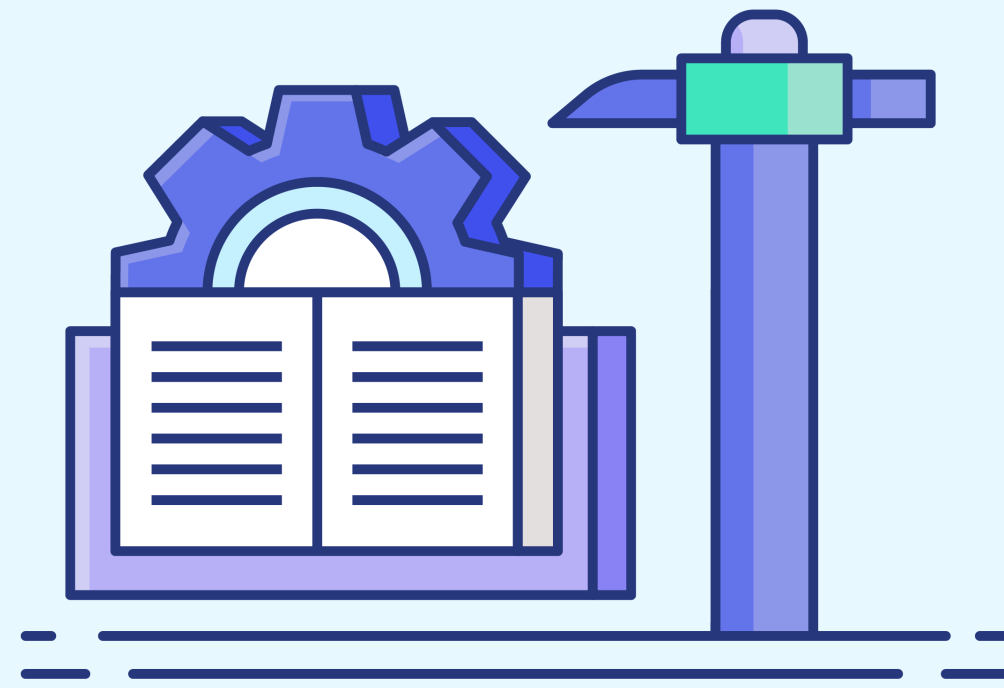
« Conservation »

« Digital Record »

« Assembly Details »

« Notre-Dame »

Text Mining, Késaco?



Source image : <https://www.ontotext.com/blog/text-mining-graph-databases-work-well-together/>

- Le Text Mining ou fouille de textes (FT) se réfère au processus d'extraction d'informations de haute qualité à partir de bases de données, de données structurées, semi-structurées telles que les formats XML et JSON, et de ressources textuelles non structurées telles que les documents Word, les vidéos et les images
- La FT est à l'intersection de deux disciplines : la statistique et la linguistique
- La FT permet de trouver des relations intéressantes, impossibles ou difficiles à détecter par une analyse séquentielle de l'information

Source : Feldman R., Sanger J., *The Text Mining Handbook, Advanced Approaches in Analyzing Unstructured Data*, Cambridge University Press, 2006

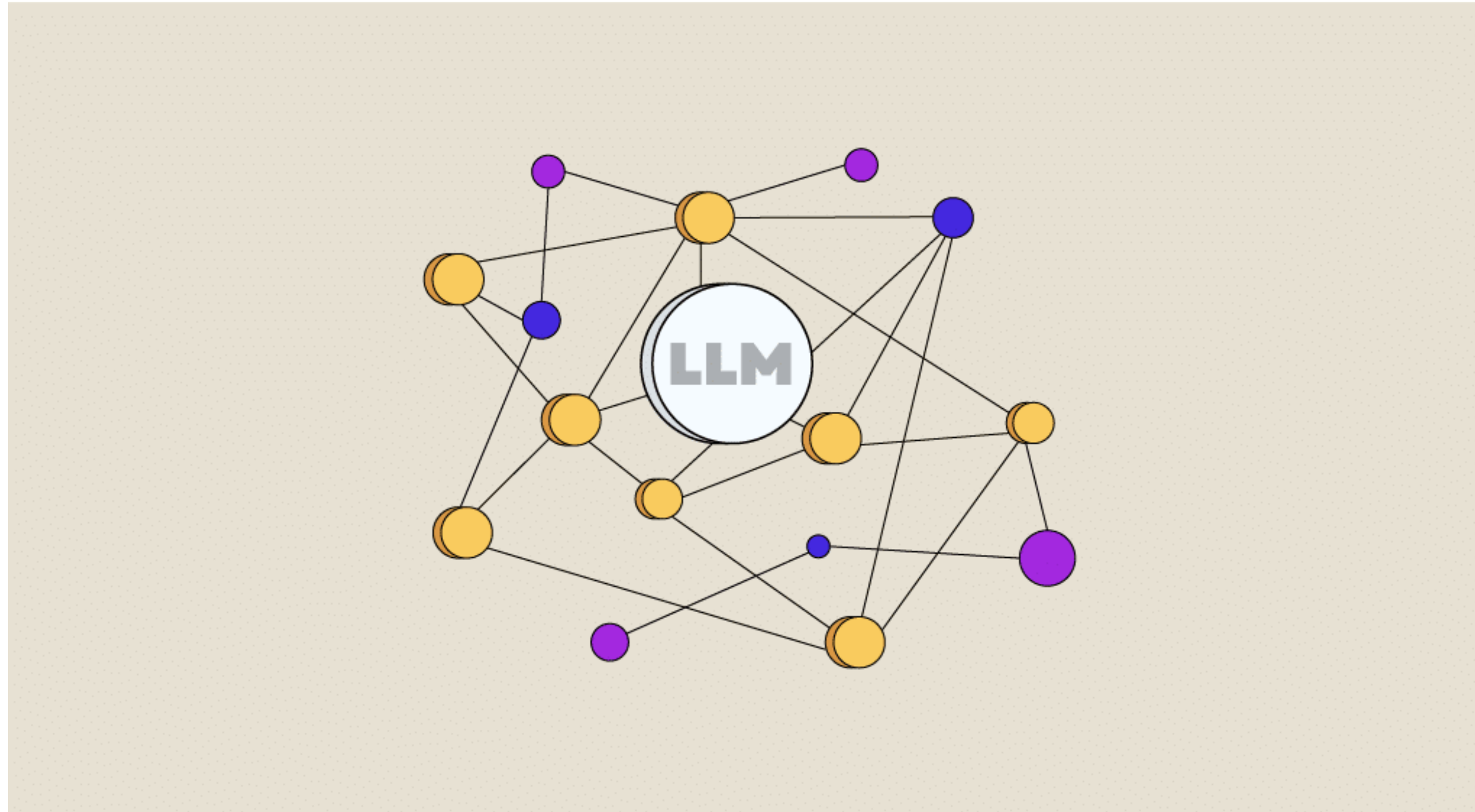
Modèle d'analyse statistique



GarganText, logiciel conçu par l'ISC-PIF pour l'exploration de grands corpus numériques. Source image : <https://gargantext.org/>

- Algorithme d'analyse statistique des textes
- Compte les occurrences
- Extraction limitée le plus souvent aux notices et aux abstracts

Large Language Model (LLM)



Source image : <https://datascientest.com>

- Modèle génératif entraîné sur une vaste quantité de données
- Réponses et pertinence des résultats conditionnées par la qualité du Prompt
- L'interface (un agent conversationnel ou Chat Bot) permet, par ses réponses, d'affiner le Prompt

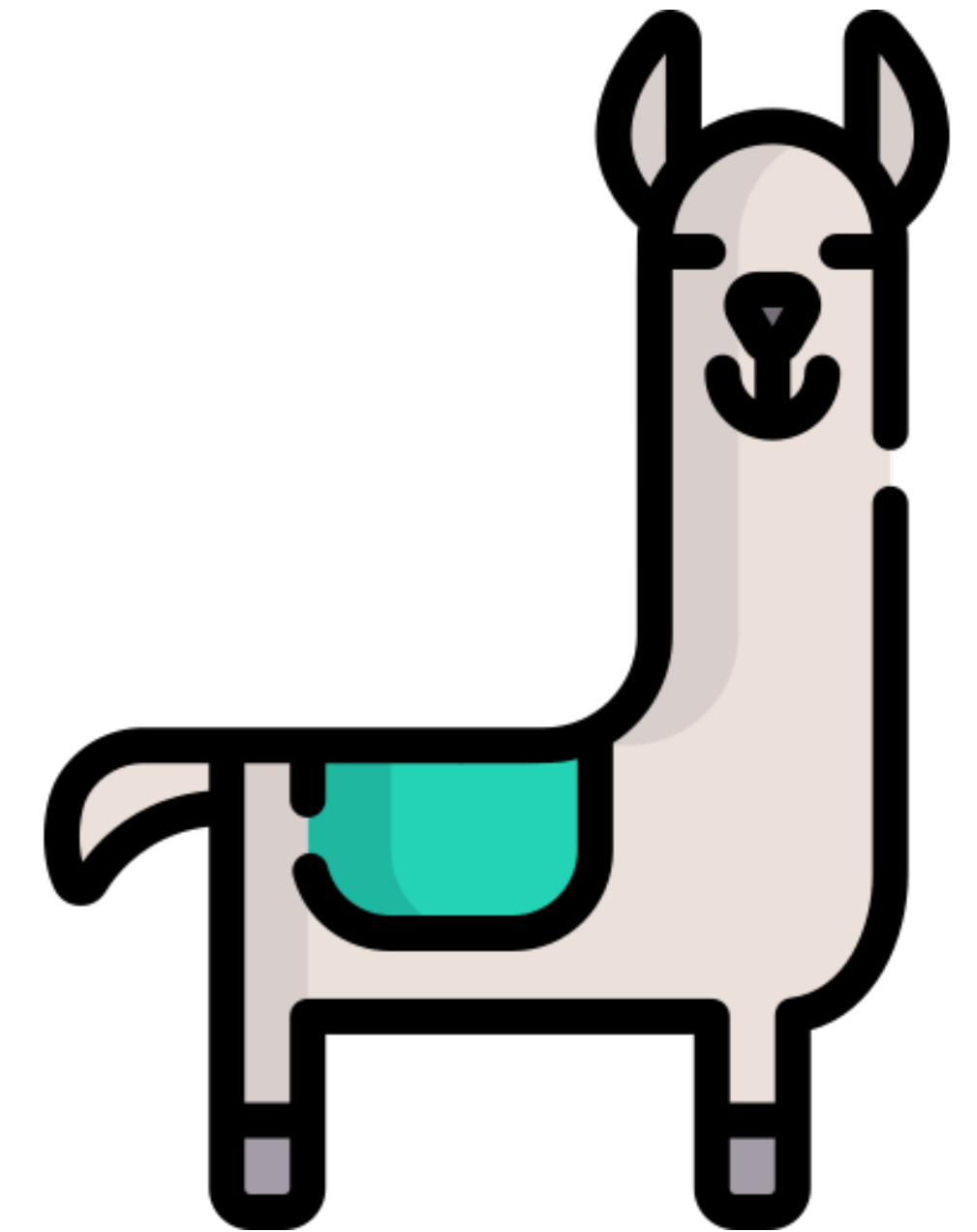
Première phase de tests - optimisation du Prompt



Chat GPT 3,5 (2020) – modèle de langage *freemium* développé par la société Open AI. <https://chatgpt.com/>



Bard (2023) – modèle de langage *freemium* de la firme Google. Devenu depuis Gemini. <https://gemini.google.com/>



LLaMa II 7B (2023) – modèle de langage *open source* développé par Meta. <https://www.llama2.ai/>

Test Prompt 3

To analyze the following text, please extract all the specialised terms according to the predefined categories. Be sure to classify each term according to the relevant category :

A1 Alteration_Phenomena / A2 Architectural_Composition / A3 Constructive_Details / A4 Elements_of_Architecture / A5 Material_Sampling / A6 Materials / A7 Remains-Vestiges

Read the text carefully. Identify and extract the terms that best fit the given categories. For each extracted term, note the number of times it appears in the text. Place each term in the corresponding category. If a term may fall into more than one category, use your judgment to choose the most appropriate category, or list it in all categories where it applies. If you encounter terms that do not seem to fit these categories but are relevant to understanding the text, create a new appropriate category. Present results in an organized and clear manner.

The text to analyze is here:

The construction of the side chapels developed from the end of the first part of the 12th century to the beginning of the 14th century, from the nave towards the choir. The chapels are located between two partition walls and open towards the side aisles. In the 19th century, during the major works carried out by Viollet-le-Duc and Lassus, the chapels were equipped with painted decorations after having been whitewashed several times in the 17th century. It was during these major works, between 1864 and 1868 that the chapels, in their entirety, were restored (painted decorations, stained glass windows, furniture). Between 1959 and 1965, work to clean the chapels was carried out. The painted decorations, considered bland, are then stripped to leave the cut stone bare. The rearrangement, in particular the reintegration of works into a new scenography, was implemented by Pierre-Marie Auzas.

	A1 Alteration_Phenomena	A2 Architectural_Composition	A3 Constructive_Details	A4 Elements_of_Architecture	A5 Material_Sampling	A6 Materials	A7 Remains-Vestiges	A8 Restoration (
Chat GPT 3,5	Whitewashed Stripped	Side Chapels Nave Choir Side Aisles Partition Walls	Stained Glass Windows	Chapels	Cut Stone	Painted Decorations Furniture		Restored Reintegration
Bard	Whitewashed	Side chapels, Partition Walls, Side Aisles	construction, restoration, cleaning	chapels, painted decorations, stained glass windows, furniture	Cut Stone		12th century, 14th century, nave, choir	
Llama 2	whitewashed	Nave Choir Partition Walls Side Aisles	Chapels Scenography		Stone	Paint Whitewash	Cut Stone + A8 restoration	Restoration

Première phase de tests – Conclusions

- Il est indispensable d'affiner le prompt au maximum (éviter les généralités, préférer les termes exacts, être précis)
- Faire systématiquement correspondre la langue de la requête avec la langue du texte.
- Eviter les textes trop longs (se limiter à un paragraphe).
- Ne JAMAIS lui demander de compter. Lorsqu'il compte, l'agent conversationnel fait de nombreuses erreurs et après plusieurs requêtes commencent généralement à halluciner.
- Ne pas lui permettre d'utiliser son jugement. Il doit s'en tenir à une requête rigide et ne pas s'en éloigner (malgré tout, il continue parfois d'interpréter).
- Possibilité de faire précéder chaque terme par un signe (ex : *), ou mettre en majuscule les termes importants. Préciser dans le prompt qu'il doit relever et classer chaque terme précédé par le signe ou chaque terme en majuscule. Cette méthode est efficace mais requiert une lecture active préalable.
- Extraire les termes importants au préalable (par exemple en ayant recours à un compteur de mots). Cette technique donne la possibilité de sélectionner les termes importants et de supprimer les termes secondaires ou non pertinents. Cette action, souvent longue, sera écartée dans la suite du processus.

Workflow Part. 1 - Segmentation

1. Segmentation



SI: Notre-Dame de Paris

A digital platform for the centralization and long-term preservation of multidisciplinary scientific data belonging to the Notre Dame de Paris scientific action

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^eCNR-ISTI, Istituto di Scienza e Tecnologia dell'Informazione, Via Giuseppe Moruzzi, 1, 56127 Pisa, Italy
^fLaboratoire de Recherche des Monuments Historiques, 29 rue de Paris, 77420 Champs-sur-Marne, France

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 Digitisation
 Information systems

ABSTRACT

This article explores the design, development and deployment of a digital platform for scholarly work at Notre Dame Cathedral and demonstrates the transformative impact of digital technology on heritage disciplines. By merging technology and human expertise, the platform facilitates the creation, integration, sharing, and analysis of extensive scientific data on the multidisciplinary post-fire study of the cathedral. This multi-layered approach includes community building for collaborative efforts, digital tools tailored to different stakeholders, data structuring approaches for managing multidimensional features, and experience-based workflows for documenting, categorising and semantically enriching scientific and restoration data. The overall goal is to introduce an integrated solution for collaborative studies and to promote a digital memory of the collective initiative in accordance with the principles of FAIR for scientific heritage data. This initiative not only supports the research and restoration of Notre Dame, but also serves as a paradigm for future conservation and documentation efforts in the field of cultural heritage.

Introduction

Digital tools for supporting multidisciplinary knowledge

In recent years, digital technology has revolutionised the way cultural heritage-related disciplines work. The introduction of new 'digital objects' has proved useful for studying forms and materials (e.g. reality capture sensors), searching and sharing data (e.g. databases, information systems, ontologies) or disseminating scientific results (e.g. multimodal virtual environments), but few experiments have explored the full path from data production to knowledge production as key to embedding human knowledge in n-dimensional digital objects, especially in the context of co-production of multidisciplinary knowledge around the same cultural heritage object. Beyond the development of an innovative

technological framework in the service of collaborative studies, the introduction of a digital ecosystem (with actors, methods, protocols and tools that produce data, information and knowledge) raises new scientific questions in the context of heritage sciences by moving the cursor from the analysis of the features of the cultural object to the analysis of the knowledge mobilised to understand it. The multidisciplinary nature of a cultural object is the ideal context in which to explore this topic, and the Notre Dame Restoration Project (involving hundreds of scholars from diverse backgrounds) presents an unprecedented opportunity. This paper presents the design and ongoing implementation of the centre-piece of this ecosystem, a digital platform to support the study and restoration of the cathedral by integrating data, information and knowledge from the many stakeholders. The project is part of the official Digital Data Working Group of the Notre Dame Scientific Action of the CNRS and the Ministry of Culture [1,2], organised around four complementary axes: the collection and integration of existing data, the production of new data, their sharing and

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2. Réorganisation

Chapitres	Paragraphes
0_Abstract	This article explores the design, development and deployment of a digital platform for scholarly work at Notre Dame Cathedral and demonstrates the transformative impact of digital technology on heritage disciplines. By merging technology and human expertise, the platform facilitates the creation, integration, sharing, and analysis of extensive scientific data on the multidisciplinary post-fire study of the cathedral. This multi-layered approach includes community building for collaborative efforts, digital tools tailored to different stakeholders, data structuring approaches for managing multidimensional features, and experience-based workflows for documenting, categorising and semantically enriching scientific and restoration data. The overall goal is to introduce an integrated solution for collaborative studies and to promote a digital memory of the collective initiative in accordance with the principles of FAIR for scientific heritage data. This initiative not only supports the research and restoration of Notre Dame, but also serves as a paradigm for future conservation and documentation efforts in the field of cultural heritage.
1_Introduction	
1.1_Digital Tools for Supporting Multidisciplinary Knowledge	In recent years, digital technology has revolutionised the way cultural heritage-related disciplines work. The introduction of new 'digital objects' has proved useful for studying forms and materials (e.g. reality capture sensors), searching and sharing data (e.g. databases, information systems, ontologies) or disseminating scientific results (e.g. multimodal virtual environments), but few experiments have explored the full path from data production to knowledge production as key to embedding human knowledge in n-dimensional digital objects, especially in the context of co-production of multidisciplinary knowledge around the same cultural heritage object. Beyond the development of an innovative technological framework in the service of collaborative studies, the introduction of a digital ecosystem (with actors, methods, protocols and tools that produce data, information and knowledge) raises new scientific questions in the context of heritage sciences by moving the cursor from the analysis of the features of the cultural object to the analysis of the knowledge mobilised to understand it. The multidisciplinary nature of a cultural object is the ideal context in which to explore this topic, and the Notre Dame Restoration Project (involving hundreds of scholars from diverse backgrounds) presents an unprecedented opportunity. This paper presents the design and ongoing implementation of the centre-piece of this ecosystem, a digital platform to support the study and restoration of the cathedral by integrating data, information and knowledge from the many stakeholders. The project is part of the official Digital Data Working Group of the Notre Dame Scientific Action of the CNRS and the Ministry of Culture [1,2], organised around four complementary axes: the collection and integration of existing data, the production of new data, their sharing and archiving, and their structuring and semantic enrichment. The design of this digital platform takes place at the intersection of these themes, aiming to collect, correlate and analyse masses of digitally generated scientific data on the cathedral's architecture, its changes over time, its structural and acoustic behaviour, its materials, as well as the damage caused by the fire in April 2019. By introducing an innovative collaborative framework, our platform also includes the implicit goal of creating a kind of "digital memory of a collective endeavour", whose content would be accessible and reusable under the FAIR principles as an emblematic example of scientific heritage data.
1.2 Collaborative efforts and technological integration	The Digital Data Working Group [3], progressively established during the first year of Notre Dame's scientific action, brings together complementary competences for the creation/documentation of scientific data central to the restoration project (LRMH (CNC) and C2RMF (NEW AGLAE), in collaboration with the SRA of DRAC Ile-de-France), for the acquisition, merging, and reconstruction of spatial data at different scales (Archeovision, MAP, MIS, LASTIG, Centre Chastel), to databases and information systems for archaeological research or heritage conservation (MSH VdL, MOM, MAP, ETIS), and to knowledge of the history of Notre Dame through the cultural, social and material dimension (Centre Chastel). Our platform also brings together in a single technological environment specific software tools from research units whose work already interacts closely with the IR* HumNum Very large research infrastructure through the MASA and 3D for humanities consortia. Finally, although outside our working group, other thematic working groups of the general scientific action, the lead architects and the public body in charge of the restoration work (EPRNDP) form a second and natural ring of partners linked to this ambitious project.



Source texte : Néroulidis A. et al., *A digital platform for the centralization and long-term preservation of multidisciplinary scientific data belonging to the Notre Dame de Paris scientific action*, in Journal of Cultural Heritage, Vol.65, p. 210, January-February 2024

Workflow Part 2. - Extraction semi-automatique

```

json
{
  "A1 Alteration_Phenomena": ["fire"],
  "A2 Architectural_Composition": ["medieval mortars", "Notre-Dame de Paris cathedral"],
  "A3 Constructive_Details": ["mortar mixes", "thermal analyses", "construction duration"],
  "A4 Elements_of_Architecture": ["transverse arch", "nave", "vaults", "choir"],
  "A5 Material_Sampling": ["mortar samples"],
  "A6 Materials": ["mortars"],
  "A7 Remains_Vestiges": [],
  "A8 Tools": [],
  "A9 Cultural_Goods": ["Notre-Dame de Paris cathedral"],
  "B1 Disciplinary_Areas": [],
  "B2 Knowledge_Domains": [],
  "B3 Research_Methodologies": ["thermal analyses", "decontamination", "characterisation"],
  "B4 Research_Questions": [],
  "B5 Institutions": ["CNRS (French National Center for Scientific Research)", "French Ministry of Culture"],
  "C1 Digital_Representation": [],
  "C2 Digital_Tools": [],
  "C3 Metadata_and_Documentation": [],
  "D1 Scientific_and_professional_activities": [],
  "D2 Scientific_and_professional_activities": []
}

```

« This study deals with the characterisation of a selection of medieval mortars used in the construction of Notre-Dame de Paris cathedral. It took place in the framework of the scientific work organized by the CNRS (French National Center for Scientific Research) and the French Ministry of Culture after the fire that partially destroyed the cathedral on April 15th 2019. The partial destruction of the building and then the installation of scaffolding to secure the walls and the vaults provided an opportunity to access structures that were usually inaccessible. About thirty mortar samples were taken during spring 2020. In this first step of an upcoming overall study, the choice of the sampling sites depended on where the safety work was being carried out and the potential requirements of the forthcoming restoration project (the necessity to determine the design of the mortar mixes). Therefore our samplings concerned the transverse arch of the nave that collapsed during the fire and in fact this structure will probably be one of the first part to be restored. As it will be shown in §5.3 (thermal analyses), the studied mortars sampled present normal results that correspond to unfired materials. The vaults of the choir were also accessible and samples were collected to be compared to those from the collapsed arch. »

A1 Alteration_Phenomena	A2 Architectural_Composition	A3 Constructive_Details	A4 Elements_of_Architecture	A5 Material_Sampling	A6 Materials
fire	medieval mortars	mortar mixes	transverse arch	mortar samples	mortars
	Notre-Dame de Paris cathedral	thermal analyses	nave	samples	lead ash
	transverse arch	construction duration	vaults		smoke
	nave	degradation	choir		
	vaults	heat deterioration	cathedral		
	choir	lixiviation			
		sulfate problems			
		lead ash			
		smoke			
		scaffolding			
		walls			
		sampling sites			

Source texte : Mechling J.M., Baquet M., *Physicochemical characterisation of the mortars from Notre-Dame de Paris cathedral – Preliminary findings and reconstitution of the fresh mix*, in Journal of Cultural Heritage, Vol.65, p. 57, January-February 2024

La suite?

LE CHAT
NOIR_

< + ↑

The following terms belong to a category called "Institutions". Please analyse those terms and place them in sub-categorie...

Rechercher... 🔍

Le mois dernier

The following terms belong to...

The following terms belong to...

The following terms belong to...

The following terms belong to...

The following terms belong to...

The following terms belong to...

Please read the following text ...

The following terms belong to...

Analyze the following text and...

PA The following terms belong to a category called "Digital_Representation". Please analyse those terms and place them in sub-categories that seems appropriate. I need no more than 6 categories. Here are the terms : 2.5D representations

2D data
 2D geometry
 2D image
 2D-to-2D photogrammetric fusion
 360° panoramic views
 3D data
 3D data visualization
 3D description
 3D digitisation
 3D for humanities platform
 3D geometrical models
 3D images
 3D lasergrammetric point clouds
 3D model anastylosis
 3D modelling
 3D models
 3D models

Posez n'importe quelle question ! ➤

PA Pierre A.
Personnel

Model: Large v

Ceci est une version bêta. Les réponses peuvent contenir des inexactitudes.

Des données numériques aux connaissances pluridisciplinaires: enjeux de documentation et de formalisation

Abergel V., Arese P., Comte F., Dudek I., Guillem A.^{1,2}, Gros A.^{1,3,4}, Reby K.¹

- 1 - CNRS/MAP/Marseille
- 2 - Ludwig Maximilian University of Munich/München
- 3 - CNRS/Laboratoire de Mécanique et de Génie Civil/Montpellier
- 4 - LISPEN EA 7515/Laboratoire d'Ingénierie des Systèmes Physiques et Numériques/Aix-en-Provence



La gestion massive des données multidimensionnelles produites dans le contexte du chantier de Notre-Dame soulève aujourd'hui de nouvelles questions et défis, particulièrement en termes de traçabilité, d'analyse, d'interrogation, ou encore de visualisation. La valeur de ces données numériques réside surtout dans toutes les connaissances qu'elles sont susceptibles de véhiculer pour une communauté d'acteurs à travers des regards orientés. L'enrichissement sémantique permet une connexion durable entre la connaissance humaine et le traitement informatique ; notre travail vise à pérenniser toutes ces ressources précieuses et explorer le chemin qui mène de la génération de données à la production de connaissances.



Figure 1. Description d'un processus d'acquisition de données photogrammétriques et enregistrement de métadonnées relatives à un résultat de recherche (research output), 2023. URL: <http://memoire-dev.gamsau.archi.fr/visiter.php>

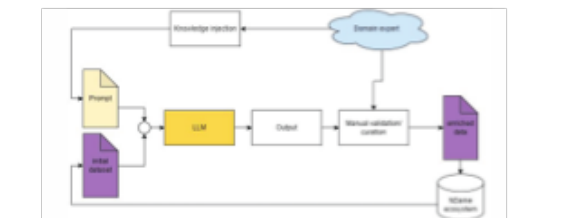
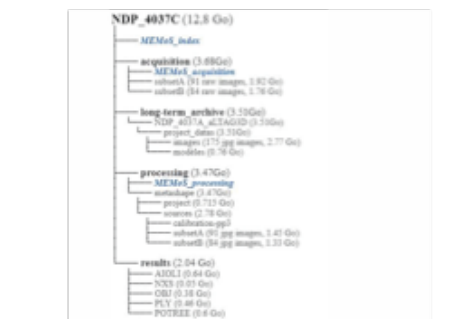


Figure 2. Schéma généralisé de l'enrichissement de données en utilisant les LLM par la création de prompts, la préparation de jeux de données et l'évaluation des résultats et visualisation des données extraites sous la forme d'un graphe.



Figure 3. Représentation des relations spatiales des espaces et éléments de Notre-Dame de Paris. Elles sont exprimées avec le modèle topologique du RCC8 sous la forme d'un graphe de données.



En suivant ce lien, vous pouvez télécharger la publication d'origine :

F. Comte, A. Parnet, K. Reby, L. De Luca. Strategies and Experiments for Massive 3D Digitalization of the Remains after the Notre-Dame de Paris Fire. 10th International Workshop 3D-ARCH «3D Virtual Reconstruction and Visualization of Complex Architectures», Feb 2024, Slovenia, Italy.

En suivant ce lien, vous pouvez télécharger la publication d'origine :

I. Dudek, J.-Y. Stasse, M. Rabaladehona. MEMORIA: An Agent for Decoding the Processes of Research. Revue des Nouvelles Technologies de l'Information, 2022. Extraction et Gestion des Connaissances 2022, NNT:4-36, pp. 453-460.

Pérenniser des données multidimensionnelles

La complexité et l'hétérogénéité des données du chantier scientifique de Notre-Dame impose une réflexion sur leur condition de production et leur cycle de vie. En particulier, le volume des données d'acquisition 3D a nécessité de proposer une structure permettant l'enregistrement de chaque étape du travail de numérisation, tout en répondant aux besoins inhérents à leur pérennité à court et long terme. Cet effort s'appuie sur : 1) une automatisation des processus de numérisation, 2) une documentation systématique par la production de métadonnées et par l'ajout de données de production hiérarchique en amont de leur production (MEMoS), 3) Une préparation des données pour leur archivage à long-terme grâce à Altaz3D (logiciel de préparation des données).

De plus, avec l'ambition de mémoriser et analyser non seulement les données, mais aussi les processus et résultats des activités de recherche afférentes, nous avons proposé une approche de description à travers le système d'information expérimental MEMORIA.

Extraire des informations sémantiques

En plus de stratégies d'enrichissement sémantique basées sur l'annotation, permettant d'intégrer des connaissances pluridisciplinaires au sein de représentations numériques 2D et 3D de la cathédrale, nous proposons des approches automatisées permettant d'extraire les éléments clés de notre corpus de documentation scientifique. Pour les textes, nous nous appuyons sur les LLMs (Large Language Models). Ceux-ci nous permettent une curation de contenus efficace et contrôlée, tant dans les actions de sélection, que de formalisation et de partage.

Des données hétérogènes aux graphes de connaissances

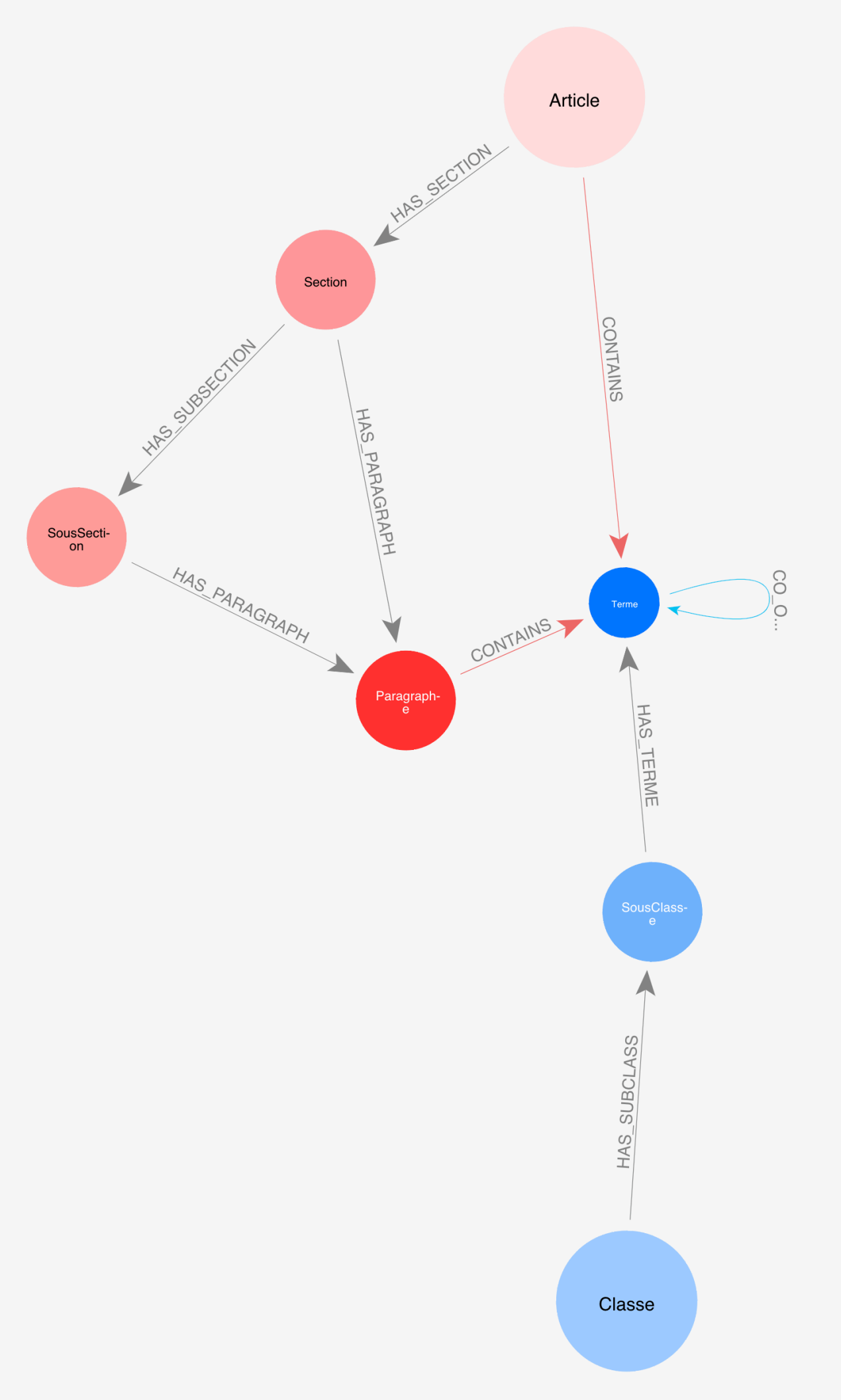
L'ensemble de ces approches offre un cadre méthodologique permettant de construire et caractériser des relations entre les données et les connaissances pluridisciplinaires du chantier scientifique, en exploitant à la fois leurs attributs spatiaux, géométriques, temporels et sémantiques. Il s'agit d'exploiter les données multidimensionnelles de Notre-Dame pour construire un modèle de connaissances capable de supporter de nouvelles stratégies d'analyse, basées notamment sur la détection de motifs récurrents ou de classification. L'utilisation conjointe d'approches par graphes et de méthodes de traitement géométrique permet alors de définir de nouvelles modalités d'exploration et d'interrogation de corpus complexes en s'appuyant sur la navigation dans un espace nD.

Colloque interdisciplinaire «Naissance et renaissance d'une cathédrale : Notre-Dame de Paris sous l'œil des scientifiques» 22 - 24 avril 2024 - Auditorium de la Cité de l'Architecture et du Patrimoine, Paris

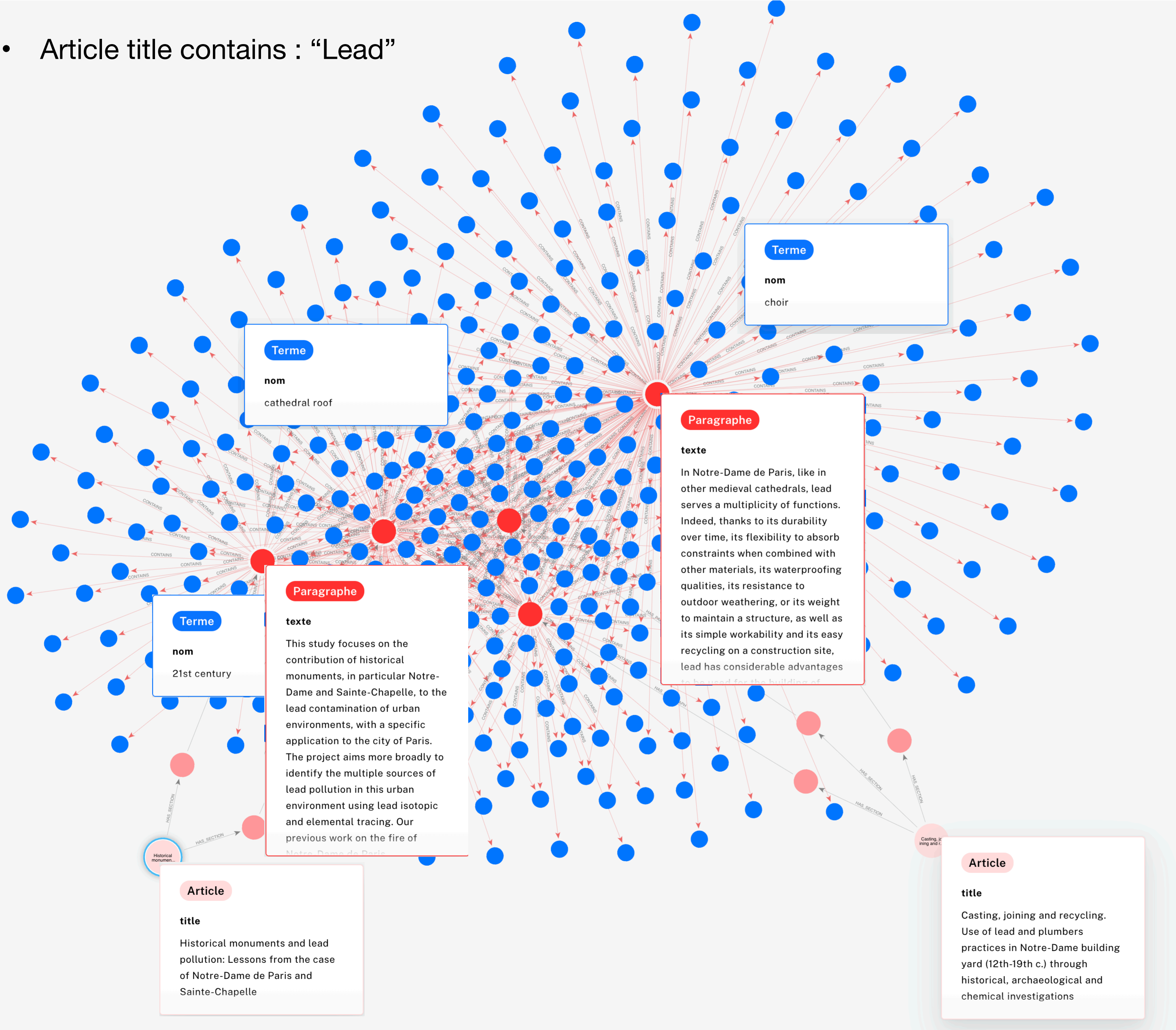
Dernières expériences conduites sur « **Le Chat** » (2024), modèle de langage *Open-Weight* développé par l'entreprise française Mistral AI. <https://chat.mistral.ai>

Source texte : Abergel V. et al., *Des données numériques aux connaissances pluridisciplinaires : enjeux de documentation et de formalisation, Naissance et renaissance d'une cathédrale - Notre-Dame de Paris sous l'oeil des scientifiques*, Poster, 2024

Construction d'un graphe



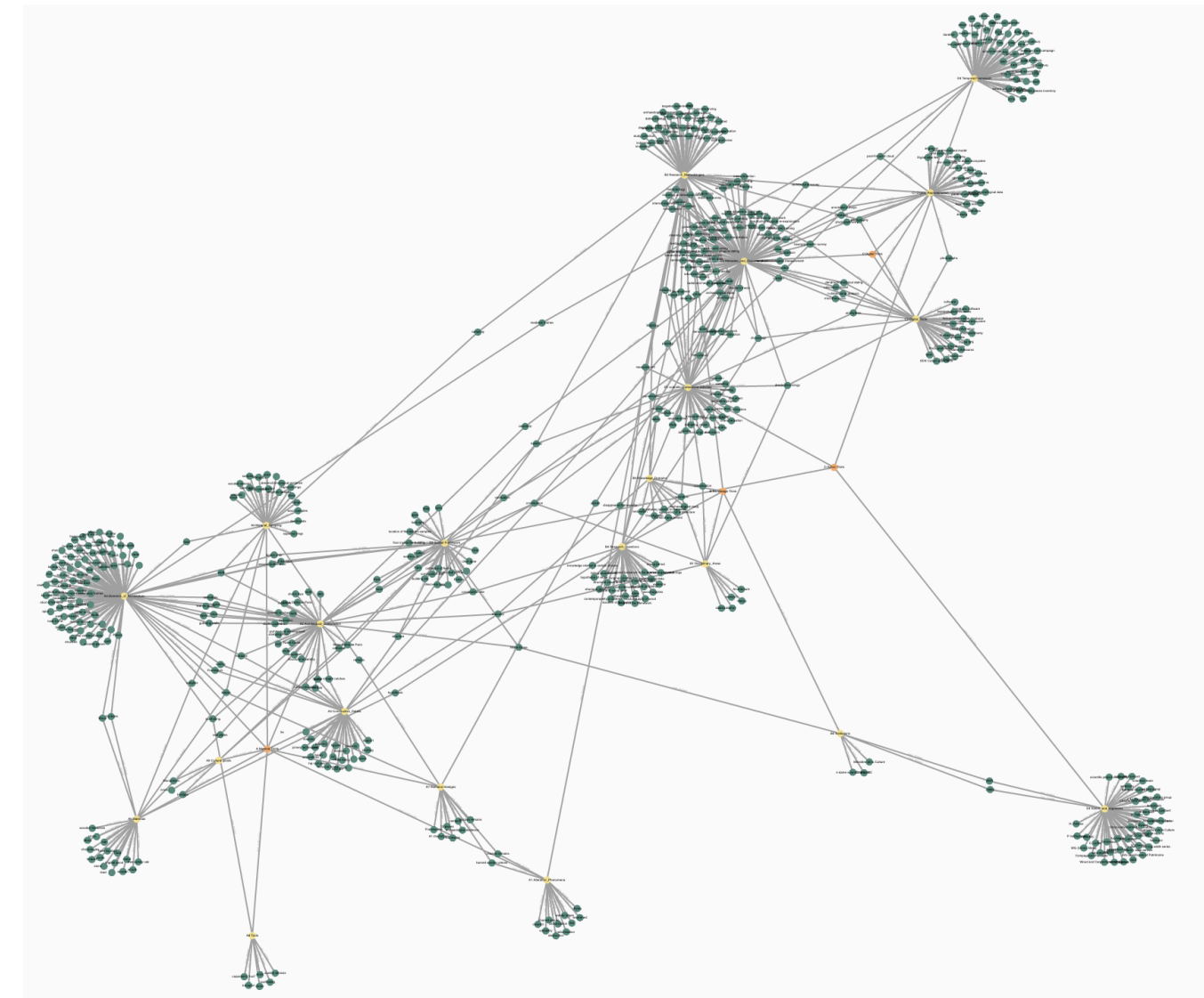
- Article title contains : "Lead"



"Signature sémantique" des articles

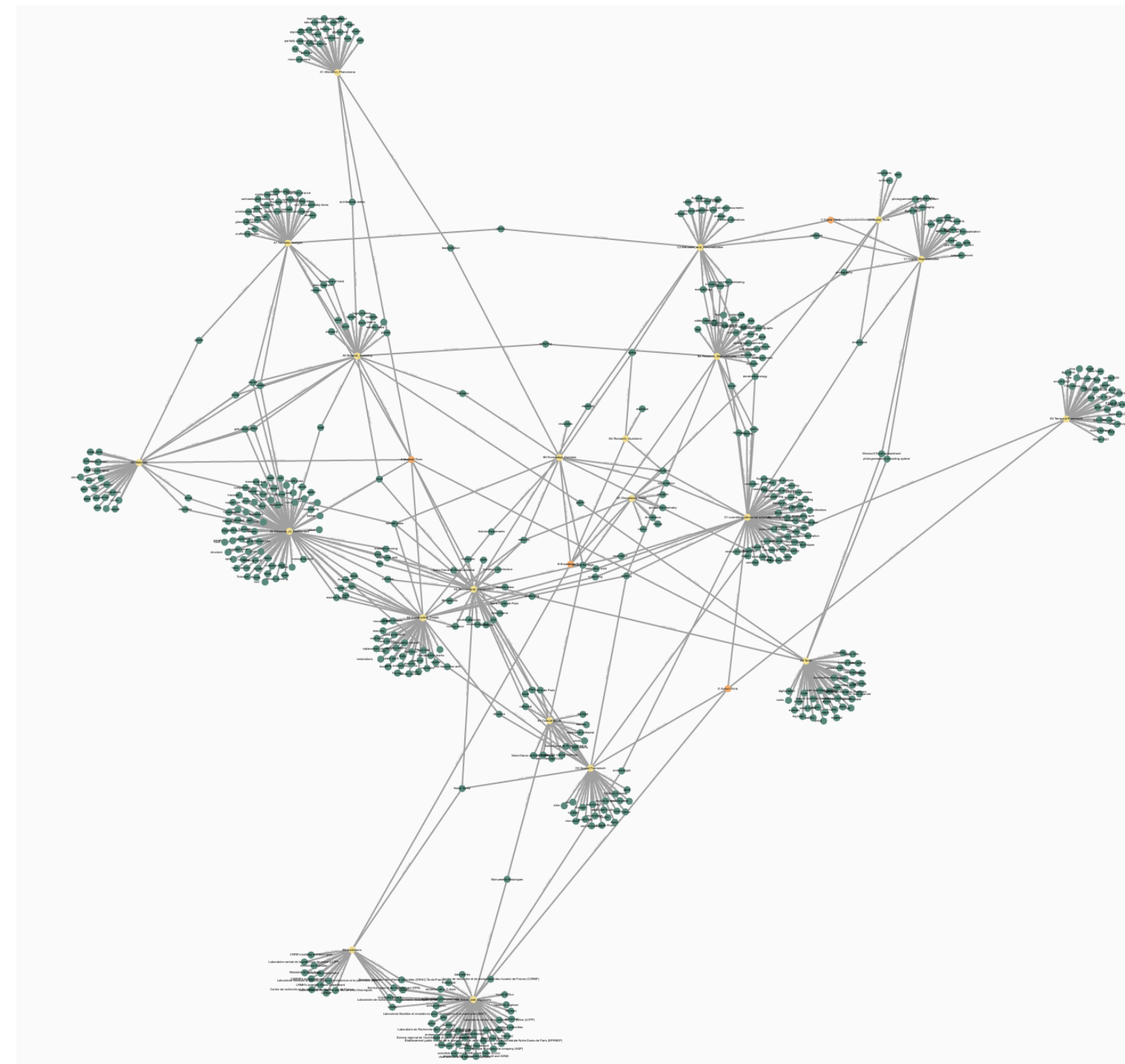
Thibaut B., Caré S., Maurin E.

**Oak beams in medieval frameworks:
Constraints and advantages for restoration**



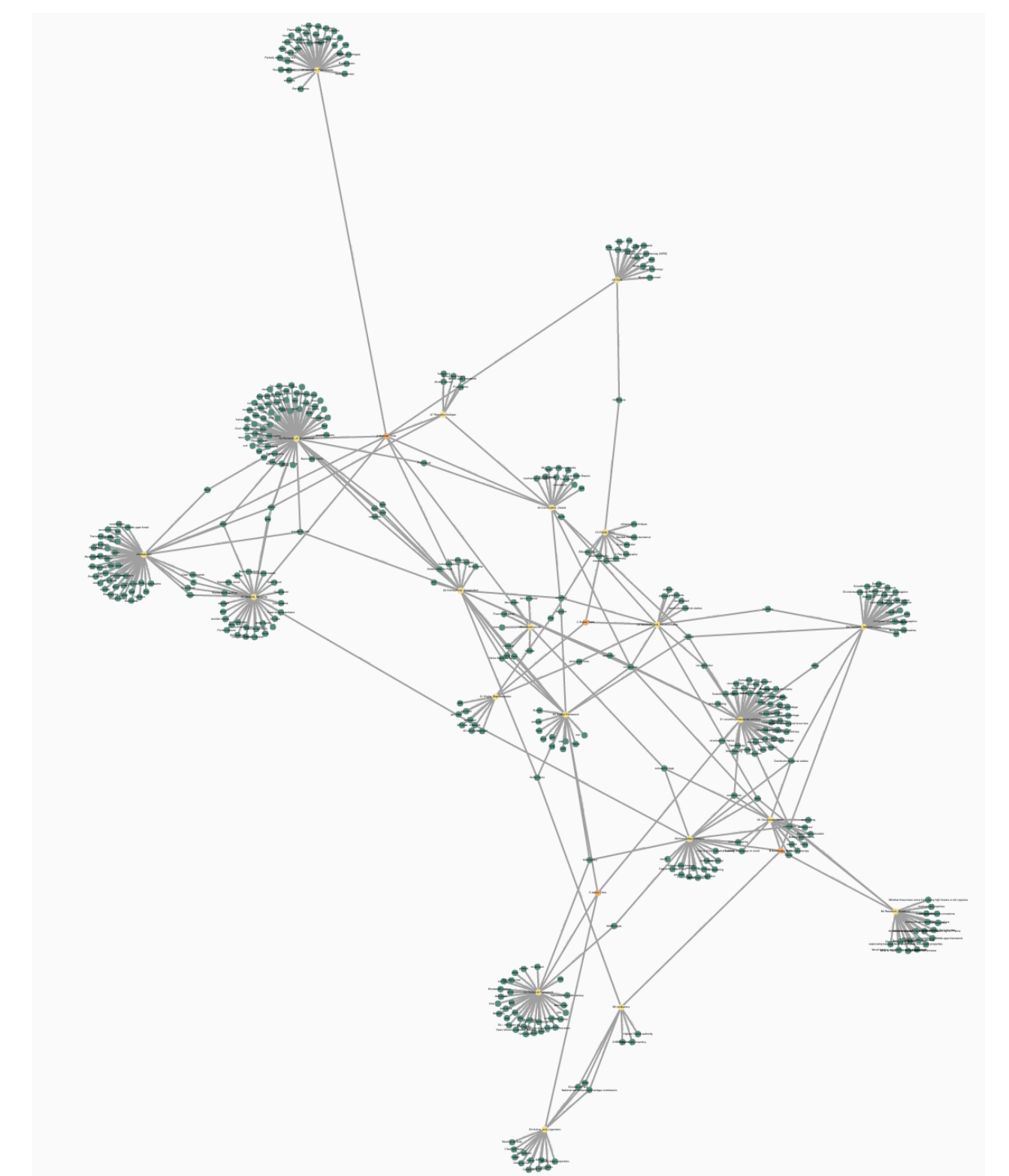
Zimmer T., Chaoui-Derieux D., Leroux L., Bouet B., Azéma A., Syvilay D., Maurin E., Mousset F.

From debris to remains, an experimental protocol under emergency conditions



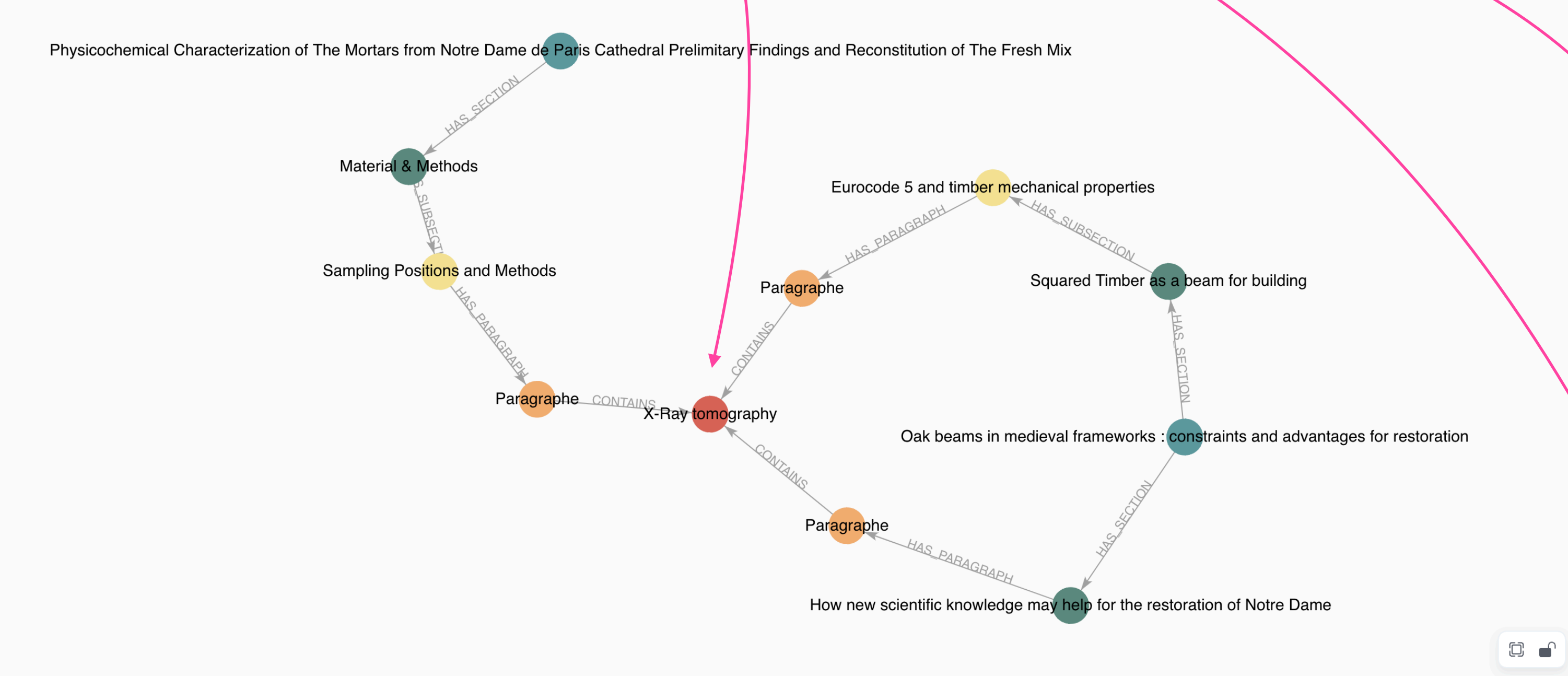
Penagos C., Girardclos O., Hunot J-Y, Martin C., Jacquot K., Cao I., Lemoine M., Brossier B., Lavier C., Coubray S., Dufraisse A.

Naming, relocating and dating the woods of Notre-Dame "forest", first results based on collated data and archaeological surveys of the remains



Premieres analyses des interrelations

Term > "X-Ray tomography"



co-occurrences

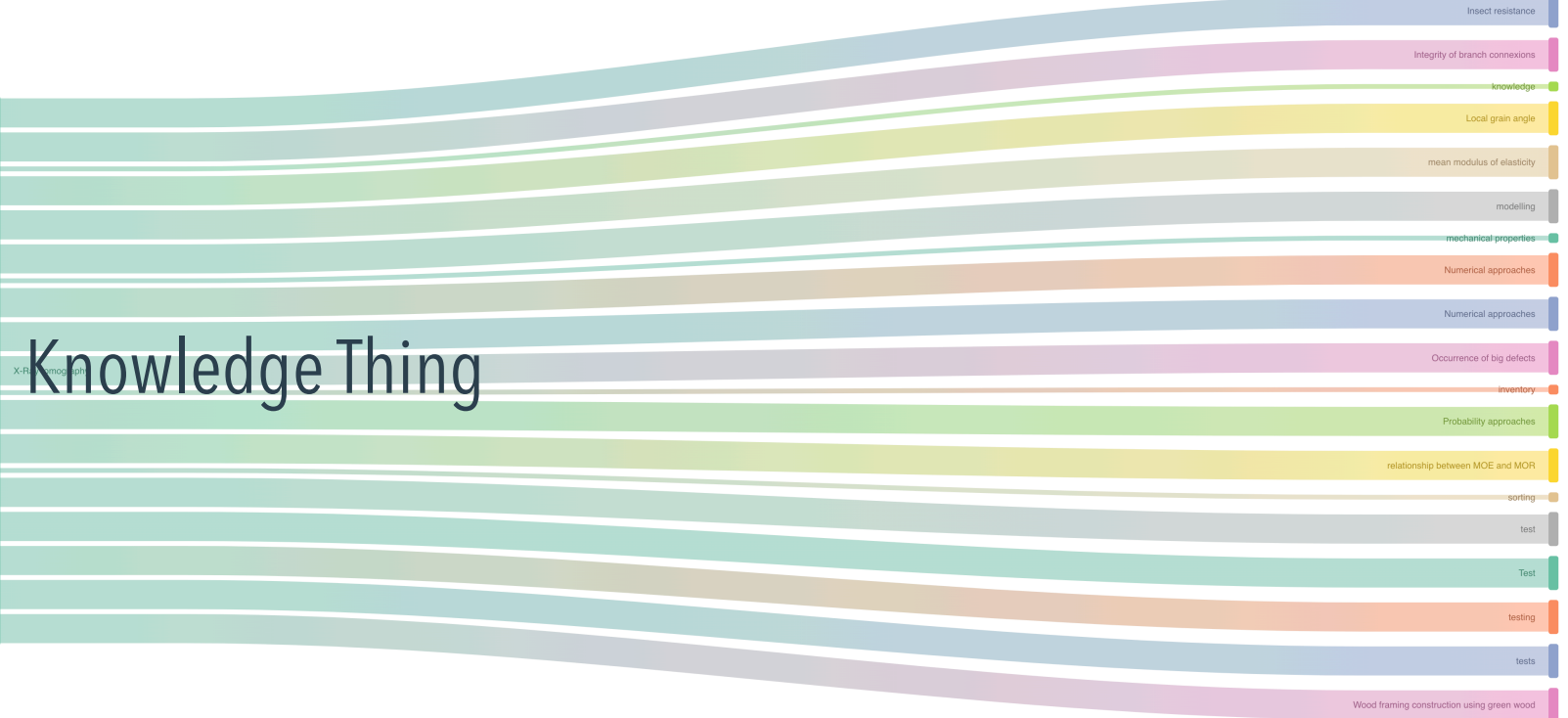
Material Thing

Knowledge Thing

Digital Thing

co-occurrences

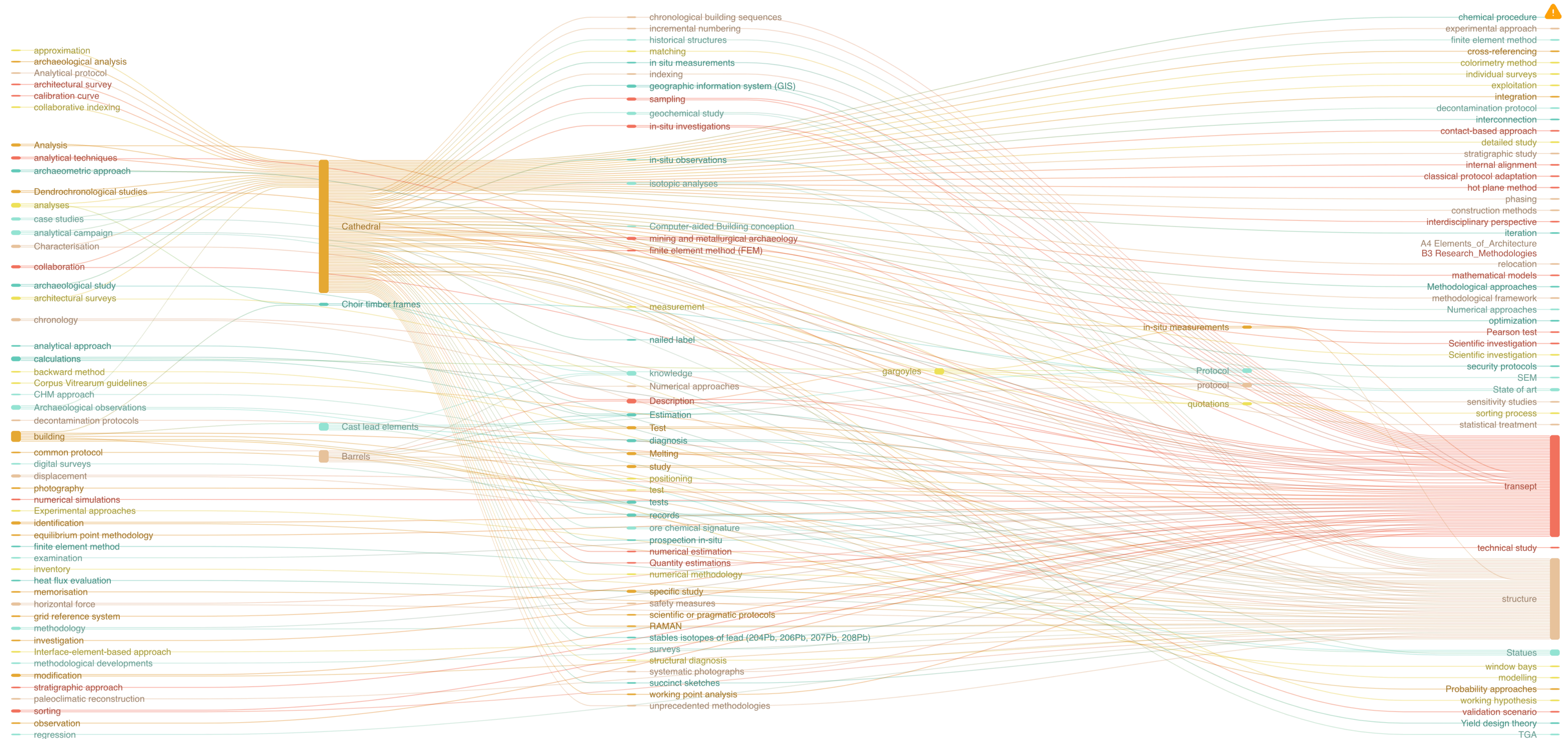
co-occurrences



Premieres analyses des interrelations

Material Thing : A4 Elements_of_Architecture

Knowledge Thing : B3 Research_Methodologies



Perspectives

Curation des concepts (désambiguïsation, catégorisation, alignement avec thesaurus...)

Automatisation de la chaîne de « sémantisation »

Extension à d'autres corpus et prise en compte des traductions

Exploration des liens entre les termes de vocabulaire et la sémantique spatiale, temporelle et morphologique

