

A digital ecosystem to document, in space and in time, the restoration of Nôtre-Dame de Paris

Livio De Luca, research director at CNRS
Coordinator of the Working Group "Digital data"
CNRS/Ministry of Culture - Scientific action for the restoration of Nôtre-Dame de Paris

FAIR Heritage
Digital Methods, Scholarly Editing and
Tools for Cultural and Natural Heritage



LE STUDIUM
Learn-Verify
Institute for Advanced Studies



Introduction

- Association "Scientists at the service of Notre-Dame"
- CNRS/Ministry of Culture coordinated action
- 8 working groups : stone, wood, metal, stained glass, structure, acoustics, heritage emotions, ...
- .. and a working group on "digital data" !
 - Over 30 years of research and development on digital technology for study, conservation-restoration and dissemination of cultural heritage;



Working Group on "digital data"

- 9 research laboratoires, 2 consortia, + 30 researchers and engineers
 - **MIS et TrAme**, Université de Picardie-Jules Verne, Amiens
 - **LaSTIG**, IGN, Paris
 - **PLEMO 3D**, CNRS-Sorbonne Université, Paris
 - **ZEMAS**, Université de Bamberg
 - **ARCHEOVISION**, CNRS-Université de Bordeaux
 - **MAP**, CNRS-MC, Marseille, Lyon, Nancy, Paris
 - **LS2N**, Ecole Centrale Nantes
 - **MSH-LSE**, CNRS Lyon
 - **Consortium 3D SHS** et **MASA**, TGIR Huma-Num, CNRS
- International cooperations (**TU Wien**, **CNR-ISTI**, **FORTH**, **FBK**, ...)



Working Group on "digital data"

- **Disciplines** : engineering, architecture, computer science, archaeology, history
- **Research themes and skills** :
 - **Metrology**: 3D laser scanning, photogrammetry, 3D microscopy, drones, acoustic surveys, 2D-3D processing, imagery fusion, ...;
 - **Analysis and reconstruction**: shape analysis, segmentation, geometric reconstruction, structural analysis, modelling of historical hypotheses,...
 - **Information systems**: multimedia databases, structuring of heritage science data, knowledge engineering, semantic enrichment, publication of data, long-term archiving, ...;
 - **Dissemination** : interactive 3D visualization, virtual, augmented and mixed reality, soundscapes, ...;

Working Group on “digital data”

• Hardware

- **Laserscanning** : Triangulation (courte distance) ; Décalage de phase (moyenne distance) ; Temps de vol (longue distance). 1 C10 (Leica) ; 3 RTC 360 (Leica) ; 1 VZ400i (Rieg) ; 4 Focus 3D (Far) ; 1 Photon (Far) ; 2 ScanArm (Far) ; 1 X130 (Far) ; 1 GS200 (Trimble) ; 1 GX (Trimble) ; Steinbichler Comet L3D 6M ; T-Scan 2 ; Artec Eva ; Artec Space Spider ; 1 VI-910 (Minolta) ; 1 GoScan120 (Créaform) ; 1 GoScan150 (Créaform) ; 1 HandyScan (Créaform) ; ViScan ; BLK360 ; Artec Leo
- **Photogrammetry & Scientific imagery** : many DSLRs & lenses, thermal cameras, multi-spectral cameras
- **Drônes** : 2 Phantom 4 Pro, 1 Asctec Falcon 8, 1 Inspire 2, 1 DJI MAVIC 1 ; 1 MAVIC 2 PRO Photo (20 Mpx), 1 DJI MATRICE 210 (caméra zenmuse en zenith et nadir), 2 3DR Solo
- **Robots** : Secure, Pioneer, ...
- **Other sensors** : Microscope 3d (Hirox) ; Géocube, Camlight, caméra TOF (IGN), 1 Grue carbone pour relevé suspendu de façades (MAP), microphones omnidirectionnels, 3D et binauraux (GT Acoustique), ...

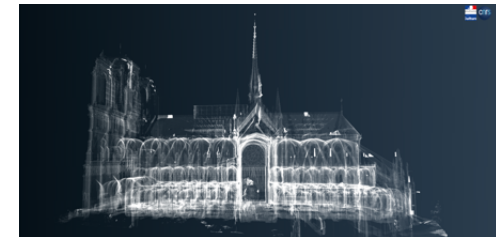
• Software

- **Photogrammetry** : MicMac, Taco, ...
- **2D-3D Processing** : toolkit for 2D-3D fusion and analysis, CloudCompare, ...
- **Data structuring and semantic enrichment** : Aiolli, Mémoira, MonArch, OpenTermAlign, PACTOLS, Opentheso, OpenArchaeo, ...
- **Web publishing & archiving** : Archeogrid, iTown, Wasure, Altag3D, Potree, 3D-HOP, sharedocs, Numa-Num Box, ...

“Scientific challenges” of the restoration site



- **Short-term ?**
- **Mid-term ?**
- **Long-term ?**



“Scientific challenges” of the restoration site

• Strong relationship with the restoration site base

• Meetings with :

- ACMH - chief architect of historic monuments,
- SRA - regional archeology service
- LRMH - research laboratory on historic monuments

• Main needs :

- Scientific knowledge on materials, behaviours, architecture: before, during and after the fire
- **For the WG on digital data)**
 - Data management for documentary research
 - Data management for diagnosis
 - Tools for the analysis of structures, spaces, shapes and materials
 - Virtual models for simulation and decision making

“Scientific challenges” of the restoration site



“Scientific challenges” of the restoration site



- **Scientific literature and diffuse skills on**
 - Comparative analysis of states (before / after fire)
 - Simulation of mechanical and acoustic behaviours
- data & Information management for diagnosis and monitoring of scientific work & restoration
- Digital reconstruction of missing elements

A digital ecosystem

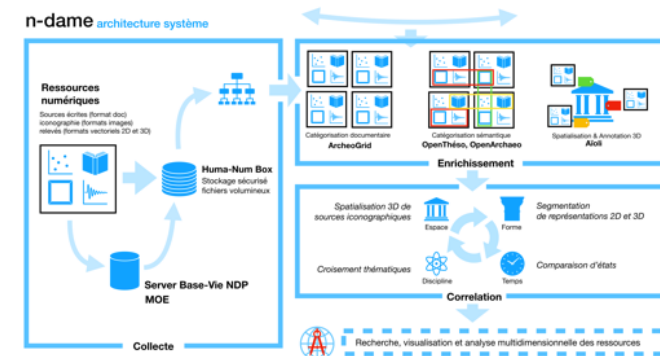
- **A platform** for the collection of data and the collaborative production of knowledge
- **An information system** to memorize in space and in time, activities produced by multiple actors, within a multidisciplinary framework
- **An interface** between the scientific site and the restoration site;
- **A collective challenge :**
 - Definition of methodological approaches for producing semantically-enriched data
 - Confrontation with the operating modes of the 8 working groups;
 - Reflection on the data life cycle;
 - Development of ad hoc tools (collection, processing, categorization, correlation, ...)

Starting points / Challenges

- **Related works and existing software bricks (from labs):**
 - 2D and 3D digitisation and processing ;
 - Modelling spatio-temporal transformations;
 - Knowledge engineering and AI for classification
 - Multimodal interfaces for publishing and sharing
- **Digital born scientific data produced by a collective adventure :**
 - Implementation of the FAIR principles (for data relating to conservation states, material analysis, etc..)
 - In-depth description of data production process (actors, instruments, methods, interpretation, etc.);
 - in-depth description of technical and intellectual activities
 - new challenges for data analysis, classification and correlation

Data centralisation platform

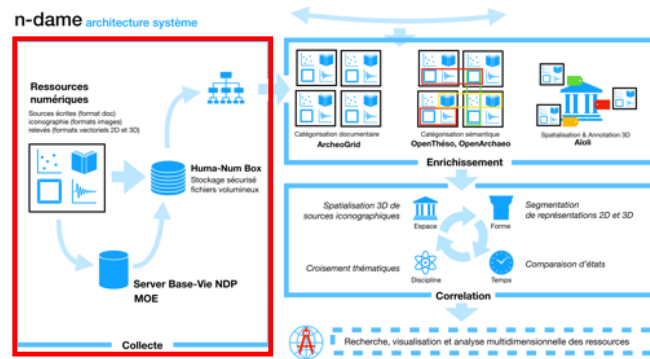
- **Task team:** Thomas Pouyet (CITERES), Denis Hayot (Plemo3D), Violette Abergel (MAP), Sara Tournon (Archéovision), Olivier Malavergne (LRMH), Isabelle Cao (MAP), Miles Rousset (MOM), Joel Marchand (Huma-Num)
- **Supervision:** L. De Luca (MAP), P. Dillmann (IRAMAT), X. Rodier (MASA), X. Granier (3DSHS), D. Sandron (Plemo 3D)



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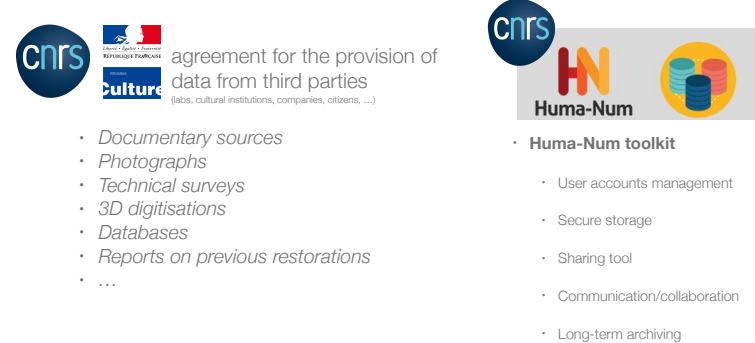
Data collection



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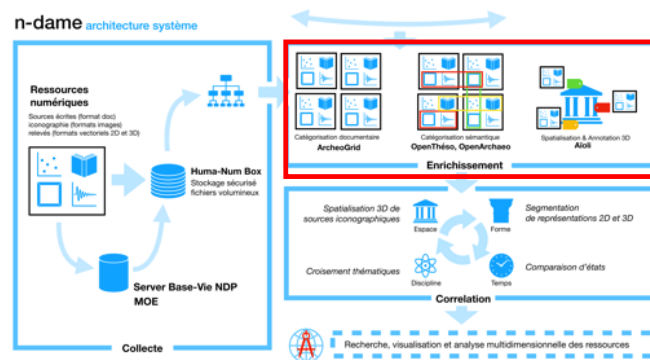
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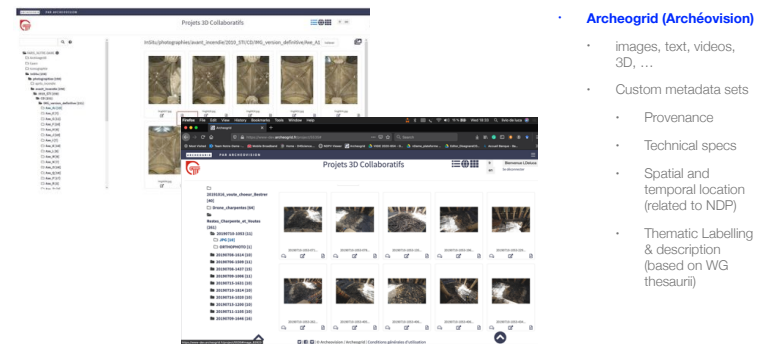
Data enrichment



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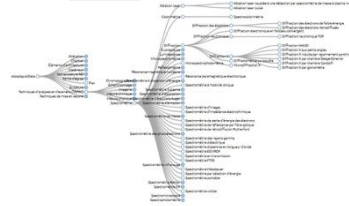
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Data enrichment



OpenThéso (MOM)

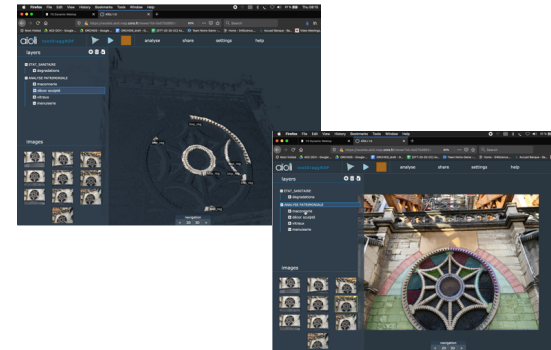
- Management of controlled vocabularies
- Architecture
- Building techniques
- Materials
- Weathering phenomena
- Restoration techniques
- Scientific analysis
- Instruments
- Actors



Data centralisation platform

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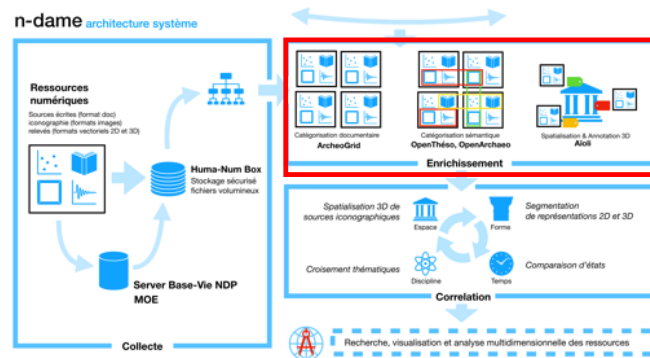
Aioli (MAP)

- Reality-based 3D annotation
- Automatic Image-based 3D reconstruction
- 2D-3D Multi-layer annotation
- Custom user descriptors
- Computed descriptors (dimensions, geometric and visual properties, ..)
- Attachments & links to other resources
- Controlled vocabularies (link to OpenThéso)

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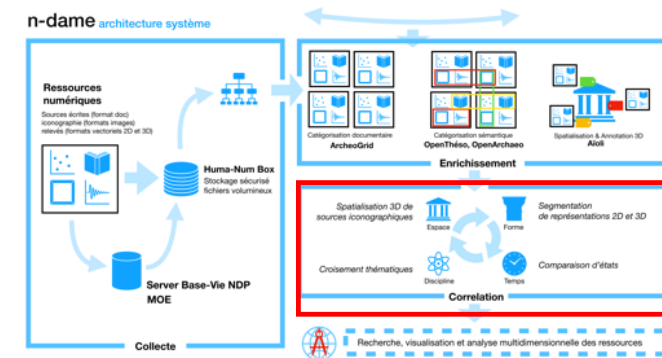
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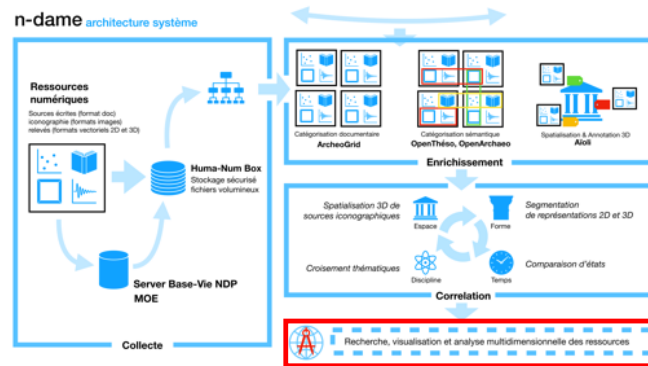
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Data correlation



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- **Data correlation**



Work in progress on on the 'forest'

• 2D-3D monitoring of the removal of remains

- **Task team:** Loïc Espinasse (Archéovision), Renato Saleri (MAP), Kevin Jacquot (MAP), Alexis Komenda (C2RMF)
- **In collaboration with:** SRA (Dorothea Chaoui-Derieux) and C2RMF (Catherine Lavier)



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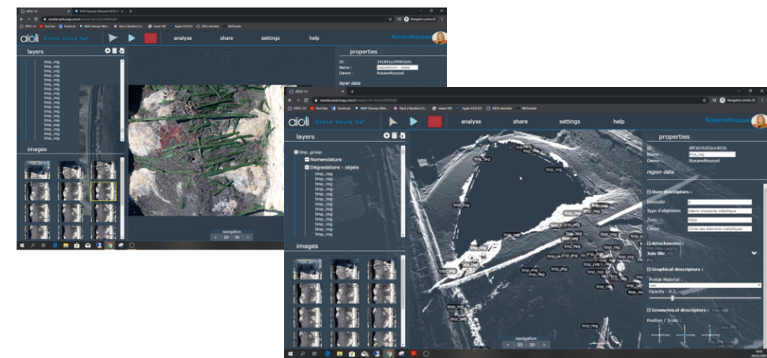
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Work in progress on on the 'forest'

• 2D-3D annotation of remains

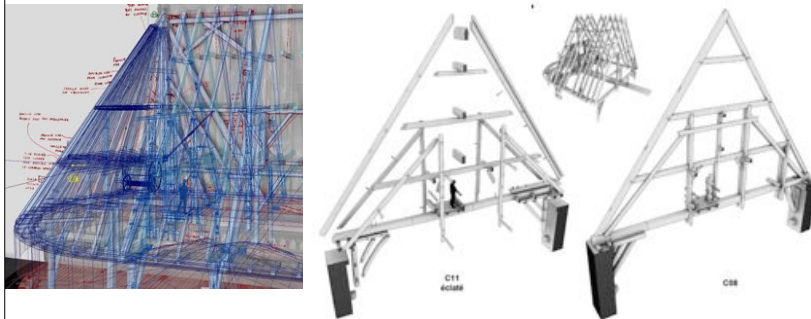
- **Task team (AIOLI - MAP):** Adeline Manuel, Anas Alaoui M'Darhri, Roxane Roussel
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Work in progress on on the 'forest'

• Geometric reconstruction - before fire

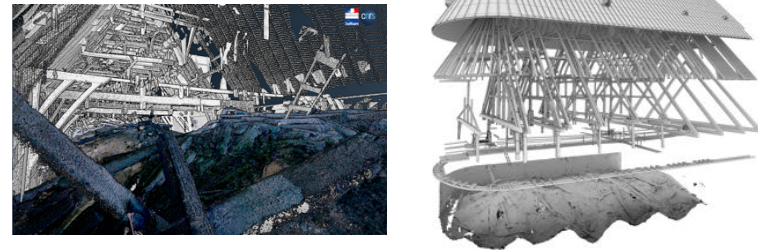
- **Task team:** Kevin Jacquot (MAP), Frédéric Epaud (CITERES)
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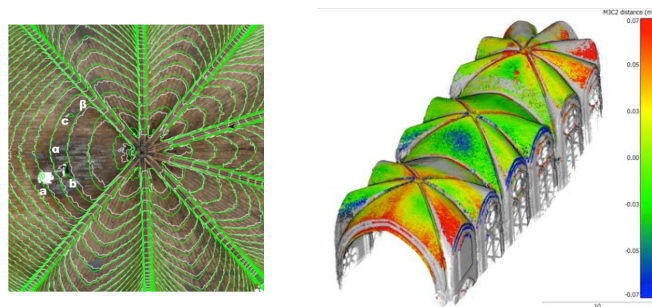
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Work in progress on the vaults

• Comparison of temporal states (2D and 3D processing)

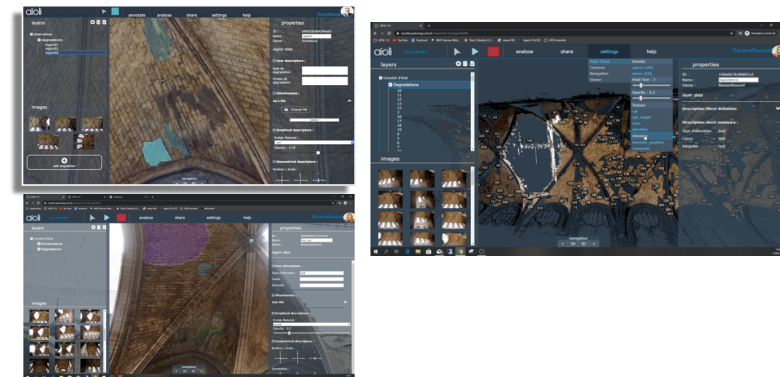
- **Task team:** Marc Pierrot-Desselligny (IGN), El Mustapha Mouaddib (MIS), Daniel Girardeau-Montaut (CloudCompare), Anthony Pamart (MAP), Roxane Roussel (MAP)
- **In cooperation with:** ACMH (Pascal Prunet) and BESTREMA (Mathias Fantin)



Work in progress on the vaults

• Comparison of temporal states (2D-3D annotation)

- **Task team (AIOLI - MAP):** Adeline Manuel, Anas Alaoui M'Darhri, Roxane Roussel
- **In cooperation with:** ACMH (Mathilde Hannin) and BESTREMA (Mathias Fantin)



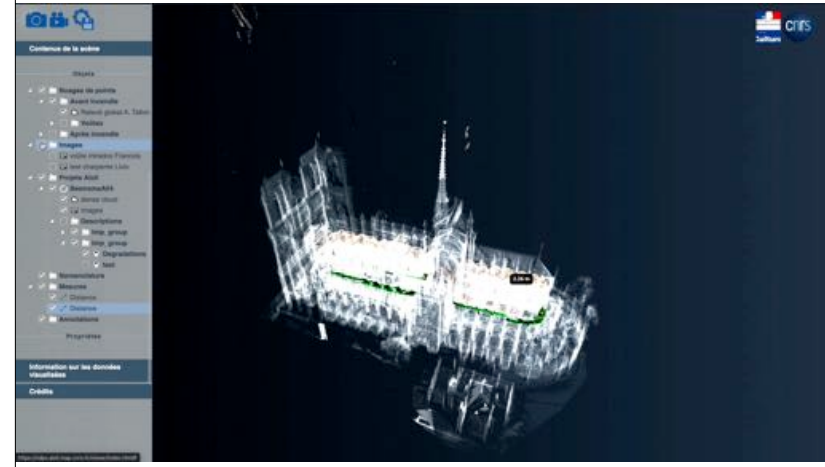
Work in progress on the vaults

• Spatio-temporal tracking of fragments

- **Task team (MAP):** Antoine Gros, Adeline Manuel, Anas Alaoui M'Darhri, Roxane Roussel
- **In cooperation with:** LRMH (Olivier Malavergne, Lise L  roux, Thierry Zimmer, Aline Magnien)



Visual exploration of the corpus



Future works

• One year after the Notre-Dame fire

- First steps of the scientific action (WG on digital data)
- ... "at least" ... 4 more years of work for helping the restauration by collecting, producing, classifying and interpret data.
 - Semi-automatic / Automatic spatio-temporal distribution of data ;
 - Semi-automatic / Automatic semantic enrichment by multimodal propagation;
 - Autonomous multidimensional correlation;
- more years of work after the restoration, ... to analyze an emblematic sample of "heritage science data" produced by this collective adventure

Thank you

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